A Period Examination Through Contemporary Energy Analysis of Kevin Roche’s Fine Arts Center at University of Massachusetts-Amherst

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A PERIOD EXAMINATION THROUGH CONTEMPORARY ENERGY ANALYSIS OF KEVIN ROCHE’S FINE ARTS CENTER AT UNIVERSITY OF MASSACHUSETTS-AMHERST

A Dissertation Presented

by

LOUIS CARL FIOCCHI, JR.

Submitted to the Graduate School of the University of Massachusetts Amherst in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

September 2016

Building Systems
Department of Environmental Conservation
A PERIOD EXAMINATION THROUGH CONTEMPORARY ENERGY ANALYSIS OF KEVIN ROCHE’S FINE ARTS CENTER AT UNIVERSITY OF MASSACHUSETTS-AMHERST

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DEDICATION

To the two people I love the most and who make me want to be better:

Jackie Braconier Fiocchi

Hathaway Fiocchi Ellis
ACKNOWLEDGMENTS

Simi Hoque whose generosity of knowledge and guidance will never be forgotten.

Alexander Schreyer and Max Page who lent such great support.

Ben Weil with whom I had so many fantastic discussions.

Nariman Mustafavi and Soroush Farzinmoghadam with whom the time spent has been a privilege.
ABSTRACT

A PERIOD EXAMINATION THROUGH CONTEMPORARY ENERGY ANALYSIS
OF KEVIN ROCHE’S FINE ARTS CENTER AT UNIVERSITY OF
MASSACHUSETTS–AMHERST

SEPTEMBER 2016

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Studies of buildings belonging to a subset of Modernist architecture, Brutalism, have included discussions pertaining to social and architectural history, critical reception, tectonic form and geometry inspirations, material property selections, period technology limitations, and migration of public perceptions. Evaluations of Brutalist buildings’ energy related performances have been restricted to anecdotal observations with particular focus on the building type’s poor thermal performance, a result of the preferred construction method, i.e. monolithic reinforced concrete used as structure, interior finish and exterior finish. A valid criticism, but one that served to dismiss discussion that the possibility of other positive design strategies limiting energy consumption, while simultaneously maintaining occupant comfort, existed in these buildings.

The University of Massachusetts-Amherst Fine Arts Center (FAC) designed by Pritzker Prize winning architect Kevin Roche, was the Brutalist building used to develop an evaluation protocol that will serve as a template for energy and/or occupant comfort
dissections and evaluations of other Brutalist buildings. A calibrated (ANSI/ASHRAE Standard 140) and validated energy model (DesignBuilder) was programmed with all requisites, i.e. geo-position, ordinal orientation, building geometry, envelope materiality, construction details, local weather and climate, program activities, mechanical systems, occupancy schedules, etc. All inputted data was synchronized and consistent with the first year of the building’s occupancy, 1976.

Analyses using the DesignBuilder model and an Autodesk Ecotect Analysis model were performed with results relating to thermal performance of the envelope, daylight harvesting, glare control, siting advantage, solar defense via self-shading, material solar absorptance impacts, thermal mass, and wind related strategies documented. Results demonstrated and quantified the inadequacy of the thermal envelope and the positive presence of daylight harvesting, glare control, and solar defense via self-shading. Results also suggest the possibility of material solar absorptance strategies, thermal mass strategies, and wind harvesting strategies.

The FAC’s EUI, as determined from the models above and a potential EUI determined from a FAC model inputted with a single energy efficiency measure (improvement of thermal envelope) was compared with EUI data from “CBECS, 2012 Table C5”. This perspective and insight into the building’s reality, within the context of energy performance and occupant comfort, cleared the haze of anecdotal evidence.
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PREFACE

It is of importance as this work begins that a disclosure is made as to the complete motivation behind this dissertation. The following defines the pragmatic and academic reasoning for the sequencing that resulted in the final document.

The work is a logical progression, taking the reader through a process that defines a singular architectural style, introduces an exemplar of that style, and develops a methodology and reasoning behind the examination of that particular building, which can then be applied to other Brutalist buildings or to an alternative style. The work concludes with a discussion of what was discovered during the examination and suggests how that information might be used to inform the Architectural, Engineering, Construction Community (AEC Community), the building stakeholders, and the public, of previously unexplored, if not unknown, sustainable strategies captured by these buildings.

The process to execute the above was a long and arduous one and was not fueled solely by academic curiosity. The motivational source for the author was one of a long held affection and admiration for architectural Modernism.

I am as appreciative as the majority of the rest of western culture of a great classical building; whether it be, the ecclesiastical exaltation of Chartres Cathedral, 1220 (Fig.P.1), Jefferson’s elevation of academia to classical Greece and Rome at University of Virginia, 1820 (Fig.P.2), or Cass Gilbert’s embodiment of the concept of “equal justice for all” in the United States Supreme Court Building, 1935 (Fig.P.3).

Throughout the western world, along with its conquered and colonized areas in the non-western world, the prevalence of the various orders of architectural capitals (Doric, Ionic, Corinthian, etc.) bear witness to the pervasive and justifiable prowess of...
classical architecture as it succeeded, at varying levels, to tectonically encapsulate humankind’s noblest aspirations.

However, I have an equal, if not greater affection, for the architecture that appeared in the late nineteenth century and flourished during the twentieth century until the mid-1970s, Modernism. It was a physical manifestation of concurrent movements in art, technology, and politics that dramatically and abruptly dissociated itself from the precedents of the previous two-thousand years. I would note at this time that while Modernism impacted far more than the United States and Western Europe; making
important appearances and contributions in Russia, Eastern Europe, South America, and Japan, it is Modernism in the United States, with some references to Western Europe, that this work restricts itself to.

The buildings of this sector absorbed the art world’s movements of deconstruction and reductionism, echoed the political world’s rebellion against classism eschewing the mendacity of decoration and its association with wealth and power, and celebrated the industrial world’s technological advancements; incorporating the plasticity of concrete, the strength of steel, and expanses of glass, which allowed freedom of geometries never before possible.

The results: Frank Lloyd Wright’s Robie House, 1910 (Fig.P.4), Walter Gropius’ Fagus Shoe Factory, 1913 (Fig.P.5), Le Corbusier’s Chapel at Ronchamps, 1954 (Fig.P.6), Mies van der Rohe’s Seagram Building, 1958 (Fig.P.7); each embracing, in individualistic ways, those contemporary influences and benchmarking the future forms of domestic, industrial, ecclesiastic, and commercial architecture.

Figure P.4: Robie House. (Teemu08 2010).

Figure P.5: Fagus Shoe Factory. (Clemens 2012).
Academia was also impacted. On campuses scattered across the country the construction of brick clad Georgian’s with their white painted classical ornamentation slowed. The new forms appeared in different locals and with different densities. Sometimes as entire campuses, e.g. Frank Lloyd Wright at the Florida Southern College, 1940-52 (Fig.P.8), Paul Rudolph at University of Massachusetts-Dartmouth, 1963-72 (Fig.P.9), Mies van der Rohe at Illinois Institute of Technology (IIT), 1943-57 (Fig.P.10). Sometimes isolated buildings at older institutions, e.g. Le Corbusier’s Carpenter Center at Harvard University, 1963 (Fig.P.11), Eero Saarinen’s Chapel at Massachusetts Institute of Technology, 1955 (Fig.P.12), or Walter Netsch’s Chapel at the United States Air Force Academy, 1962 (Fig.P.13).
At the University of Massachusetts-Amherst (UMass-Amherst) Modernism appeared as the dominant style during the 1960s and 1970s when a major building boom occurred on the campus. Following the first surge of students post-World War II, where campus enrollment nearly doubled from 2,400 to 4,700 students, by 1967 campus enrollment was 15,000 students. Approximately six million square feet (557,418.24 m²) of space was built in those two decades, of which the vast majority was Modernist.¹

Notes

¹ (UMass Amherst Campus Planning 2012)
This collection of Modernist buildings exists at UMass-Amherst because, in 1961, on the heels of selecting landscape architect Hideo Sasaki of Sasaki, Walker and Associates to develop and design a master plan that divided the campus with arts and humanities to the south and sciences to the north. The trustees made a deliberate decision that in contrast to many older universities that had developed campuses in the Gothic Revival (Fig.P.14) and Colonial Revival (Fig.P.15) styles that they would retain world-class modernist architects for the design of the key campus buildings.2

The new buildings were to be uncompromisingly modern and to that end masters of that style, e.g. Marcel Breuer (Fig.P.16), Edward Durrell Stone (Fig.P.17), Kevin Roche (Fig.P.18), and Hugh Stubbins (Fig.P.19) went to their drafting boards and built on the Western Massachusetts campus. It is on this campus, both within and around these buildings, that I have spent the last nine years, both studying and teaching architecture and building physics. I have seen the buildings at dawn, in the brightness of full sun, on...
foggy days, during winter storms, at sunset, and illuminated at night. Their forms, their creation of shadows, their material solidity, their heroic sculptural stature, the bravery and innovation of their designs, and the architects who drew them inspire me.

Figure P.16: Lincoln Campus Center, 1970, UMass-Amherst. (Horatius 2013).

Figure P.17: DuBois Library, 1973, UMass-Amherst. (Eraboin 2005).

Figure P.18: Fine Arts Center, 1974, UMass-Amherst. Courtesy of UMass-Amherst Library Special Collection and Archives.

Figure P.19: Coolidge & Kennedy Hall, Southwest Dormitories, 1966, UMass-Amherst. (Phelan 2010).

In addition, one building in particular whose north lit design studios were home for three years as I learned about architecture is especially valued. It is Pritzker Prize winning architect, Kevin Roche’s Fine Arts Center (Fig.P.20).
There are times around this building when admiration turns to awe; for at certain moments, when the light is just right, the forms of the building and the shadows they make can touch an architectural soul.

It is this final sentence, in concert with the pragmatic and clinical methodologies of this work, which provides the complete impetus and motivation behind this dissertation and supplied sustenance of sorts through the past years of work.
INTRODUCTION

The purpose of this work is to establish a template for the examination of a singular style of Modernist architecture, Brutalism. The template is constructed through an exploration of an exemplar of the building typology, the Fine Arts Center (FAC) at the University of Massachusetts-Amherst. Buildings belonging to this subset have been principally examined within the contexts of geometry and material selection as they relate to the art, literature, political, and technological changes that informed the development of the Modernist Movement in architecture, with scant attention paid to the strategies related to sustainable building performance, e.g. shading, daylight harvesting, glare control, surface albedo influences, thermal mass impacts, mono-material assembly advantages, wind related strategies, or siting opportunities. The actuality that some or all of these strategies were incorporated into and can be found in buildings conceived and designed by the Modernist masters is of equal importance to those of a building’s geometries and materialities, especially with respect to building evaluation; as the Brutalist collective represents a substantial tectonic inventory, a major embodied energy sink, and an enormous operational energy consumer.

The work progresses through three chapters. Each chapter contributes a vital component, which in concert with the others establishes, first, the merit of the building type (Brutalism) and then, in turn, the merit of the work. The established merit then provides justification of the substantial work necessary to complete a template as robust as what was proposed and has been executed here.

Notes

3 (Forty, Words and Buildings: A Vocabulary of Modern Architecture 2000, 161)
The first chapter, Architecture, begins with an overview of Modernism, examining the social and artistic climate that led to a seismic shift in building forms. An understanding of the historical drivers: economic, social, and political that resulted in a new building paradigm is critical in enabling an understanding and appreciation of these revolutionary forms.

The dissertation’s first narrowing of focus then occurs as Brutalism, one of the two major building categories within Modernism, is dissected. The second and final narrowing will be when the subset Brutalism is narrowed to a single exemplar of the type, University of Massachusetts-Amherst’s Fine Arts Center.

The analysis of Brutalism is directed at not only its idiosyncratic and eccentric geometries, but also, the contemporary social and architectural drivers that spawned the unique form. Analysis begins with the coinciding positive validations Brutalism received in the form of contemporary critical responses, municipal support, and public approval. This is followed by an exploration of the relatively abrupt reversal, from an initially positive and favorable response, to one of decided negativity.

Immediately following and in contrast to the examination of Brutalist negatives is a discussion directed at positive attributes that might, possibly, contribute to a second perception reversal of the building type and a return to one resembling the initial positive perception. Topics addressed include: the shift, i.e. relaxation, of the historic preservation movement’s (for Modernist buildings) primary focus on building fabric to considerations of design intent, the continued and relentless evolution of building occupant comfort expectations and demands, the possible impacts of educational efforts directed at societal understanding of aesthetics and peripherally the art of photography as
it relates to the Brutalist building form, and the peculiar contradictions that arise when Brutalism’s rejection is contrasted with the acceptance of Green Building aesthetics or the concrete architecture of Tadao Ando.

The first section, Brutalism, concludes with an examination of the early cultural and the pre-formal architectural educational backgrounds of the mid-century Modernist architects and explores the impacting pressures exerted on them by early formative behavioral influences, conceived in environments with primitive central heating systems, limited electricity and absence of active mechanical cooling systems exposing them to requisite traditional passive strategies necessary to maintain occupant comfort and optimize convenience. This examination of early exposure is followed by an examination of their formal training at Architectural schools where a commonality of curriculum and Modernist theory was nearly universal. The relevancy of the melding of these two life experiences and the possible impacts of these experiences on their Brutalist designs completes the Brutalist section’s discussion.

Perhaps to some, sections or even all of the first chapter might, at first, appear superfluous to the second and third chapters of the work, as this first chapter addresses the softer non-scientific aspects of examination and evaluation of a building as opposed to the harder scientific components that the second chapter, “Methodology”, and third chapter, “Analysis”, undertake with resulting definitive metrics.

It is, however, very appropriate, as although it is the geometry, materials, and siting of a building that are presented to the public view and realm it is a mistake to believe that they generate, by themselves, public opinion. The additional forces, enumerated in the first chapter, also contribute to perception of the building and must be
understood; for if a building is unappreciated and perceived as having little value while occupying a valuable site, its demise can be imminent, e.g. Paul Rudolf’s Orange County Government Center,⁴ 1967⁵ (Fig.I.1).

![Figure I.1: Orange County Government Center. (Case 2005).](image)

Just as there have been moments in the past when shifts in art or music were unappreciated or disparaged, e.g. Louis Spohr, German composer, conductor, violinist, and contemporary of Beethoven writes after hearing the glorious Ninth Symphony:

*I must even reckon the much admired Ninth Symphony among them, the three first movements of which, in spite of some solitary flashes of genius, are to me worse than all of the eight previous Symphonies, the fourth movement of which is in my opinion so monstrous and tasteless, and in its grasp of Schiller's Ode so trivial, that I cannot even now understand how a genius like Beethoven's could have written it.*⁶

Alternatively, recall the obstacles encountered by the great Impressionist painters when first having their work exhibited:

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**Notes**

⁴ (Fight Continues Over Modernist Building in New York Town 2015)
⁵ Note: All building dates are dates of completion.
⁶ (Taruskin 1989, 246)
The Impressionists had a particularly difficult time getting their work to be accepted for exhibition in the Salons. In 1867, for example, the jury refused most of the work of the Impressionists, which included that of such leading artists as Monet, Pissarro, Sisley, Cezanne, and Renoir.7

Changes of perception have also happened in architecture. Witness the shifts in American architecture (albeit easier to understand, as all subscribe to a classical foundation) from the periods of the Colonial, to Georgian, to Federal, to Victorian in a span of less than two hundred years. Driven by fashion or world events, e.g. the Centennial Exhibition of 1875 reigniting interest in Colonial architecture during the midst of the Victorian Period, resulted in the emergence of the Colonial Revival.8

Modern architecture, just as Impressionism did in its time, requires a shift from the traditional reliance on visual stimulation where images activate the same areas of the brain as comparable real-life experiences. Moreover, brain scans have shown that abstract patterns (in contrast with representational images) fail to activate the regions of the brain traditionally associated with higher cognitive functions, in particular, the areas that manage both emotion and long-term memory.9 Education as to what the artist’s intent was becomes critical. Different levels of education for different artists at different times, but always necessary. At the extreme:

And what can the ordinary person make of one of Malevich's black squares on a white field? Could anyone guess that the black square was meant to represent "feeling," while the white field was meant to be "the void beyond this feeling"? 10

Notes

7 (Wijnberg 2000, 326)
8 (Theobald 2002)
9 (Zeki and Marini 1998, 1676,1678,1681)
10 (Malevich 1959, 76)
Yet Malevich, like many later abstract painters, thought that he could represent emotion directly through such purely abstract shapes.\textsuperscript{11}

Thus, it is only with the coupling of this dissertation’s first chapter with the subsequent two chapters that the inherent historic and societal value of this effort’s representative building, FAC, and the building type it represents, Brutalism, can be fully appreciated.

In the second chapter, Methodology, the work delineates the process that was undertaken when a large, geometrically and programmatically complex existing building, drawn and constructed in a period pre-dating digital technology, is first recreated digitally in a three-dimensional drawing program (Autodesk Revit) and then imported using gbXML protocol into two energy modeling programs (DesignBuilder and Autodesk Ecotect). The process is minutely detailed and discusses obstacles existing in the present technology that thwart the desired outcome, improvements and alternative techniques discovered that optimize and facilitate the process, and specific choices and decisions that a modeler must make to result in validated results.

The second chapter discusses not only the methodology employed in the creation of accurate complex geometry within a 3D modeling program, but also enumerates the idiosyncrasies of the requirements of model construction that are quite different from the ones required to create digital architectural models. This chapter also encompasses all of the additional aspects of programing a detailed energy model requires, e.g. construction and material details, Heating Ventilation Air Conditioning (HVAC) system selection,

Notes

\textsuperscript{11} (Kamhi 2012)
zoning criteria, occupancy and equipment schedule creation, lighting and equipment load selections, adjacency shading impacts, elevations of impacting topography, etc.

The third chapter is an exploration of the sustainable strategies found in the FAC through discussions supported by analysis from the Energy Models. Several strategies are techniques that were deliberately incorporated into the building by the designer, Kevin Roche, in an effort to optimize occupant comfort, e.g. daylighting, shading, and glare control. Other sustainable strategies exist in the building as coincidental companions to design decision made at a time, which were not informed by the implications of climate change and enjoyed what proved to be an inaccurate belief as to the inexpensive and unlimited availability of fossil fuels, e.g. thermal mass, siting, window-to-wall ratios, or albedo impacts.

In conclusion, the work realizes and justifies a distinct methodology created to examine buildings of this type, representing a singular yet substantial segment of the built environment. The work contributes to the existing body of knowledge relating to Brutalism along with the possibility of positively affecting the general perception of the collective. In addition to providing a methodology to evaluate the use of sustainable strategies and fostering understanding of the performance of these structures, designed and constructed before the advent of contemporary technologies, the creation of energy models of this sophistication will aid stakeholders in evaluating both the economic and the climate impacting realities in response to retrofitting and upgrading opportunities.
CHAPTER 1
ARCHITECTURE

1.1 Modernism

1.1.1 History

In the latter part of the nineteenth century a shift occurred in the tectonic plates that had supported the foundations of architectural design since the emergence of the Classical period in ancient Greece (circa 500 BC) followed by engineering and material adaptations in ancient Rome as documented by Vitruvius (circa 15 BC) in De Architectura, known throughout today’s contemporary world of architecture as The Ten Books on Architecture.

Lost to the world for centuries, Giovanni Giocondo translated an original, illustrated it with woodcuts, and published it in 1511.\textsuperscript{12} For the next 400 years, beginning and evidenced by the impact on such Renaissance masters as DaVinci, Michelangelo, Bernini, Alberti, and Brunelleschi it would supply the didactic precedent and inspiration for western architecture. As styles transitioned from Baroque to Palladium to Georgian to Federal to Neo-classical to Victorian, it was the consistent denominator of each faction.

The turning from these ingrained traditions was relatively abrupt in the latter part of the nineteenth century as architecture shadowed the trends in art, politics, and technology. At present, from a contemporary vantage point, one sees that over the

Notes

\textsuperscript{12} (Ciapponi 1984, Start 72)
subsequent one hundred plus years this new tradition, while only achieving modest acceptance in the residential and collegiate sectors, has in the commercial, institutional, and governmental sectors become the defacto paradigm. The new tradition is the style termed Modernism. The varying degrees of acceptance across building sectors will be discussed (see 1.1.3, “Residential Sector” & 1.1.4, “Corporate and Institutional Sectors”).

What precipitated the shift incorporates similarities to what had occurred when the Gothic style transitioned back to the purely Classical in the sixteenth century. The impetus was not one of a material or a construction technique innovation, nothing at the time could compare with the mastery of the medieval masons, but rather a shift in aesthetics driven by the writings of Petrarch and Dante.

Architecture has never been a frontrunner in a transition to newer aesthetic ideas and philosophies, for unlike the other arts, e.g. literature, painting, or music, which can be completed, if not widely circulated, by a single artist with limited financial requirements; architecture cannot be. Architecture requires financial patronage to become reality and that patronage is not often a readily available commodity in the world of commerce. Most frequently, an architectural commission is awarded only when the patrons feel a degree of assuredness that their financial risk will be rewarded by public acceptance. Architecture has historically been a powerful foot soldier in the army of change, but rarely, if ever, a strategy planning general.

Notes

13 (Mumford 1972, 415-416)
14 (Glancey 2006, 272-74)
15 (Pevsner 1968, 187-201)
The leading instigators and influencers of this aesthetic change were spread across Europe. In the Netherlands, led by artists Theo van Doesburg and Piet Mondrian (Fig.1.1) and architects J.J.P. Oud and Gerrit Rietveld (Fig.1.2), their collaboration, DeStijl,

![Figure 1.1: Composition in Red, Yellow, Blue and Black. Piet Mondrian. (Hannolans 2016).](image1)

![Figure 1.2: Schroeder House, 1924. (Basvb 2010).](image2)

embraced an abstract, minimal aesthetic of visual simplicity and primary colors.\textsuperscript{16}

In Italy, the avant-garde movement, Futurists, promoted the destruction of older forms of culture, replacing it with the new technologies, which encapsulated the beauty of the machine, speed, violence and change (Fig.1.3).\textsuperscript{17} In France, Picasso, Braque, and others led the cubist movement, deconstructing traditional forms, reducing them to fragmented essences (Fig.1.4).

In England, Marx and Engel’s, Communist Manifesto, while not explicitly setting forth a coherent Marxist theory of architecture, did infer that while architecture could not overcome what Manfredo Tafuri described as \textit{form without utopia... to sublime}

\textbf{Notes}

\textsuperscript{16} (Overy 1991, Start 216)
\textsuperscript{17} (Humphreys 1998, Total 80)
uselessness;¹⁸ it could at least promote a lucid awareness of societies’ conditions, and an understanding of the subjective experience the forms produced,¹⁹ which at the time was traditional architecture’s adulation and paean to capitalism and elitism (Fig. 1.5).

Notes

¹⁸ (Tafuri 1976, ix)
¹⁹ (Cunningham and Goodbun n.d.)
1.1.2 Transition and Evolution through Practitioners

It was into this cauldron of western societal change that the first architectural practitioners of Modernism emerged, born in the late 1860’s, these men, e.g. Frank Lloyd Wright, Auguste Perret, Peter Behrens were, each in turn, individuals of the first magnitude. Yet their combined work, when viewed as a whole, revealed a convergence of doctrine that was based on both their theories and built works. The choices of materials, treatment of ornament, and emphasis on structure and program was almost exclusively emulated by the next generation of architects, similarly to the way the Romantic Classical had been at the opening of the nineteenth century.20

The mantle of the first generation was passed to a second generation, born in the late 1880’s. Men such as: Walter Gropius, Mies van der Rohe, Le Corbusier, and Eliel Saarinen. Succeeding them, a final generation of elite Modernist practitioners emerged, each of whose members can be traced back to a second generation mentor; Marcel Breuer to Walter Gropius. Philip Johnson to Mies van der Rohe, I. M. Pei to Le Corbusier, Eero Saarinen to Eliel Saarinen and in turn Kevin Roche (attention will be focused here later).

In the United States the cross-pollination, dissemination, and eventual dominance of Modernist theory and design in practice was fostered by the influences of Walter Gropius at Harvard where he chaired the Graduate School of Design from 1938 to 1952,21 Mies van der Rohe, Director of Architecture at Illinois Institute of Technology (1938 to

Notes

20 (Hitchcock 1977, 419)
21 (Koeper n.d.)
1959), 22 the 1932 Museum of Modern Art’s International Style Exhibition curated by Henry-Russel Hitchcock and Philip Johnson, 23 and the grandfather of architectural periodicals, Architectural Record, which has documented notable architectural projects since 1891. 24 In consort, these influences dominated the education and development of the emerging architectural practitioners and the outputs from their drawing tables (see 1.2.6.2, “Architectural Education”), but not all building sectors responded with equal enthusiasm.

1.1.3 Residential Sector

As the decades passed and the thirties turned to the forties, then to the fifties, and finally the sixties and early seventies Modernism increased its presence in the architectural world, but there was a disunity of acceptance between the building sectors of corporate and municipal architecture (see 1.1.4, “Corporate and Institutional Sectors”) versus residential architecture, with academic architecture vacillating somewhere in between the two.

Unlike the corporate and municipal world, which had embraced Modernism and what these Modernist buildings represented, the residential segment, excluding a few notable exceptions, resisted the transition, with many, but not all, academic communities responding in similar fashion.

Notes

22 (Von Eckardt n.d.)
23 (Merin 2013)
24 (Rybczynski 2006)
The reasons behind this resistance in the United States lie deep within the American psyche. Americans have an intense and abiding attraction to their roots, embedded in the soil of European traditional architectural forms. Appropriately scaled (more or less) peaked and shingled roofs, clapboard or shingled siding, red brick chimneys, divided light windows flanked by louvered shutters, and six-raised-paneled entrance doors symmetrically balanced by matching pair of coach lights have proliferated across the American landscape (Fig.1.6).

Replaced in the last few decades by the McMansion, a frequently staggeringly ill-proportioned and engorged version of the above, containing most of the previously enumerated features, often constructed with value-engineered elements, plus an ill-considered palladium window caricature or two or three (Fig.1.7).

The cedar and slate shingles of roofs are reborn as asphalt, wood clapboards have been replaced by vinyl, masonry chimneys are now clad in wood as mechanical exhaust no longer requires non-combustible enclosure, the appearance of divided lites in windows are achieved with snap-in plastic grills, articulating louvered and operable shutters are now stamped, two dimensional, fixed in-place constructs that are typically both
incorrectly sized as well as placed, the wood raised panel door is now stamped metal, and the coach lights have never been near a horse drawn coach or even a wagon. Yet they are desired and loved. Why?

Setting aside the Heideggerian principles of dwelling and hearth, it was Robert Venturi and Denise Scott Brown who best answered the question. In 1972, two years after their *Learning from Las Vegas Studio* and simultaneous with the publishing of *Learning from Las Vegas*, Venturi and Scott Brown headed up a second studio entitled, *Learning from Levittown*. Although this studio did not produce a second book, it has a particular relevancy to this topic. Levittown was a postwar commercial suburban housing project designed to meet the huge demand for houses after World War II. The houses were compact designs offering modern conveniences in a traditional vernacular form, along with affordability. The development was a huge success for both consumer and developer and spawned a wave of similar projects all across America.

This American suburban phenomenon as we know it today was born in the fields of Long Island and it was greeted with disdain, resentment, and disapproval from all corners of the professional architecture world. Barbara M. Kelly in *Expanding the American Dream* quotes Lewis Mumford, the architectural critic at the New York Times, in a contemporary criticism: *Suburbs are stratified not only by class and age, but also by state in life.* The suburbs are also stratified socio-economically by virtue of the sheer numbers of dwellings replicated at the same cost and selling price.

Notes

25 (Hays 1998)
This resulted is what Mumford called a *low-grade uniform environment from which escape is impossible*. The unrelieved residential character of these suburbs, such critics held, created a stultifying environment in which all disharmonies were either removed or denied; the houses were architecturally bland, uninspiring, and repetitive - the children, *homogenized*.26

In studying Levittown, Venturi and Scott Brown acknowledge through their focus, by their academic positions, and with the scholarly mantle of Yale’s School of Architecture that a program of this type of architecture is worthy of study in order to deconstruct the conventions followed in the design. Through analyzing references made in the design it is possible to understand what it was that attracted so many people to these houses. It was the analysis of the components and or ornaments of these decorated sheds that provide the answers to Modernism’s exclusion in the residential realm.

The University of Westminster had funded a lecture series called *Supercrits*, wherein architects were invited to present in the traditional formal design studio presentation format (Crit) work that they have previously produced. In 2004, Venturi and Scott Brown presented *Supercrit #2, Learning from Las Vegas*, with accompanying information on *Learning from Levittown* to a full jury. This offered an unusual contemporary insight into an historic work being presented in the first-person, thirty-five years after the publication of the work and those presenters were the high priest and priestess of Postmodernism.27

**Notes**

26 (Kelly 1993, 55)

27 (Hardingham 2007)
Accompanying the presentation was a drawing from the Yale Archives from the 1970 studio, which more than evidences the points made about ornament and imagined references, i.e. vestigial pilasters translate to Parthenon façade, a fence fencing in nothing establishes foreground to imagine a sweeping middle ground of estate lawn, and coach lamps light the way for the arriving four-in-hand (Fig.1.8).

![Figure 1.8: Learning from Levittown. Courtesy of Robert Venturi and Denise Scott Brown.](image)

The publishing of this drawing and accessing it was a sort of architectural missing link. That sagging, sun faded, two dimensional, screwed on, ill sized aluminum shutter had found its spiritual manufacturer.

The residential sector was not completely devoid of Modernist examples. There was a scattering of exclusive (expensive) exercises for wealthy clients, e.g. Frank Lloyd Wright’s Fallingwater (1939) for Edgar Kaufmann (Fig.1.9), Eero Saarinen’s and Kevin Roche’s Miller Residence (1953) for Irwin Miller (Fig.1.10), Mies van der Rohe’s Farnsworth House (1951) for Edith Farnsworth (Fig.1.11), or Richard Neutra’s Miller House (1937) for Crac Lewis Miller (Fig.1.12).
Neighborhoods emerged in a few areas, e.g. Wright’s Usonia community in Mount Pleasant, New York (Fig.1.13), or The Architects’ Collaborative’s Six Moon Hill in Lexington, Massachusetts (Fig.1.14), but the vast majority of residential construction was of traditional design.

It was also not unusual for Modernist architects to enjoy local concentrations of their residential skills in idiosyncratic areas, e.g. Paul Rudolph with Ralph Twitchell’s
collection in Florida (Fig.1.1.15) or one-off exercises illustrating their philosophies, e.g. Charles and Ray Eames’ personal residence in California (Fig.1.1.16).

It was a principally ignored idiom with minimal impact on residential America with one anomalous exception of Modernist influence by Frank Lloyd Wright.

Born in 1867, the first of what would be two separate and lengthy periods of creative architectural design began in the offices of Joseph Silsbee in 1887. Far from Europe where Modernist architecture was incubating, this first period would be bookended twenty-three years after it began with an exile to Europe following the completion of Robie House in 1910, which in 1991 was recognized by the American
Institute of Architects (AIA) as one of the ten most significant structures of the twentieth century (Fig.P.4).\textsuperscript{28} It was a harbinger of Wright’s future work.

Segueing on those first twenty-three years, Wright developed and expanded on a singular vision for the American home. On the exterior, it was long, low, and sleek with ribbon windows and deep, sheltering, cantilevered overhangs. Interior spaces lacked traditional divisions and merged into each other. They were free and open, more in keeping with what Wright accurately perceived to be the modern American lifestyle. Wright called his design a source of world-wide architectural inspiration.\textsuperscript{29}

Although the design would be simplified and corrupted, its interior innovations would influence American architecture as in the reductionist variation, i.e. “ranch-style homes”, spreading across America and eventually (undoubtedly to Wright’s mortification) to the suburban great rooms of America’s McMansions.

The importance of including the above discussion on Modernist residential architecture might seem to be a misstep from the discussion of the specific Modernist building type with which this work concerns itself, a type far removed from the residential form. Its relevancy will become clear when the degradation of public perception of Brutalism is examined (see 1.2.3, “Negatives - Loss of Favor”).

\textbf{Notes}

\textsuperscript{28} (Frank Lloyd Wright Trust 2016) \\
\textsuperscript{29} ( WTTW Chicago 2016)

Author’s Note: To the list of master practitioners and educators, it would be remiss not to mention names such as, Alvar Aalto, Gordon Bunschaft, Louis Kahn, Richard Neutra, Oscar Niemeyer, and Paul Rudolph. Each of these practitioners and there are many others that could be added, adhered to the Modernism doctrine and ethos while implementing and inserting their own masterful and often innovative imprimaturs on their designs.
1.1.4 Corporate and Institutional Sectors

Shunned by the American residential sector, conversely, Modernism was enthusiastically embraced in the corporate and institutional sectors and sporadically included in the academic sector as previously mentioned. Within the two embracing building type market segments of Modernism, three materials would dominate - steel, glass, and concrete. Each material had experienced the technical benefits of nineteenth century scientific advancements. In the case of steel, it was the Bessemer process decreasing cost,\(^30\) in the case of glass, the development of plate and sheet glass processes allowed for greater sizes,\(^31\) and for concrete, although available for over two thousand years as a compressive stalwart, when coupled with steel reinforcement, the addition of tensile capacity opened up opportunities of form never before available.\(^32\)

All were used in varying proportions in every building, each contributing its signature quality. Steel lent strength, tensile toughness, ductility, weldability, and durability. Glass offered transparency. Concrete added plasticity, compressive strength, and weatherability. Depending on the design and relative percentages to each to the other of the three materials - two broad sub-styles emerged within Modernism.

The first style to evolve, seized on by the corporate world of commerce, was one dominated by steel and glass. It was the tectonic personification of efficiency, sleekness, transparency, and modernity, quite understandably all qualities corporations wished to project to the public. Termed by Hitchcock and Johnson, the International Style, its

Notes

\(^{30}\) (Encyclopædia Britannica 2016)
\(^{31}\) (Cable 2004, 33-34)
\(^{32}\) (Schaeffer 1992)
success was evidenced by the enormous proliferation of the building type in every major city. In some cities the glass and steel constructs with their platonic geometries dominated a street, e.g. Park Avenue in New York which included two spectacular and iconic instances, i.e. Gordon Bunshaft’s Lever House, 1952 (Fig. 1.17) and Mies van der Rohe’s Seagram Building, 1958 (Fig. P.7).

Unfortunately, in the case of these two icons, Lever House and Seagram Building, they were surrounded with linear phalanges of pale international style pastiches; characterized by Frank Lloyd Wright, with biting witticism:

...boxation architecture, anachronistic bosh, boxes next to boxes, glassified landscape, style for style’s sake by the glass-box boys.33

Notes

33 (Tafel 2001, 61)
In other cities, as corporations commissioned new buildings, the new International Style buildings joined both their stylistic brethren and their earlier traditionally styled brethren, e.g. Chicago’s Skidmore, Owings and Merrill, Sears Tower/Willis Tower, 1973 (Fig.1.18) or in Montreal, I.M. Pei’s, Place Ville Marie, 1962 (Fig.1.19).

![Sears Tower/Willis Tower](image1)

![Place Ville Marie](image2)

Figure 1.18: Sears Tower/Willis Tower. (Hough 2007).

Figure 1.19: Place Ville Marie. (Archives de la Ville de Montréal 2012).

The exemplars were effective spokespersons to an appreciative society. Lever House, for example, possessed the new technologies of glass curtain walls, integrating gleaming reflective materials speaking to science and progress. The building’s towering symmetry announced rational, disciplined, impressive power. The transparency of the entry level space beneath the green glass of the tower welcomed the community at large, above there was the uniformity of workspace where the office worker, the new collective farmer, would toil. These buildings were the anthropomorphic realization of contemporary corporate success and power.

With few exceptions, e.g. Le Corbusier, Oscar Niemeyer, and Wallace Harrison, United Nations Headquarters, 1952 (Fig.1.20), in the municipal and government sectors concrete was to dominate. In contrast to the qualities exemplified by the International
Style, the second style of Modernism used massive geometric forms of concrete to project a real world image of solidity, permanence, and power. All were qualities that the government and civic leadership programs, housed within these buildings, wished to be associated with and project to the world. About Boston City Hall (Fig.1.21), an exemplar of its type, the New York Times’ architecture critic, Ada Louise Huxtable, wrote:

What has been gained is a notable achievement in the creation and control of urban space, and in the uses of monumentality and humanity in the best pattern of great city building.34

Notes

34 (Vidler 2012)
As is evident from the discussion thus far, Modernism’s possession of two distinct styles is consistent to what its hosting category, Architecture, possesses only with two multiples of styles rather than many multiples. Not surprising as Architecture’s time span is millennia and Modernism’s is only years, but Modernism styles have a unifying commonality that does not exist between the styles within Architecture. The two styles within Modernism may have distinct periods, distinct materials, distinct technologies, distinct audiences, and distinct successes. However, a commonality envelops both. It is a distillation of an architectural ideology into an honesty of program, structure, and form that, when tectonically executed correctly, spiritually encapsulates a period of social, artistic, and technological change.

To that end, for this work, a descent, a narrowing of focus, now begins down the bifurcating staircase, of Modernism. A descent that will examine Modernism’s most controversial style. A style that is admired by some for its radical and monumental geometries and recapitulation of society’s tenets, but misunderstood or even hated by the others for its seeming lack of humanizing elements, perceived negative impact on the urban environment, and difficult to relate to principle material, concrete. It is the style named - Brutalism.
1.2 Brutalism

1.2.1 Definition

Simplified to its essence, the style is defined by monumental sculptural masses, concrete supplying both structure and finish (interior and exterior), with reduced window to opaque wall ratios.

First appearing in Le Corbusier’s Unité d’Habitation in Marseilles, 1952 (Fig.1.22), the term, Brutalism (see 1.2.2, “Ethical and Aesthetical” & 1.23, “The Name” for semantic derivation) described Le Corbusier’s use of monumental, sculptural shapes composed of raw, unfinished, molded concrete. It was an approach that represented a sharp departure from Modernism’s entrenched International Style.35

Brutalism did not eradicate the International Style, which remained dominant in the corporate sector, but in the government and civic sector it did became the dominant

Notes

35 (Encyclopædia Britannica 2016)
style. From the mid-1950s until the mid-1970s the Brutalist’s style of monumental concrete forms coupled with the International Style’s glass and steel would almost completely control the world of commercial, municipal, and government architecture.

A total inventory of the number either of Brutalist buildings built or of the total square footage of Brutalist buildings is not readily available. Inferences can be drawn to establish the fact that it was a spectacularly substantial number. A google search, “Brutalist Buildings using “select the local” (filling in “select the local” with the name of any major city), will return an impressive result. Turning to the often-cited repository of all knowledge, Wikipedia, one finds a list with links to principal Brutalist structures worldwide that totals over two hundred.36 There also is a website, Brutalism: Online, …that aims to document all Brutalist structures across the world and provide a single resource for hardcore fans of Brutalism.37

Accepting the fact that there are a substantial number of these buildings in the world the discussion shifts into one of how and what and why this particular style became so prevalent during the twenty-year period, bracketed by Le Corbusier’s first building in the style, Unité d’Habitation (Fig.1.22), and the penultimate and finally ultimate representatives of the type in the mid-1970s preceding the architectural migration into Postmodernism.

Notes

36 (Wikipedia 2013)
37 (Brutalism Online 2016)
1.2.2 Ethical and Aesthetical

As stated previously, this work concentrates on Brutalist architecture in the United States with only scattered references to Western Europe when relating to the origins of Modernism, Brutalism’s links to Le Corbusier, or an occasional reference to a specific building in Canada, South America, or Japan. It would be remiss, however, not to mention, examine, and clarify a division of ideologies that occurred early in Brutalism’s reign.

The first use of the word as a style was in England by the architectural historian Reyner Banham in 1954, referring to the work of Alison and Peter Smithson’s School at Hunstanton in Norfolk, because of its uncompromising approach to the display of structure and services, albeit in a steel building rather than reinforced concrete.38 Banham refined the category further by adding an adjective and coining the phrase, New Brutalism. Interestingly, Banham was already wondering by 1955 if the term was for a building type or for a building program.39 The Smithson’s had taken the position that:

Brutalism tries to face up to a mass-production society, and drag a rough poetry out of the confused and powerful forces, which are at work. Up to now, Brutalism has been discussed stylistically, whereas its essence is ethical.40

It was a manifesto of sorts and a position that the Smithson would continue with in their work, focusing on public schools and social housing projects, e.g. Robin Hood

Notes

38 (Waters 2016)
39 (Banham 1955)
40 (Smithson 1957)
Gardens, 1972 (Fig.1.23). Banham would concede that the name migrated and devolved from the Smithsons’ intent and became for most part a descriptor for the hard-edged formal qualities of concrete.41

Figure 1.23: Robin Hood Gardens. (Cadman 2008).

In the United States, inspired by the work of Le Corbusier’s deconstruction of form into monumental geometric shapes in both Unité d’Habitation (Fig.1.22) and his High Court Building, 1956, in Chandigarh, India (Fig.1.24) designers moved away from the International style buildings of glass and steel inspired by Walter Gropius and Mies van der Rohe.

Figure 1.24: Chandigarh High Court Building. (D. Morris 2006)

Notes

41 (Pasnik 2015, 16)
Both early and later examples representing the aesthetic are plentiful: Paul Rudolph’s Blue Cross Blue Shield Building, 1960 (Fig.1.25), Eero Saarinen’s Dulles Airport, 1962 (Fig.1.26), Louis Kahn’s Salk Institute, 1965 (Fig.1.27), I.M. Pei’s Christian Science Center, 1970 (Fig.1.28), Kevin Roche’s Oakland Museum, 1969 (Fig.1.29), and Marcel Breuer’s Whitney Museum, 1966 (Fig.1.30).

Figure 1.25: Blue Cross Blue Shield Building. (Bisanz 2009).

Figure 1.26: Main Terminal at Dulles International. (Ravi 2011).

Figure 1.27: Salk Institute. (Harper 2004)

Figure 1.28: Christian Science Center. (Rizka 2014).

Figure 1.29: Oakland Museum. Courtesy of KRJDA.

Figure 1.30: Whitney Museum. (Calleja 2007).
1.2.2.1 Original Critical Response

The mid 1950s and very early 1960s represented a period in the United States of social tranquility. World War II was in the past, albeit the near past, but the economic stability of the Eisenhower Administration (1952-1960) was empowering. The election of John F. Kennedy supplied inspiration and unvarnished hope for the future. The Eisenhower Interstate Highway Project was near completion, connecting the continent as never before imagined, the Servicemen's Readjustment Act (G.I Bill) had educated and supplied home ownership (see 1.3.2.1, “Background”) to the returning serviceman, energy was inexpensive (gasoline: thirty-one cents/gallon in 1960)\(^{42}\), unemployment figures hovered around 5% or even lower,\(^{43}\) and Kennedy had announced the United States would be on the moon before the decade was out.\(^{44}\) The looming turmoil caused by imminent threat of nuclear war, the conflict in Southeast Asia, the eruption of racial unrest with accompanying violence, and the scandal of Watergate were all obscured in the fog of the future. Mainstream America understandably respected and supported its government. The public at large felt secure in the positions the government subscribed to and the safety of the political courses onto which the leaders would steer the ships of state.

It would be much too strong a position to take that Modernism and the prevalent glass and steel constructs of the International Style was in crisis, but the International Style was under siege.

Notes

\(^{42}\) (Department of Energy 2016)  
\(^{43}\) (Statista: The Statistics Portal 2016)  
\(^{44}\) (Kennedy 2016)
At the forefront of the siege was a young, particularly outspoken, architect, Paul Rudolph. At the June 1954, annual meeting of the AIA Rudolph was a member of a panel with the topic *The Changing Philosophy of Architecture*.45

The architects on the panel reviewed Modernism’s current, increasingly positive, reception in America, but expressed dissatisfaction with the repetition of the flat roof, glass encased, rectilinear boxes of the International Style; most lacking any form of relieving ornamentation or form capable of lending any enhancement (in their opinion) to the public realm. Rudolph exhorted, *the architect’s prime responsibility is to give visual delight and to that end, it could be accomplished with reconsidering traditional urban forms*.46

Wright was not in attendance, but was undoubtedly, in his own iconoclastic way, in support of the position as can be evidenced from not only the previous mention of his boxation architecture disparagement, but also by the recent completion of the Guggenheim Museum (Fig.1.31), design and its construction, which had begun in 1953.

![Figure 1.31: Guggenheim Museum. (Döringer 1995).](image)

Notes

45 (AIA 1954)
46 (Rohan, The Architecture of Paul Rudolph 2014, 33)
Rudolph and architects as a group, having been exposed to Le Corbusier’s Unité d’Habitation (Fig.1.22), and the extensive work in Chandigarh, India (Fig.1.24), were well equipped and eager to use as precedent Corbu’s geometric complexities of form and the textural variability of concrete to create sculptural masses that responded to the sun’s movement with ever changing and enchanting shadows and in doing so adding visual delight to the public realm.

Rudolph continued to espouse this position, receiving physical tectonic support as individually and characteristically distinctive Brutalist designs emerged from the practices of his architect contemporaries, e.g. Eero Saarinen, Edward Durrell Stone, Marcel Breuer, I.M. Pei; and philosophical support from the architectural press of the time, e.g. Ada Louise Huxtable’s 1957 New York Times’ article characterizing the buildings on Park Avenue as stark glass boxes...shocking and strange... [creating] monotony and uniformity reserving praise solely for Lever House (Fig.1.17) and Seagram Building (Fig.P.7), then under construction,47 or an article in the 1959 Architectural Forum, The Monotonous Curtain Wall expressing similar dissatisfaction.48

Rudolph’s and his contemporaries’ position and focus became a uniformly pervasive design strategy in the expanding construction arena of government and civic buildings. The adaptation of this new evolved Modernist style was spectacularly ascendant.

Notes

47 (Hession and Pickrel 2007, 35)
48 (Rohan, Challenging the Curtain Wall: Paul Rudolph's Blue Cross and Blue Shield Building 2007 , 88)
Commercial and corporate continued its relationship with the steel and glass of the International Style with a few notable exceptions, e.g. Marcel Breuer’s Pirelli Building in New Haven, Connecticut, 1969 (Fig.1.32), just as the United Nations Building (Fig.1.20) was an anomaly in the Government sector. Academia divided allegiances between traditional, remaining the dominant form, but with Modernist forms making more than token appearance as discussed previously (see “Preface”).

The residential sector maintained its entrenched fascination with the traditional for reasons also previously discussed (see 1.1.3, “Residential Sector”).

The forces behind the almost universal acceptance within the related relevant communities, separate from the AEC Community, i.e. the government and civic authorities responsible for the initiation and approval of projects, was twofold.

First, the adjectives describing the architecture itself offer some explanation: heroic, monumental, imposing, honest, powerful, singular, and sculptural. It is easy to understand the connection with the optimism of the time:

The forward-looking optimism of concrete architecture in the United States communicated the social ideals of John F. Kennedy’s New Frontier and Lyndon B. Johnson’s Great Society programs, emblems of
the collective will to capitalize on growing national wealth to broadly repair and enrich the public realm.49

Secondly, elected officials at the national, state, or town level, supporting new civic construction were impacted by and shared a commonality of societal influence. At that particular period in time, the aesthetic experience of art was widely accepted as a positive influence on the public:

This attitude was championed with great vigor in American schools and universities in the decades after WWII. Postwar philosophers, educators, psychologists, and artists argued that aesthetic experience is a basic psychological aptitude and need in human beings.50

Additionally, inspired by the consistently glowing reviews of early completed projects, the civic and institutional leaders and powerbrokers’ choices of building type of this era was bolstered by synchronistic cost effectiveness of a period when construction labor costs were affordable,51 and a period of time when opportunity for new construction was increased by urban renewal.

Urban renewal, at the time, meant clearing large swathes of the older, depressed, non-gentrified or modern urban cityscape populated by slum-dwellers and removing them, i.e. relocating people and razing the buildings, often with government subsidization.52 The newly cleared land opening up opportunities for new construction sites in cities not seen since Chicago’s Great Fire had produced such abundant

Notes

49 (Pasnik 2015, 29)  
50 (Sroat 2005, 5)  
51 (Pasnik 2015, 26)  
52 (Gans 1965, 29)
opportunity.\textsuperscript{53} The results: Brutalist building inventory swelled across the American landscape.

Ada Louise Huxtable’s positive review of Boston City Hall was not a singular incident; there were many other positive responses to the building type.

In Boston, The Harleston Parker Medal, awarded annually by the Boston Society of Architects to what in their estimation was the most beautiful building in Boston, began in 1964 with awarding the medal to Le Corbusier’s Carpenter Center for the Visual Arts at Harvard University (Fig.P.11). This would begin a ten-year sequence of awarding the medal each year to a concrete building, save one exception in 1971.\textsuperscript{54}

At Yale University in New Haven, Connecticut, Paul Rudolph’s Architecture and Art Building, 1964 (Fig.1.33) made the covers of the three leading architectural magazines in the same month, Architectural Forum, Architectural Record, and Progressive Architecture; illustrated and discussed it with extensive articles. The Architecture and Art Building was also highlighted in non-trade periodicals, e.g. New York Times Magazine and Time Magazine. At Architectural Forum, the critic, Sibyl Moholy-Nagy describe the building, as \textit{a much needed return to architecture as art}.\textsuperscript{55}

For the next twenty years, well into the 1970s, Brutalism continued to be the dominant construction form in American city after city. To underscore the universal acceptance of the type’s impact, one more example is offered as a singular, but not

Notes

\textsuperscript{53} (Condit 1973, 19)  
\textsuperscript{54} (Pasnik 2015, 24)  
\textsuperscript{55} (Rohan, The Architecture of Paul Rudolph 2014, 112)
extraordinary representative of the style. The building is Bertrand Goldberg’s Prentice Women’s Hospital, 1975, in Chicago (Fig.1.34).

The following articulates the extensive accolades that the buildings of this type garnered in their contemporary construction time period. As documented in the building’s National Trust application for Landmark status:

*It was celebrated in architecture and building technology publications around the world, including Building Design & Construction (March 1974 cover story), Inland Architect (January 1974 and April 1976), Architecture and Urbanism (Japan, July 1975), Architecture d’Aujourd’hui (France, January-February 1976), Modern Healthcare*
Magazine (March 1976 cover story), Architectural Record (July 1976), Informes de la Construction (Spain, November 1976), Cement (Netherlands, 1977), Concrete Construction (February 1980), L’Industria Italiana Del Cemento (Italy, No. 7-8, 1980), and Concrete Abstracts (cover image, January/February 1986. Four years after its completion, in 1979, the building was recognized for its ingenious use of materials and structural engineering in a show at the Museum of Modern Art in New York entitled “Transformations in Modern Architecture”.56

1.2.3 Negatives - Loss of Favor

Even as the Prentice Hospital was receiving its accolades there was a powerful professional and societal shift in play that would spell the demise of the building type’s relatively brief chronological, but prolific existence and acceptance. Not even the weight (visual and real) of these massive concrete forms could resist these winds of change. Factors causing the change were multiple.

Some arose from the architectural world’s transition from Modernist dogma to Postmodernism fueled by Robert Venturi and Denise Scott-Brown’s book, Complexity and Contradiction.57 The shift to Postmodernism bears a degree of commonality with American domestic architecture’s fascination with and allegiance to the representation of traditional classical forms, e.g. pediments and pilasters (in various degrees of accuracy), as discussed (see 1.1.3, “Residential Sector”).

Postmodernism’s evolution of form, in either exaggerated caricaturization, as in Michael Grave’s Portland Building, 1982 (Fig.1.35) or in a more understated, yet heroic,

Notes

56 (Ribstein 2012, 11)
57 (Hardingham 2007)
manifestation as in Philip Johnson’s AT&T Building, 1984 (Fig.1.36) focused on similar classical and traditional architectural cues.

In the professional world of architecture, the shift affected the design outputs of the professionals, but did not necessarily affect their perception or appreciation of the Brutalist buildings they had designed and constructed over the previous twenty years.

Architectural styles have historically migrated and changed. Sometimes radically, as in the shift from the classical understatement of the Georgian periods (Fig.1.37) to the exuberance of the Victorian (Fig.1.38) in the mid-nineteenth century America, or
sometimes, more subtly and gradually, as in the shifts from early colonial primitivism (Fig.1.39) to a slightly more elegant second period colonial (Fig.1.40) in the early part of the seventeenth century. When those shifts occurred there was a typically understandable humanistic desire for the new, but there was not antithesis directed toward the previous style and in some quarters, a retained fondness for the previous style persisted.

For Brutalism, the judgement of the world and support of the building type, separate from the arena of the architectural cognoscenti, did not endure. The buildings acquired a degree of public and civic approbation that has never abated.

How buildings that were originally seen as reflecting the democratic attributes of a powerful civic expression – authenticity, directness, strength – eventually came to signify hostility, coldness, and inhumanity. Ambitions, which had been viewed as positively monumental, were condemned as bureaucratic and overbearing. As a banner for a movement, Brutalism, was a rhetorical catastrophe. Separated from its original context and reduce in meaning. It became an all-too-easy pejorative, suggesting these buildings were designed with negative intentions.58

Notes

58 (Pasnik 2015, 19)
An incredible and meteoric shift, to be sure. These building were not perceived as “old-fashioned”, but rather as anathema by many.

There are several factors implicit in the public shift in perception and the following will address them one at the time. Each one, although valid, might not have been enough to produce the shift, but in consort, they have been most successful.

1.2.3.1 The Name

The term Brutalism is indeed a brutal title. It comes from the French Bèton Brut meaning raw concrete. Other forms of architecture have names that might suggest a loftier association, e.g. Romanesque, Greek Revival, Arts and Crafts; or at the very least, imply little judgement, e.g. Colonial, Art Deco, and Moderne. Not so with the Brutalist name. The word conjures up the hostile images that the word is meant to convey. As evidence from *Merriam Webster Dictionary*:

> Brutal: Simple Definition:
> Extremely cruel or harsh.
> Very direct and accurate in a way that is harsh or unpleasant.
> Very bad or unpleasant. 59

Of course, it is of small value to attach a great deal of meaning to an unfortunate name, but it is of note that it is, at best, an ironic title which has dovetailed with the building type’s size and material and the subsequent perception of Brutalism. It must be allowed that few works of any sort receive benefit from an ill chosen title

**Notes**

59 (Merriam-Webster 2016)
Although first used by Reyner Banham in written form to define a style, referencing the Smithson’s work, the term was actually first used by Le Corbusier when executing Unité d’Habitation (Fig.1.22) in 1955. His selection of the word is clarified in correspondence with Josep Lluis Sert, Dean of Harvard’s Graduate School of Design:

...there were 80 contractors and such a massacre of concrete that one simply could not dream of making useful transitions by means of grouting. I decided: let us leave all that brute. I called it, bêton brut. The English immediately jumped on the piece and treated me (Ronchamps and the Monastery of La Tourette) as Brutal... They called that “the new brutality”. My friends and admirers take me for the brute of brutal concrete! 60

Yet despite the unfortunate name, it is quite clear that at the time of its introduction, as a design alternative, Brutalism was received enthusiastically into the armament of architectural designers as evidenced by its proliferation across the tectonic landscape.

1.2.3.2 Building Geometry

Without question, the Brutalist buildings are large and dwarf earlier more traditional building typologies, which were hosts to the earlier structural and technology limitations that precluded large heights, spans, and volumes. Yet many contemporaneous International Style buildings have similar or larger volumes to Brutalist buildings, e.g. University of Massachusetts-Dartmouth Library (Fig.P.9) or Orange County Government

Notes

60 (Sekler 1978, 302)
Center (Fig.A.1) at 250,000 sq.ft. (23,225.76 m²)\textsuperscript{61,62} each vs. Lever House (Fig.1.17) at 267,000 sq.ft. (24,805.11 m²)\textsuperscript{63} or Seagram Building (Fig.P.7) at 820,000 sq.ft. (76,180.49 m²)\textsuperscript{64}. Although volumes can be similar or greater for these admired International Style buildings there are elements relating to scale that separate the two styles dramatically and each is a contributor to Brutalism’s negative image.

First is the typical footprints of the buildings. The International Style buildings are more often than not members the tall building community, i.e. skyscrapers. The two International Style examples above are 21 and 38 stories high, respectively. Their geometries are rectangular towers with clearly identifiable entrances at the street level. The buildings capture the anthropomorphic qualities of efficiency, sleekness, transparency, and modernity. They are personifications of the corporate power within them as was discussed (see 1.1.4, “Corporate and Institutional Sectors), but an additional quality supplied by the simple geometry of the footprint is a defined and obvious point of access, which to these bastions of money and power is a distinct positive.

When visiting these buildings there is never a question of approach or threshold. The architecture supplies all the necessary cues of access, even if the large scale and gleaming expensive finishes are intimidating to some. The ease of identifying entrance removes the stomach tightening sensation of, “How do I find my way in?” for those seeking access.

Notes

\textsuperscript{61} (UMass Dartmouth 2016)  
\textsuperscript{62} (Taylor 2015)  
\textsuperscript{63} (Oser 1983)  
\textsuperscript{64} (TRD Data 2016)
Brutalist buildings are the antithesis of the above. The two mentioned above are three to four stories with multiple levels. The results are low sprawling constructs with substantial footprints and complicated geometries, e.g. a description of Orange County Government Center supplied by Docomomo, U.S. underscores the complexity:

... comprised of three interconnecting concrete buildings with similar massing and forms. Each building is three stories tall consisting of a series of concrete boxes, or blocks, stacked upon one another and cantilevered out by concrete beams, each extruding mass is further defined by its fenestration. The individual boxes vary in size but are uniform in their style and use of floor to ceiling single panes of glass. Portions of the structure appear organic: some blocks are smallest on the first floor and grow with each succeeding story so that it appears that the building is growing like a tree from the ground. Other facades have a heavier orientation caused by blocks and stories that appear to merge and lose form.65

Approach and threshold are not readily or easily located because of the complexity of the continually articulating and expansive footprint. Additionally, because of the size of the footprint the entrance can be at times a relatively lengthy journey that is dependent on the serendipity of from which direction one happened to have approached the building’s site and the commensurate distance required to reach an entrance that is not only at considerable distance, but is also not defined with the typical façade cues that were always supplied by traditional buildings. This is the polar and hostility producing opposite to the American ideal of entrance, i.e. a “six-raised-paneled entrance door symmetrically balanced by matching pair of coach lights” (see 1.1.3, “Residential Sector”).

Notes

65 (Taylor 2015)
The creation of confusion and inconvenience are qualities that users do not suffer lightly and these feelings are exacerbated when these building appear adjacent to traditional buildings where architecture supplies both welcomed and welcoming signals when directing approach and threshold, contrasting and reinforcing the comfort of long established traditions - negative one.

1.2.3.3 Building Scale

As noted above, the Brutalist buildings are not necessarily any larger than International Style buildings in volume, but because of the extended footprints of these buildings and the scale of these buildings when viewed from the ground level and streetscape, which is the perspective most relevant to building occupants and passersby (pedestrian and automotive), the buildings appear to be much more imposing. This quality is again exaggerated by the building’s materiality and scale of construction module, each addressed below.

For the building’s occupants and users there is an additional component that adds to the perception of large scale existing within the interior. International Style buildings are able to effectively address movement within the building via elevators. This vertical transport provides extraordinary convenience in accessing all areas of the building. The simple geometric footprint allows all but the most “sense of direction” challenged to maintain orientation while following the logical sequence in reaching a destination by elevator and then completing a moderately brief journey to the most remote corner of the footprints relatively compact area.
Just the opposite is at play in a Brutalist building. Elevators may be present, but often few and far apart. The result is extended travel once inside, e.g. I.M. Pei’s Christian Science Center, 1970 (Fig.1.28) is one tenth of a mile long. The travel might not only involve relatively long distances over multiple levels, but also include navigations involving corridors with multiple turns organized in response to the irregular footprint. A frequent and exacerbating companion to these long disorienting treks is created by Brutalism’s reduced glazing percentages and diminished opportunity for orienting exterior views.

Thus, scale as related to size and volume is not the issue that contributes to the negative perception, but rather the discomfort that is created by the particular methodologies by which Brutalism achieves its volumes, resulting in another less than positive experiences for the occupants, visitors, and passersby - negative two.

1.2.3.4 Construction Module Scale

Separate from the gross building scale and related to the dominant material used in construction, concrete (see 1.2.3.8, “Brutalism’s Concrete”) is the quite visible building module scale. Certainly a more micro-scale than the gross building scale; it is, however, far from micro. It is a scale dictated by the joints created by the concrete forms used during its construction. The joints are spaced at intervals delineated either by the building’s geometry or by the design pattern that the joints create as intended by the designer.

Both have additional limitations levied by the requirements of material expansion coefficients, which impose maximum control and expansion joints separation distances
that are dependent on slab thickness and aggregate size with typical distances being two to twenty-four feet (7.62 m.) between joints, again depending on material limitations and design intent.

![Image](image-url)

**Figure 1.41: Module Scale - Approximately: 4’ x 8’.
Image by Author.**

It is large and the never before witnessed tectonic visual scale resulting in what is no longer a human sized module (Fig.1.41). Gone are the human worked, hand-sized brick modules; the larger, but still manageable, ashlar or rubble stone units; or the familiar repetitions of clapboards and shingles. In addition, absent are the individually, piece-by-piece, constructed cornices and architraves connecting roof to wall or wall to window, or wall to door with each element appearing on stage at their designated moment in the traditional construction production. Although each was constructed, installed, and finished with the intent to visually join the larger whole, they clearly evidence the human scaled bits they are. They never lose that identifiable quality of individuality, even as their parts are absorbed into the whole.

The impact of increased module scale, intensified by great opaque expanses (see subsubsection, “Transparency”), the dominating street level presence of the building (see
subsubsection, “Building Geometry”), and the material itself (see subsubsection, “Concrete”) results in a structure appearing absent of the work of the human hand, a fortress constructed by something larger than human. It is an absence of humanity - negative three.

1.2.3.5 Lack of Ornamentation

The dishonesty of architectural ornamentation was intrinsic to Modernist dogma. Originally, many of these ornaments had been functional as well as decorative intents, e.g. pilasters increasing load capacity or window architraves allowing insertion of less structurally robust fenestration elements, but many had become imposters, paeans to past importances as the expanded structural capacity of new technologies dismissed their need. For instance, the massive ionic columns of the entrance portico to the U.S. Supreme Court Building (Fig.P.3) are not there to hold up the pediment of the portico, but rather to conceal the slender steel columns that are the true structural members hidden within the columns interiors.

If the elimination of the architectural elements resulted in only a reductionism of the buildings geometry from the intricate topographies of the classical style, e.g. Palais Garnier (Fig.1.5) then perhaps, even with the substantial differences from the International Style in geometry, materiality, and transparency, Brutalism might have enjoyed some of the perception of the modern that the International Style enjoyed.

Unfortunately, eliminating these elements and others like them, i.e. cornices, belt courses, projecting windowsills, water tables, etc. had an additional and unanticipated impact on Brutalist buildings and their principle material, concrete. While the
International Style buildings followed the identical doctrine, the gleaming slick material properties, of glass, steel, and aluminum proved more resistant to environmental degradation.

It was a problem avoided in the International Style buildings, but not one in Brutalist buildings. Early in a Brutalist building’s life, fresh from when the forms were stripped from the concrete, the building appeared with crisp clean joints accenting its intricate geometry. Concrete was young and even in coloration.

The great expanses of concrete facades on these buildings, clearly different in color and module size from the traditional building or the International Style buildings, provided a novelty of a new building form coupled with the strong positive association humans have with objects that are characterized with adjectives such as white, creamy, or crisp and granted these buildings a grace period, albeit a brief one, as there were unsuspected and unforeseen ramifications of total ornament removal.

The removal of these traditional decorative details, while effectively eliminating associations to the classical style and the political and class affiliations that traditional buildings were associated with (see 1.1.1, “History”), also eliminated the inherent “water shedding” capabilities that had been importantly and practically inserted into the geometry and aesthetics of the ornaments designs (Fig.1.42).

Figure 1.42: Water Shedding at Casa di Dante, Rome, 1511. Courtesy of Mathew Bronski
As a Brutalist building ages the concrete begins to transform itself as a result of natural weathering processes, a patinization that on traditional buildings can sometimes be aesthetically acceptable. In the case of the Brutalist building, the stripping of traditional water shedding geometries as facades were pared down to their structural and geometric essences by their designers had unsuspected consequences as it left the building and its concrete far more susceptible to water staining and related moisture damage than traditional buildings.

North facing facades and other protected and/or shaded areas accumulated dirt, mold and mildew resulting in uneven and unsightly patinization (Fig.1.43). Worse still water’s invasion at cracks or failed joints penetrated the concrete slabs, at the least efflorescing the surfaces (leaching to the surface salts and other internal compounds), and at the worst, rusting the embedded steel reinforcement causing additional staining on the surfaces along with even more consequential structural degradation. In northern climes, the freeze/thaw cycle initiated spalling and exacerbated cracks as the weather and seasons changed.

Figure 1.43: Weathered and Mildewed Concrete. Image by Author.
A secondary, but of equal impact on these building, precipitated by the removal of traditional ornament, was the absence of geometrically protective buffers that could be repaired in isolation from the building façades as a whole. An example of a geometrically protective buffer would be a painted wood pedimented doorway (Fig.1.44) at the entrance to a Georgian Town Hall.

![Figure 1.44: Georgian Doorway. (Clough 2006).](image)

This surround, which supplies both importance and direction to the entrance (see 1.2.3.2, “Building Geometry”) also protects the adjacent brick or stone from damage. The wooden corners and surfaces of the architrave absorb the dents, gouges, and abrasions created by continual traffic and are easily repaired by the traditional crafts of carpentry and painting, returning the surfaces to a like new condition whenever maintenance is necessary.

Not so with concrete, its reliance on a surface regularity and evenness of finish and color are the results of the initial continual uniform pour accompanied by vibration.

![Figure 1.45: Damaged Outside Corner. Image by Author.](image)
It resists repairs that could blend smoothly and invisibly into the adjacent undamaged areas. Damage at vulnerable locations such as outside corners compounded by concrete’s brittleness are not uncommon. The fact that these areas are frequently in the most conspicuous locations adds to the visual degradation.

Over the life of a building it is inevitable that some of these areas are chipped or broken (Fig.1.45) with the attendant repairs quite challenging, if not impossible. Finally, these surfaces are also continually contacted by passersby with the attendant buildup of dirt and grime, which unlike the continually touched extremity of a favored bronze statue in a public garden that gleams a soft warm gold, is not the case for concrete, which becomes increasingly soiled and unsightly with identical attention – negative four.

1.2.3.6 Maintenance

Although this is an academic document accompanied by appropriate verifiable citations, it must be allowed that there is an acceptable place for anecdotal evidence that might be reasonably categorized as common sense even in a work such as this. Proceeding with the caveat of anecdotal, it is reasonable to report the following.

A Google web search for window washers located in any major American city yields many firms in each city willing to be of service. Those services, if engaged, provide annual, bi-annual, or seasonal maintenance to seventy to ninety percent (depending on the spandrel material and size and the mullion profile) of all of the exterior wall surfaces of International Style buildings occupied by corporate or municipal stakeholders. The cost is born as a percentage of the maintenance fee that is integrated into the lease or the rental fee that is charged to a tenant or born by the stakeholder, if
they are their own tenants. It is, also, a very regular occurrence to witness, at the entrances to these buildings, either door attendants or maintenance staff cleaning the glass or polished metal surfaces incorporated into the architectural entrance.

The traditional and/or historic buildings of cities or campuses are maintained to varying degrees depending on the financial resources of their stakeholders. Brick and stone, if detailed properly with appropriate water-shedding architectural details, defends itself well (see 1.2.3.5, “Lack of Ornamentation”). The variegated natural qualities of the masonry with attendant mortars tolerate some capricious topographical patinization from varying weather and shade exposures at the assorted building elevations.

Indeed, there is a posture, long established in the Historic Preservation community that explicitly advocates the effects of weather and time on masonry surfaces. In 1877, the Society for the Protection of Ancient Buildings was founded by William Morris (English textile designer, poet, novelist, translator, and socialist activist) to counteract the highly destructive “restoration” of medieval buildings being practiced by many Victorian architects. The society’s Manifesto is principally a plea.

Protection in place of Restoration... recognition of original fabric and precision of original craftsmanship with focus on materials and patinization... the elegant effect of time and weather on surfaces and structures.66

Wooden elements on these traditional masonry buildings are typically painted to protect the more vulnerable substrate, which if left unprotected (excepting a few weather resistant species) deteriorates, i.e. rots. The opaque finish of the coating, white in many

Notes

66 (W. Morris 1877)
cases with other colors being introduced as fashion dictated, needed rejuvenation via recoating every five to ten years depending on weather and climate. The work was necessary, not only to maintain a crisp and clean surface, but to rejuvenate a surface that even if intact was impacted by weather and subject to airborne pollutants such as mildew and mold spores attaching and proliferating on a degraded paint film. It was also at this time that any damage to the wood substrate could be repaired and then made invisible under the new protective coating.

The surfaces included might be only trim elements (cornices, windows and doors with surrounds, porch elements, etc.) for a masonry building, e.g. a brick Federal style library; or they might include all exterior surfaces, e.g. a white clapboarded New England Congregational church. This was an ongoing and anticipated expenditure that as long as funding was available was executed at the required intervals.

The Brutalist buildings have proven to be exceptions to maintenance programs and have followed a protocol that might best be termed “active neglect”. The original attitude that concrete does not need maintenance of any sort proved to be a fallacy as evidenced by the deterioration of their surfaces (Figs.1.43 & 1.45). Few Brutalist buildings, although most are fifty years or older, have received much cleaning or maintenance, excepting when water invasion precipitates internal problems or in the extreme structural issues.

If window washing is included in their schedules it has little impact on the building as the windows are overwhelmed by their soiled and stained adjacent opaque wall members and the public realm receives less than little visual gain as the buildings continue in a downward spiral of deterioration - negative five.
1.2.3.7 Transparency

The International Style and the transparency of the building type’s glass curtainwalled facades, invite in daylight as well as the public view, speaking to both light and safety after entrance. Once inside, the glass walls offer unrestricted views. The terrific solar loads that are intrinsic to the system are compensated for with massive energy intensive cooling systems, not thought to be an issue when energy costs were inexpensive and climate related impacts of fossil fuel combustion not yet realized. The ratio of glass to opaque wall was extremely high; early examples eschewed even the use of opaque spandrel panels to obscure structure, e.g. Walter Gropius’s Bauhaus Workshop Building, 1926 (Fig.1.46).

Brutalism’s use of glass varied from project to project, typically responding to program. Providing reduced ratios in museums, religious, and cultural centers where programs focused on interior function rather than view, e.g. Oakland Museum (Fig.1.29) or Whitney Museum (Fig.1.30). Conversely, responding with increased glazing
percentages where view and daylighting were appropriate, e.g. Blue Cross Blue Shield
Building (Fig.1.25) or Salk Institute (Fig.1.27).

It is, also, important to notice the variation of glazing percentages as the
building is circumnavigated. No longer are there the four identically sided geometries of
the International Style, with Brutalism the variation of glazing percentages on different
elevations responds to the programs within the area of the building behind that particular
façade; not to the context of the building as a whole. Reference UMass-Dartmouth
Library’s (Fig.P.9) collection stacks as opposed to common areas or Carpenter Center’s
(Fig.P.11) exhibitions spaces versus studio spaces, where each areas glazing quantity is
treated according to the program within and then protected by the addition of horizontal
or vertical fins of concrete, depending on the solar exposure, defending the glazing from
solar gain or glare.

The resulting difference when compared to the International Style is that an
opaque material, concrete, dominates from almost every perspective. Gone is the
invitation to light and safety. It is replaced with a uniformity of opacity that makes a fair
and substantial contribution to the fortress like appearance of the building – negative six.

1.2.3.8 Brutalism’s Concrete

It is necessary to now address, in a general sense, the principle component of
these buildings, concrete, as it relates to the perception of Brutalism. An in depth
discussion of its material properties will follow in the Analysis chapter. For the present
discussion it is concrete’s use as a monolithic slab (vertically or horizontally) that
provides, in addition to structure, the principal finishing component of a Brutalist’s
building’s façade, adjacent landscape or privacy walls, and roofs (if visible from a pedestrian vantage point).

Concrete is a substance that has historically produced a less than positive reaction from an aesthetic point of view.

There is an undoubted prejudice against the look and even the feel of Portland cement wrote the English journal, The Builder in 1876. An element of revulsion seems to be permanent, structural feature of the material.67

Categorizing concrete has never been simple. Frank Lloyd Wright’s description encapsulates concretes dilemma:

Is it Stone? Yes, and No.
Is it Plaster? Yes, and No.
Is it Brick or Tile? Yes, and No.
Is it Cast Iron? Yes, and No.
Poor Concrete! Still looking for its own at the hands of man.68

Concrete is a composite material consisting of four natural materials, cement (fired limestone or slaked lime), small and large aggregate (sand and gravel), and water. The four ingredients must be mixed in a precisely measured and ordered procedure, formwork is needed to be constructed to exacting tolerances to capture the desired geometry, and steel for tensile qualities, if required, needs to be incorporated to allow concrete to achieve its intended part of the constructed whole.

Concrete is a combination of both materials and a process that morphs from semi-liquid to solid. It can result in any shape or scale depending on its formwork. It requires a

Notes

67 (Forty, Concrete and Culture 2012, 10)
68 (Wright 1928)
process to reach its final form as do other building materials. In the case of aluminum - from mining, through refining, to manufacturing, to work site installation of a prefabricated unit or panel; or in the case of stucco or render - from sourcing of ingredients, to site mixing, to plastering by tradesman; or in the case of stone - from quarrying, to shaping and/or polishing, to installation by masons; or in the case of brick, which incorporates mining of ingredients, semi-liquid to solid in firing process before installation by tradesman.

Yet, concrete is maligned as none of the others. Of course, there are the related issues of weathering and maintenance and discoloration, discussed previously. If these issues were addressed and the buildings were returned to their original condition, would attitudes change? Impossible to predict. Hopefully to a degree, but the other five negative obstacles to acceptance discussed above would still be present.

There is, however, a very singular and unique attribute that concrete possesses with all of the above materials that adds an additional obstacle to public acceptance. It is an obstacle that is possibly the most challenging for the building type to overcome. It is related to and concerned with the visibility of process.

As the other finish materials move from their origins at mine or quarry on through their manufacturing phases, the view to the public at large is obscured by the nature of the locations of the mines or quarries and the closed, secure world of manufacturing. When these products, needed to execute the finished result, arrive at a construction site to begin the process of integration into the building in total it appears to an observer as just another one of the many construction processes that are occurring simultaneously on the
site. It is a part that will contribute to a whole, a process that has been repeated countless times throughout history.

An interested observer can witness craftsman as they work at their trade or craft. In the case of stucco or render the craft belongs to the plasterer, with brick or stone the craft belongs to the mason, with aluminum the craft of high-tech curtainwall installation belongs to the technician/mechanics, and with wood the craft belongs to the framer, carpenter, or cabinetmaker.

These craftsmen all use human scaled materials, human scaled tools, and humanly executed procedures. The materials and process are decipherable and relatable in every respect to the viewer.

The value of craft cannot be overstated. Awareness of craft is a quality that adds enormously to the perceived value of an object. The wood in a museum quality piece of furniture is admired for its selection of species, joinery, and finish. It calls out to be touched (the reason for warning signs in galleries). The care and skill required to execute the finish product is admired and valued even if the style of the piece is not something that the viewers ever wish to acquire for themselves (an important caveat). The compound curves of an antique automobile’s bodywork, finished with multiple coats of hand-rubbed lacquer, elicits a sensuous appeal, even for the non-automotive enthusiast. The carved gargoyles perched as finials on a flying buttress call out to the photographer to capture on film or digitally what the stonemason art brought forth centuries before.

It is craft that draws us to objects, small and large. The precise techniques might be a mystery, but the presence of the human hand is apparent, as is the guidance of that
hand by a human mind. It is the decisive connection that a human has with an object, be it a building or a jewel box.

There is a human connection made with traditional construction processes involving craft and the resulting traditional building. When a viewer sees either a completed traditional building or a traditional building under construction, they see craft and there are powerful personal connections made.

In any residence all of the above traditional materials or their material cousins and associated crafts are incorporated into the structure. These structures are homes, a construct that literally encapsulates an individual’s existence, implanting deep within the subconscious the Heideggerian principles of dwelling and hearth.$^{69}$

Subliminal associations are always present, e.g. perhaps it is a valued brick façade on the front elevation, or an admired elaborate cornice in a Dining Room, or as subtle as simply a room of wood, plaster, and paint that speaks to comfort and security. There is a powerful river of human connection through craft that weaves its way from a traditional construction site to the shelter provided by a dwelling and it never abdicates. The emotions that are evoked, consciously and unconsciously, result in acceptance of and affection for the traditional forms with their evidence of humans and their crafts

The concrete of foundations and basements of the home are not included in that affection. They are out of sight, located beneath the space where humanity resides and are hosts to several of the above-enumerated Brutalist negatives. They are also constructed

Notes

$^{69}$ (Hays 1998)
by a process similar, if reduced in scale, to the one used in constructing Brutalist buildings.

On a Brutalist building’s construction site, when the concrete work is in progress, human scale connections are absent or at the very least extremely difficult to discern. A single material is replacing the myriad of traditional ones. Concrete will supply the roofing and wall structure and the ceiling and wall finish. It will surround the windows and doors. It will join roof to wall, wall to wall, and wall to foundation. It will provide any necessary shading screens for windows. It will provide retaining walls and privacy walls.

A Brutalist building site is unlike any other. The scale of the process is enormous (Fig.1.47). Forty-five-thousand-pound tandem axel concrete mixers line up in ques, each waiting their turn to contribute to the day’s continuous pours. Each truck carries approximately ten cubic yards of concrete weighing an additional thirty-five thousand pounds. The total amount of concrete required for a building is, of course, dependent on the building. In the case of the FAC, which will be examined in detail, twenty-five thousand yards were required.70

Viewed from the site’s perimeter the building itself is obscured by the staging required to construct the formwork and the shoring (where necessary) required to support the reinforced concrete until it is cured sufficiently to withstand its calculated loads.

Notes

70 (University of Massachusetts-Amherst 1971, 2)
The site itself is a maze of formwork, steel reinforcement, and subsidiary materials; some allowed to be exposed to the elements and others protected in temporary structures. Equipment of all sizes from cranes, lulls, and forklifts, necessary to move objects far too heavy for manpower alone, to generators and power tools necessary for formwork fabrication. All of it heavyweight, industrial, a requirement absolutely necessary to help harness the forces that are needed to work with the heavy soon to be inflexible material.

This is a site and a process that speaks of the machine, of man’s technological prowess and of the future. This is the essence of Modernism. It is the construction process required to realize the Futurist’s turn of the nineteenth century vision of architecture (Fig.1.3) or Mies van der Rohe’s Friedrichstrasse Skyscraper conceptualization. (Fig.1.48).
Gone is a time-honored association of craft, tradecraft, and associated human connection, but only in appearance to the nonprofessional eye. The skill level and degree of craftsmanship required to work with concrete is every bit as exacting as any other craft. In fact, at the highest level of tolerance and finish, concrete not only requires superior craftsmanship (see 1.2.5.2, “Tadeo Ando’s Concrete”), but adds the additional complication of disallowing any reversal of process. Once the concrete is formed and poured, the unalterable, unstoppable chemical process that changes it from semi-liquid to solid begins and cannot be stopped. Once it achieves solidification, there is not a methodology to remove a section or repair a surface that does not leave evidence of intervention (see 1.2.3.5, “Lack of Ornamentation”). This is unlike every other material (wood, stone, metals, plastics, etc.) where invisible repair, while sometimes challenging, can always be achieved as always nearby are joints or corners that allow segmental replacement---not so with monolithic concrete.

So craft is present, but, again, only present to the cognoscenti, the architects, engineers, contractors, and workmen who design and execute with the product. The
complicated and densely populated - with men and equipment - Brutalist building site obscures all of the craft and Brutalism pays the price for this obfuscation of humanism - negative seven and perhaps the most problematic even if only true in perception and not reality.

1.2.3.9 Negatives - Subsection Summary

The problematic nomenclature, the diminutization of passersby created by monumental scale, the disquiet associated with geometric disorientation, the lack of transparency (both physical and psychological), the elimination of ornamentation bestowing humanizing cues and the subsequent disfiguration of surface precipitated by the absence of the water-shedding qualities of these features, the acknowledgment of the culture of deferred maintenance or active neglect, and finally the apparent exclusion of humanism from the buildings are the reasons for Brutalism’s shift into public disparagement and opprobrium. Perhaps Brutalism might have survived one or two of these obstacles, but all together, they have proven insurmountable. The question that must be now posed and which will be addressed is whether it is possible to remove some of these obstacles and lighten the negative load on these buildings, which represents so many billions of square feet of the built environment.

1.2.4 Positives - Possible Redemption

As discouraging as the list of negatives relating to these buildings is there are associated positives that are helping or might help in the future to inform, or reinforce, the
perception of the building type. Some are passed down and inherited from the overarching category of Modernism and some are related specifically to Brutalism.

1.2.4.1 Recognition and Resolution within Historic Communities

It is now approaching fifty years since the last of the Modernist buildings were completed. The great majority of them are recently eligible or have been eligible to be designated as historic buildings and subsequently have garnered varying degrees of attention and protection. Many obstacles had existed that limited the inclusion of all but the most spectacular, e.g. Wright’s Guggenheim Museum where not only is the exterior protected, but also the interior, Mies van der Rohe’s Crown Hall at ITT, or Walter Netsch’s Chapel at the United States Air Force Academy.

The reasoning behind the resistance was fundamentally based on public perception derived from the negatives discussed in the previous subsection, but there have been additional obstacles that have required overcoming.

Durability of many of the “new at the time of construction” technologies of both materials and assemblies has fallen short of period expectations and resulted in both fabric and structural degradation. How to address these material and assembly failures was at first extremely problematic as the preservation community had traditionally slavishly concentrated on building fabric and its unassailable protection. From the time of William Morris’s Society for the Protection of Ancient Buildings (1877) through the Athens Charter (1931) at the First International Congress of Architects and Technicians

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71 (Sprinkle 2007)
of Historic Monuments, followed by the *Venice Charter* (1964) at the Second *International Congress of Architects and Technicians of Historic Monuments* it was problematic in the world of preservation to address these Modernist constructs, as failures of the original materials and technologies made reintroducing them counterintuitive and self-defeating.

It was not until the *Burra Charter* (1979) and its adoption by the *International Council on Monuments* that increased opportunities for Modernist preservation appeared. Burra states that significance may lie in more than just the fabric of the place; it is defined as aesthetic, historic, scientific, social, or spiritual value for past, present, or future generations. This explores a flexibility in interpreting environmental authenticity through values that has not previously existed:

> Continuing, modifying, or reinstating a significant use is deemed an appropriate, even preferred, form of conservation, even if this requires significant changes to the fabric or involves substantive new work.\(^2\)

Burra Charter’s (especially 1999 revision) strength lies in its definition of cultural significance and its recognition that the meaning of significance is relative and that it has to be assessed on a case-by-case basis.

Traditional buildings inherently lend themselves to a restoration process similar to their original step-by-step construction process with emphasis on craftsmanship and quality of materials (see 1.2.3.5, “Lack of Ornamentation1”). Modernist Buildings with larger assemblies and integrated systems make this type of restoration, addressing a building in partial or separate entities, less economical, plausible, or desirable. A greater

Notes

\(^2\) (Gillon 2016, 51)
emphasis must be placed on the overall building – its performance as a system and its intended appearance; and thus the artistry of its design.

Therefore, with Modernist buildings, the skills necessary to construct buildings were transferred to an earlier part of the process, the quality and expertise of the designer and the designer’s design intent. Design intent is recognized as the fundamental proficiency or craft, for Modernist preservation, allowing fabric to migrate, when appropriate, to a secondary position.

This was ground-breaking shift and has provided resolution and solution for problematic situations that have arisen for buildings under the protection of the National Trust for Historic Preservation (NTHP) or State Historical Preservation Organizations (SHPOs) where work on buildings must comply with the U.S. Secretary of the Interior’s Standards. This has worked well and examples are plentiful.

At the Guggenheim Museum (Fig.1.31), replacement of the original single glazed, uninsulated, steel framed curtainwall of the Monitor (the smaller rotunda) was replaced with double glazed thermally broken frames of identical proportions, as enhanced performance was required to remedy the condensation problem created by the interior space’s change of use from what was originally office space to exhibition space with the attendant increase of humidity necessary to conserve artwork. The change to the double glazed wall was allowed because the original and primary intent of the building, as a whole, was to exhibit a collection of art and that intent overrode any secondary function of space, even though designated as office space in the original program.73

Notes

73 (Ayon and Rose 2011, 59-66)
At Crown Hall (Fig.P.10), during the 2005 renovation, a change in upper story plate glass thickness and weight (mandated by codes) required interior glazing stops to be enlarged from 5/8 inch to 3/4 inch in depth. To maintain the original elevation reveal required a slope, as without the slope the deeper reveal would look heavy, so by sloping the stop from 3/4 inch at the glass to 5/8 inch at face, it would read the same as the original.

The purists rebutted that it would be blasphemous to introduce any amount of slope in a Mies van der Rohe rigidly rectilinear structure. They also argued that Mies used off-the-shelf extrusions, and a sloped stop would have to be custom fabricated, a clear violation of his Modernist principles.

The slope prevailed, because all the interested parties were convinced that, first, the slope cannot be seen as it was on an elevated level. Secondly, compromising on the custom-design issue would preserve the design intent and was better than specifying a heavy, and thus inappropriate, stock stop.74

This shift in preservation fabric dogma has opened up opportunities for addressing the weaknesses in a building fabric or assembly, permitting improvements in comfort (see 1.2.4.2, “Comfort Expectations”) as well as durability, both improvements that are necessary to insure the building’s ongoing viability and continued existence.

Notes

74 (Schweinberg 2012)
1.2.4.2 Comfort Expectations

The reasoning that supported changes in building fabrics or assemblies that have over time proven lacking in durability and resulted in envelope failures, which compromised the usability or appearance of a building, e.g. leaks from environmental water through failed roofing materials, window or door caulks, or sealing compounds, etc. is not difficult to understand, but the related and justifiable improvements and interventions impacting occupant comfort, energy use, and energy use’s attendant impact on climate change can be less obvious, but every bit as important.

Massive mechanical systems have been the solution in Modernist buildings to maintaining occupant’s thermal comfort expectations. This meant that the resolution of thermal comfort expectations when these buildings were constructed was accomplished with energy, i.e. fossil fuel consumption, either directly onsite with the combustion of fossil fuel sources to meet heating requirements or indirectly offsite via the consumption of electricity, which was supplied by predominantly fossil fuel fired electrical power plants.

Heating system prowess addressed and compensated for:

- Radiative heat loss to single pane, thermally unbroken glazing systems by washing the glazed surfaces with forced hot air or proximity to hydronic radiators.
- Conductive heat loss affected by the minimal presence or complete absence of insulation in roofs, walls, and foundations.
- Air exfiltration heat loss created by the AEC Communities ignorance of the impact of air leakage in building on space heating loads.

Cooling system prowess addressed and compensated for:

- The seasonal inverses of energy flows to the above heating systems burdens.
- Solar overload through both transparent surfaces and an uninsulated opaque elements of the envelope.
- Substantial internal heat gains caused by occupancies and activities, inefficient lighting systems, which were at best, early fluorescents, or at worse, incandescent. Plus, there were the related heat loads of building appliances, equipment, and processes that were present depending on program.

The absence of operable windows was addressed with powerful active ventilation systems, frequently absent of any heat exchange technology, which injected substantial quantities of seasonal outside air, diluting the conditioned (heated or cooled) air supplies, and subsequently contributing to increased system sizing requirements.

Temporarily ignoring the mechanical system’s profligate use of fossil fuels and the attendant issues of climate impact, it is a certainty that the resulting occupant comfort index, although addressing sensible temperature, did little to address mean radiative temperature and the commensurate impact on operative temperature as the distances for occupants to single glazed, thermally unbroken windows and window walls, uninsulated opaque walls, and uninsulated slabs naturally varied with their desk or task locations. All these individual comfort requirements could not be reasonably compensated for with a zone sensitive thermostatically controlled sensible temperature adjustments, whether in the heating or the cooling season, as the area controlled served multiple occupants in multiple locations.

Separate from mean radiant temperature, but a contributor to thermal discomfort are drafts, caused by unintentional and uncontrolled infiltration or exfiltration. The impact is typically felt by individuals depending on their proximity to the source. The inability of zone-based thermostats to selectively improve disparate individual comfort
requirements within the same thermal zone is inadequate and similar to the problem experienced relating to mean radiant temperature.

Yet for all of the above comfort deficiencies, Brutalist Buildings were accepted and received acclaim for the first twenty years. Why were these deficiencies tolerated? The answer lies within the societal expectations of the period. During the two decades of Brutalism’s ascendancy and expansion (mid-1950’s to mid-1970’s), even though the shift to these powerful mechanical systems supplied a degree of comfort within the buildings and disallowed human manipulation of the interior environment via any occupant controlled connection with the external environment as had previously been the paradigm (windows had always been operable) there was not the same high expectation of human comfort as exists today\textsuperscript{75}.

The majority of the occupants of these buildings had grown up in a pre-air-conditioned environment. Absence of cooling systems in homes, schools, or businesses was commonplace. Indeed, many residents in less developed areas in America had been brought up without central heating systems. Variations within a building were acceptable and thought of as ordinary and commonplace.

\textit{Thermal comfort is, indeed, malleable and is ultimately a subjective state of mind that depends on social and cultural expectations. People have been shown to adapt to flat thermal homogeneity if that is what they are exposed to repeatedly. Alternatively, people can also adapt to variable indoor climates... Lifestyle shapes our comfort expectation.}\textsuperscript{76}

Notes
\textsuperscript{75} (Crowley 2001, 291-92)
\textsuperscript{76} (Cole and Lorch 2008, 198)
Today there is far less of a tolerance. Can a new automobile be bought without
air-conditioning?\textsuperscript{77} Would the purchase of an older automobile without it even be
considered? Air-conditioning has become a requirement/necessity in all but the simplest
of homes, even in climates with marginal cooling degree day requirements\textsuperscript{78}.

The absence of some occupant comfort providing features is actually a positive
for the Brutalist buildings. The iconic ones are afforded opportunities for comfort
improvements when implemented within the framework of the preservation guidelines, as
discussed (see 1.2.4.1, “Recognition and Resolution within Historic Communities) and
for the more plebian members of the community interventions that improve their comfort
quotient are even more possible due to the tolerance for less restrictive, but still respectful
changes. Changing glazing systems, improving air sealing, or improving the robustness
of the thermal envelope are all reasonable interventions that might improve perceptions
as well as comfort.

\textbf{1.2.4.3 Aesthetics}

The original enthusiasm and continued acceptance among the architectural
cognoscenti is understandable. Members of this community have been schooled, either
formally or informally, in the origins of Modernism, the evolution of Modernism, the
designs and built forms of its preeminent practitioners, the emergence of Brutalism, and
the design pedagogy intrinsic in the forms.

\textbf{Notes}

\textsuperscript{77} (Henry 2007, 5)
\textsuperscript{78} (Henry 2007, 4)
The acceptance by the larger community is the issue, as the court of public opinion yields enormous power with resulting consequences. It is possible for opinions to change as has been discussed in this document, e.g. the initial lack or restricted acceptance of Beethoven’s Ninth Symphony and French Impressionist painting was followed by public adulation, which continues to the present was offered as proof (see, “Preface”). There are also the oscillations of acceptance that can occur similarly to what occurred with the repopularization of Colonial style in America after the Centennial Exhibition of 1875 (see, “Preface”).

What drives the changes can be difficult to precisely define. It can be addressed with education, but this is a simplification, for education only is effective on a participating and receptive student. Two successive ingredients are subsequently required. First, the recipients (independent of the numbers) of that education must have methodology and avenue to widely disseminate that information, and secondly, the disseminated information must be received and perceived as worthwhile by the larger community.

In the case of Brutalist buildings, this is a significant challenge. The prevailing attitudes, based on the negatives dissected previously (see 1.2.3, “Negatives - Loss of Favor”), are entrenched and will be as difficult to dislodge a mortared stone.

However, efforts are being made on many fronts, spearheaded by the *International Committee for Documentation and Conservation of Buildings, Sites and Neighborhoods of the Modern Movement* (Docomomo) and specifically in the United States by *Docomomo US*. These international and national efforts are joined by smaller local efforts, e.g. *Friends of Modern Architecture* in Lincoln, Massachusetts, Sarasota.
Architectural Foundation in Sarasota, Florida, or Los Angeles Conservancy in Los Angeles, California. All are focusing attention on the legacy of important Mid-Century Modern buildings. Success is a possibility, but not an easy one.

To attempt to understand how such visceral, i.e. emotional responses, in very substantial population segments are evoked it is helpful to turn to the study of Aesthetics and the underlying philosophies of the discipline.

Immanuel Kant’s *Critique of Judgment*, defends purely emotional aesthetic evaluations. John Dewey’s *Art as Experience*, presents aesthetic judgments not as lying within the domain of emotions alone, but as being a holistic encounter with an object.\(^{79}\)

The detailed dissection of the two theories is far beyond the scope of this document, but a condensed summation is offered.

Kant limited the decision as to whether an object was beautiful or not beautiful (ugly) to purely an emotional response.

\[
\text{In order to decide whether or not something is beautiful, we do not relate the representation by means of understanding to the object for cognition, but rather relate it by means of the imagination (perhaps combined with the understanding) to the subject and its feeling of pleasure or displeasure.}^{80}\]

Kant defends the definition with the position that the emotional feelings that an object engenders are *a priori*, a position and view that is knowable and independent of any experience. That these emotional connections are common sense, *sensus communis*,

Notes

\(^{79}\) (Gray 2012, 1)  
\(^{80}\) (Kant 2008, 89)
which promulgates a transcendental principle of universal acceptability, i.e. beauty at whatever level and understood by all.

In contrast, Dewey claimed that there does not exist a universal subjective perception of beauty; Dewey argued that individual experiences and even psychical influences permeate our perception of what is beautiful.

*By advancing an aesthetic that integrates interest, individuality, and purpose, we are able to understand beauty as a total experience with an object, rather than simply as an emotive response.*

Kant published in *Critique of Judgement* in 1781; Dewey published *Art as Experience* in 1934. The dates are particularly germane to this discussion, if restricting the philosophical discussion to architecture. Certainly in Kant’s life and experience ugly buildings existed, but they were structures that belonged to the lower echelons of humanity and society, e.g. the hovels of beggars and the poor in early slums or temporary kiosks of venders in marketplaces. The remainder of the built environment, as constructed by the elite and powerful, conformed to traditions of classical architecture and was perceived and valued as objects of beauty, albeit to varying degrees, by the society at large.

Dewey’s work coincided with almost the precise midpoint of Modernism. Art, music, politics, and architecture were transitioned into new forms (see 1.1, “Modernism”). Dewey’s theory provided an articulation and a framework, which established a new criterion and methodology for appreciating what artists, composers, and architects were producing.

**Notes**

81 (Gray 2012, 13)
Both philosophers were correct when considering traditional forms of architecture, but for Modernism it is only Dewey who provides the reasoning required for aesthetic interpretation of an object's value. Dewey’s interpretation of the process behind the aesthetic appreciation of beauty clarifies the division of Brutalist appreciation that exists between the architectural cognoscenti and the general public. It clarifies, but does not offer a means of disseminating this information. This is problematic.

1.2.4.4 Impact of Photography

In *Concrete and Culture* Adrian Forty makes the point that what contributed to the acceptance of Brutalist architecture was:

> ...photoënio: the process by which photography makes ordinary things beautiful, operates by decontaminating the scene represented from all the contingency and excess of reality that renders it uninteresting or unobservable.82

The early concrete buildings were photographed principally for advertising and publicity purposes, necessary for the early firms working with concrete technology to promote their systems. When coupled with the architectural and engineering drawings the photographs were then visual proof that a project was an actual built project rather than an unbuilt and untested new technology.

In the early decades of the twentieth century photographs of concrete buildings, surprisingly, began to be published in art periodicals and books dealing with architectural

Notes

82 (Forty, Words and Buildings: A Vocabulary of Modern Architecture 2000, 269)
aesthetics. Where previously these images had been used solely for commercial purposes they were now being used in art-based sources that were directed at cultural impact.

The images of the buildings were exploiting the ability of the art of photography.

... find beauty in whatever it is turned on.\textsuperscript{83}

\begin{quote}
Photography succeeded in turning reinforced concrete into a medium of culture where earlier attempts by the concrete entrepreneurs to achieve the same result by promoting architectural works in the medium had largely failed...look no further than Le Corbusier’s famous definition of architecture as ‘the masterly, correct and magnificent play of masses brought together in light’ – which might as well be a definition of photography.\textsuperscript{84}
\end{quote}

Concrete supplied all that a photographer could desire from a surface. When exposures were taken in hazy diffuse light, using fine grain film with long exposures the subtle variations in the texture and shades of grey or color variations within the concrete surface was captured in elegant nuance and magnified detail (Fig.1.49). In strong sunlight faster films captured transient optimal moments where dark contrasting dark shadows created by the building’s tectonic geometries carved new forms on the lighter concrete facades (Fig.1.50). In raking sunlight both subtly textured and fiercely distressed surfaces could be isolated in a frame and capture, for all to see, what had in reality been only a transient moment in time as seen from a unique position (Fig.1.51). The permanence of concrete, perhaps not as perfect as it was when construction was completed, offers

\section*{Notes}

\textsuperscript{83} (Sontag 1977, 85-112)
\textsuperscript{84} (Forty, Words and Buildings: A Vocabulary of Modern Architecture 2000, 268)
photographers, photographic collection curators, and photography admirers the same
qualities of visual appeal as it did in the early years with an attendant and reflected
positive association with the Brutalist building itself.

All of these qualities have been retained by the Brutalist buildings and are still
available, but only if the buildings are taken care through consistent maintenance, which
sadly has not been typically the case (see 1.2.3.6, “Maintenance”).

There is scant realistic hope that a proliferation of artful photographs of concrete
buildings will cause a shift in perception, as it is improbable that the marketplace would
provide a viable outlet and without economic demand, there is little chance of supply.
Nonetheless, it is of import that concrete’s photogenic surface is a positive that must be
recognized as exploitable knowledge should a synchronous opportunity arise.
1.2.4.5 Positives - Subsection Summary

The preservation movement’s adjustment to architectural Modernism’s evolved fabric and assembly requirements naturally includes the Brutalist buildings. This shift offers avenues of solutions that are not only absolutely necessary to preserve and improve the durability of these buildings and insure their longevity, but also allows opportunities to address any deficiencies to occupant comfort that the building might possess with appropriate and sensitive interventions.

Understanding the underlying theories of aesthetic appreciation and the subtext of the perception of beauty is helpful in underscoring the importance of education and its relevance for Brutalist building forms as is perfectly evidenced by the acceptance of “modern art”. It is not likely, however, given the historical reductions of educational facilities’ budgets, that funding for art and music will return to the relatively substantial levels of the 1950s and early 1960’s. Architecture was given scant attention even in those times, but perception of these buildings can be influenced by alternate and unsuspected cultural processes, as evidenced by the discussion of the unexpected shift photographs of concrete buildings experienced in the late nineteenth century as they transitioned from strictly commercially directed printed outlets to artistic and culturally targeted outlets. However, it cannot be overly emphasized that the buildings need to be prepared for such a happenstance, unlikely as it might be, and that returns the discussion to maintenance and the associated diminution of the applicable negatives.

If the necessary changes are made and the buildings are returned to a reasonable facsimile of their original condition, coupled with improvements that meet contemporary comfort expectations, while they may not be loved, they at least might not be hated.
The instigation of a change in perception must come from the stakeholders of the buildings. They are the parties in control of possible interventions that can improve the building’s human comfort requirements, earning the affection of its occupants and users. The stakeholders are also the ones in the position to enforce implementation of correct maintenance procedures that can return the buildings to near approximations of where they were at the time of construction when a more positive association was prevalent. These efforts, in tandem, would accomplish a strategic humanizing of the building, which would help to establish the requisite positive psychological associations similar to those existing in admired traditional architecture and might reverse the “ugly” perception, but it will be difficult.

1.2.5 Contradictions

Separate but relevant to the positives are two anomalous building types that bear some intriguing commonalities with Brutalist buildings. The commonalities are germane, because they are perceived as either positive attributes, or at the least as discounted negative attributes in these two building types where in Brutalist buildings they are negatives.

1.2.5.1 Green Buildings

Sustainably designed buildings (Green Buildings), at the present time, have a certain accord with the Brutalist buildings. The accord is based on a migration from both traditional geometries and materials to new materials, many of which are not only
technologically new, but also quite visually dissimilar to ones previously used in traditionally styled architectural forms.

Currently, the Green Building industry is nearing completion of its second decade of construction. Green rating systems, led by the United States Green Building Council (USGBC), appeared in the late 1990s. The integration of their mandates into the construction process has been bolstered by municipal, corporate, and academic building code mandates and requirements and resulted in the emergence of a new building type.

As a direct response to reducing energy loads (electrical, heating, cooling) and reducing associated environmental impacts on water, air, and land the imposed changes have resulted and precipitated buildings that no longer have either the traditional building geometries we were so familiar with or the clean shining geometries of the mid-century Modern corporate/commercial world.

The system and material additions and modification to traditional building forms can be quite extensive. Shading devices of varying mechanical technologies deflect solar gain. Solar panels are positioned to maximally convert sunlight into electricity or domestic hot water. Roofing materials are selected based on reflective qualities to reduce the Heat Island Effect or participate in cooling load reduction. Glazing systems have become massively more robust in order to limit heat flows. Mechanical systems continue to evolve and new ones emerge, e.g. enthalpy wheels, heat pumps, and sophisticated ventilation systems to meet the demands of various activities in the building.

Some of this technology is able to be tucked away out of sight in the building, but much remains in view. Now, when we look at the building the view is not of slate covered hipped roofs, white painted cornices, red brick facades punctuated by
symmetrically placed multi-lite sash with pedimented entryway. It is not the gleaming glass and steel construct with decorative spandrel panels concealing floor plates and plenums all focusing on the central entry opening to the grand atrium. Now it is a cacophony of elements that at times seems to either bristle and porcupine or obscure and confound the new construct - all in an effort to introduce sustainable performance (Fig.1.52).

This is a new building paradigm. Are we moved by its form? Do we stand back and admire its geometry? Is our spirit elevated by being within its shadow? Do we pause and look at a beautifully constructed detail? Is this building soon to be an architectural destination?

Figure 1.52: Parliament House, Renzo Piano. (Continentaleurope 2015).

The absence of a constructed Green Building that answers yes to all or even any of these questions is a debated topic within the AEC community.⁸⁵ All of the questions above can be responded to in the affirmative by traditional buildings or International Style buildings. Examples come readily to mind, UMass-Amherst’s Chapel (Fig.1.53),

Notes

⁸⁵ (Alter 2009)
Saarinen’s MIT Chapel (Fig.P.12), Wright’s Guggenheim (Fig.1.31), Kahn’s detailing in Yale’s British Museum (Fig.1.54), or at the Salk Institute (Fig.1.27).

Pejoratives attached to Green Architecture when associated with unsuccessful, ineffectual, or poorly performing design strategies are valid criticisms. Materials that fail can be granted critical latitude with the understanding that an attempt for a greater good had been attempted. Is Kant’s aesthetic being visited here? Generalizing the group, they are a series of buildings with not infrequent inadequacies; yet, they are not just tolerated, their proliferation is encouraged.

It is not difficult to understand why both the cognoscenti and the public are accepting and encouraging. Even individuals, in either group, who might not be aware that buildings consume over 40% of our energy,86 are aware at some level that a substantial amount of energy is necessary to operate any building and this unusual building form is attempting to reduce that consumption. The building’s quite apparent

Notes

86 (U.S. Energy Information Administration 2014)
functionality has earned it a reprieve from traditional architectural criticism and the
general public’s judgment.

It is a comforting thought to think that as Green Buildings proliferate one will be
designed and built that does answer many of the previous “aesthetic value questions” in
the affirmative.

At the outset of the 1970s energy crisis, economist E.F. Schumacher
wrote: “Ever bigger machines, entailing ever bigger concentrations of
economic power and exerting ever greater violence against the
environment, do not represent progress: they are a denial of wisdom.
Wisdom demands new orientation of science and technology towards
the organic, the gentle, the non-violent, the elegant and beautiful: Four
decades later, the design industry has begun successfully to orient
science and technology toward organic and the “gentle” by establishing
popular standards for a less violent impact on the earth, but it has yet to
outline a clear concept and practical approach for the elegant and the
beautiful.87

There is, however, only an unlikely hope that this tolerance for geometries and
materials at the service of other qualities in Green Buildings will cause a revision to the
positive of the general public’s regard for our Brutalist buildings. They have been quite
comfortable with judging and categorizing architecture in segments and will continue to
do so.

1.2.5.2 Tadeo Ando’s Concrete

Brutalism’s concrete and the attendant issues related to the public’s perception of
it based on its dehumanizing construction processes, large module scale, difficult damage

Notes

87 (Hosey 2012, 28-29)
repair issues, and lack of aesthetically required maintenance have been examined (see 1.2.2.6, “Maintenance”). The cessation of creating these large concrete structures after their twenty-year reign resulted in a loss in the AEC industry’s designers and contractors that were comfortable and competent with working with the plastic, yet rigorously demanding material, on a large building scale.

More than two decades after the decline of Brutalism’s concrete the Pulitzer Foundation for the Arts awarded the design of their new Pulitzer Arts Foundation Building in St. Louis to Tadeo Ando. The building, completed in 2001, with addition by Ando in 2013, is entirely of concrete and glass, with concrete dominating (Fig.1.55).

Ando (awarded 1995 Pritzker Prize) is known for his preferred use of concrete as a building material; employing it as both the exterior and interior finishes (Fig.1.56) as it comes directly from the forms without additional finishing techniques. Ando’s body of work, over one hundred fifty built projects, is dominated by concrete’s materiality.

Figure 155: Pulitzer Foundation. (Garfield226 2008).

Figure 1.56: Ibaraki Kasugaoka Church of Light. (Bergmann 2006).

Notes

88 (Architecture for Architects n.d.)
89 (Nasvik 2001, 1)
Ando’s success with the material, acknowledges the ability of concrete to not only be accepted, but actually be admired as an interior or exterior finish. This does not discount Ando’s eloquent mastery of space, geometry, light, and landforms creating a tranquility and elegance that has hallmarked his enormous talent, but it must be realized that concrete plays a principal role in his architectural performances.

Ando’s concrete construction is a process where maximum oversight and craftsmanship is demanded and that demand eliminates many of the deficiencies of concrete that were detailed previously (see 1.2.3.8 “Brutalism’s Concrete”). From a Tadao Ando interview by Spencer Bailey in *Surface Magazine*

> Architecture is something I cannot accomplish myself. We need a site supervisor, a construction manager, concrete-forming carpenters, rebar arrangers, and so forth. If all these different people work under a single vision, I think it’s possible. That’s how we do it. It’s the same as a medical operation or surgery: You can’t make a mistake. In this case, no mistakes have been made. Even a single mistake, you have to redo it. In order to make sure there are no mistakes in the concrete preparation and actual forming of it, you need to know the overall planning of the project and its details, as well as the process of making the concrete.90

Tadeo Ando’s body of work and the acceptance of his use of concrete as the principal material, which began in 1973 with the Tomishima House in Osaka,91 and continues to this day with current projects, serves to raise a reasonable doubt that it is not the material itself, concrete, that is the villain in Brutalism’s rejection. More appropriately, the blame may be placed on the construction process and maintenance.

**Notes**

90 (Ando 2015)  
91 (Moeunsak 2015)
1.2.6 Architects

As this discussion of Brutalism moves toward conclusion, attention is turned from the buildings themselves to the men who designed these buildings. They were almost exclusively white and male, and naturally, products of the societal norms and expectations of the times in which they were raised, educated, and practiced. They had all endured the hardships and privations of two world wars. They had similar, if not identical, early social and educational exposures followed by formal educations that had marked similarities. They were all enormously successful in their practices, creating buildings of fantastic complexity and expense for the commercial, institutional, and academic powers. They were the architectural elite, the men who envisioned fantastic new forms with new cutting edge technologies, forecasting a future never before imagined. Did they jettison their pasts when designing these buildings?

1.2.6.1 Architect’s Personal Experiences

Although the architects of Modernist buildings came from diverse geographic and socio-economic backgrounds, all were born, raised, and educated before the middle of the twentieth century, e.g. Walter Gropius (1883-1969), Le Corbusier (1887-1965), Louis Kahn (1901-1974), Edward Durrell Stone (1902-1978), Marcel Breuer (1902-1981), Eero Saarinen (1910-1961), I.M. Pei (1917-), Paul Rudolph (1918-1997), Walter Netsch (1920-2008), Kevin Roche (1922-).

The importance of this observation is that while all would design buildings which satisfied occupant comfort demands and expectations through reliance on the powerful mechanical systems, i.e. heating, cooling, ventilation, and lighting systems, driven by the
plentiful, as well as inexpensive, energy sources that were available during the zeniths of their professional careers, all had been exposed to earlier, alternative methods of establishing and maintaining occupant comfort.

Mid-Modernist buildings, of both International and Brutalist styles, met their heating needs on site by combusting fossil fuels, i.e. coal, oil, or natural gas. Cooling and electrical load needs were met, typically offsite, by electrical generating plants fueled principally by coal. There was little, if any, awareness of the negative impact combusting these fuels would eventuate.

Additionally, the fuels were inexpensive, e.g. crude oil market price 1950-1970 was consistently under four dollars per barrel (Fig.1.57); adjusted for inflation they were under twenty-five dollars per barrel (Fig.1.58). Coal, fuel oil, natural gas, and gasoline prices were proportionate with crude oil prices as these products were industrially and competitively cross-linked with crude oil.

The point should be made at this time and it will be reiterated and reinforced again later, that there should be neither criticisms nor blame attached to the use of these
technologies as, at that historical moment, the availability of fossil fuels was thought to be unlimited and climate impacts not widely considered.

At that time, it was thought than human influences were insignificant compared to natural forces, such as solar activity and ocean circulation. It was also believed that the oceans were such great carbon sinks that they would automatically cancel out our pollution. Water vapor was seen as a much more influential greenhouse gas.92

Central heating systems had come into use in larger commercial and industrial buildings in the nineteenth century, driven by the need of many manufacturer’s processes to maintain temperatures above freezing in their buildings for reasons relating to their manufacturing process.93 The contemporary residential inventory along with new construction, relied on point sources for heating, e.g. fireplaces, wood or coal stoves, etc.

Toward the end of the nineteenth century, two types of central systems became more commonplace in the residential marketplace. The first, hydronic systems (hot water or steam) supplied by coal fired boilers and distributed by cast iron pipes and radiators; the narrower piping diameters allowing insertion into most structures with minimal disturbance to the existing building fabric. The second, coal fired furnaces, which, in the absence of electricity to power fans or blowers, distributed the heat via natural convection through systems of ducts. The sizes of the larger ducts, when compared to a hydronic system’s small diameter piping, required a somewhat more invasive retrofit with attendant fabric disruption on all but first floor levels where basements were below. It

Notes

92 (Enzler 2016)
93 (Bruegmann 1978)
was not until the mid-1930s that forced hot air furnaces utilizing fans came into use as the availability of electricity became more widespread.  

The development of air-conditioning systems followed a greatly retarded timeline with Willis Carrier’s 1902 invention not seeing an installation until 1917 in a movie theatre and only after 1928 in the White House. Residentially, “through the window units” finally reached a more affordable price point with 1953 sales exceeding one million units. Two additional decades would pass before central air-conditioning systems would become a not uncommon feature of an American home.

By the 1930s, although ninety percent of urban dwellers had electricity, only ten percent of rural dwellers homes were electrified. Private utility companies, the suppliers of electric power to most of the nation's consumers, claimed it was too expensive to install poles and lines to areas without sufficient population density. *The Rural Electrification Act of 1935* funded by the *Work Projects Administration*, a program resulting from Franklin Roosevelt’s *New Deal* funded and brought about a change, but still, even by the early 1940s, only 33 percent of farms had electricity.

The relevancy of this brief history of the introduction of modern energy driven conveniences into our buildings relates to what the mid-Modernist architects had experienced and learned about a building’s environmental controls before the beginning of their formal architectural education. Their early experiences and efforts, assimilated and acquired in order to achieve and maintain comfort and to optimize convenience in the

**Notes**

94 (Sustainable Dwelling 2007)
95 (Sustainable Dwelling 2007)
96 (Reinhardt and Ganzel 2003)
homes they inhabited as children with their families or as adolescents and young adults in
the schools, churches, and establishments they attended and visited before they began
their formal training in architecture are relevant, for life’s experience informs and is
carried forward throughout one’s life – personal and professional.

The contention that these practitioners’ Brutalist design decisions were informed
by these early experiences involving the application of strategies to maintain thermal
comfort along with strategies to maximize daylight, whenever possible, could only be
supported in a tangential fashion through scattered references in the writings or
biographies of the men. Of the two instances of support offered to buttress this position
the first is an interview with Kevin Roche and will be included in a subsection that is
exclusively devoted to Roche (see 1.3.1.1, “Roche’s Personal Experiences”).

The second is most germane as it references Walter Gropius’s behaviors and
dictates in his own residence. In 1937, at the age of fifty-four, Gropius arrived in the
United States, precipitated by the European political and economic crisis and related right
wing events of the 1930s, but it was not solely an action in pursuit of safe harbor.

Gropius had accepted the offer of a position at Harvard University’s Graduate
School of Design as a full professor in 1937 and then as Chairman of the Department of
Architecture (1938-1952). During his tenure at Harvard, amplified by Gropius’s
background and experiences as a first generation Modernist designer in Germany and
founder of architectural Modernism’s high church of education, The Bauhaus School,
Gropius influenced scores and scores of architects who would, upon graduation, inhabit
the professional world of architectural practices.
There are not, at present, many contemporary energy performance studies that
discuss in depth Modernist energy saving strategies, let alone quantifying the energy use of Modernist buildings. Most of the literature on the energy responses of Modernist buildings focuses on fairly obvious vernacular traditions and relate to strategies employed in locations of climate extremes.\textsuperscript{97,98} Two notable exceptions are Neil Summers’ 1977 paper \textit{Analyzing the Gropius House as Energy-Conscious Design},\textsuperscript{99} and his follow up article, \textit{Climactic Adaptation and Solar Performance of the Gropius House}.\textsuperscript{100} Summers work was done in conjunction with interviews with Ise Gropius, Walter Gropius’s widow, and provided firsthand information concerning behaviors within the house relevant to energy usage.

\begin{quote}
\begin{quote}
Comfort conditions can be maintained by turning off all the convectors in the hall and some in the bedrooms, closing the doors leading from the living area to the hall on the first floor, and opening the door to the basement, where the furnace is located. Thus, heat leaking from uninsulated parts of the furnace is scavenged to economically heat the staircase and hall.\textsuperscript{101}
\end{quote}
\end{quote}

Summers’ papers and the concurrently published monograph, \textit{Gropius House: A History},\textsuperscript{102} by Ise Gropius, make it very clear how aware and reliant on passive strategies Gropius was. Ise Gropius relates the following:

On landscape shading strategies:

\textbf{Notes}

\textsuperscript{97} (Kimura 1994)  
\textsuperscript{98} (Supic 1982)  
\textsuperscript{99} (Summers 1977)  
\textsuperscript{100} (Summers, Climactic Adaptations and Solar Performance of the Gropius House 1977)  
\textsuperscript{101} (Summers, Climactic Adaptations and Solar Performance of the Gropius House 1977, 198)  
\textsuperscript{102} (Gropius 1977)
... We decide that planting trees was just as important as planning the house, which was going to be exposed to the relentless impact of sun and wind with temperatures between 6° below zero and 106° above (Fahrenheit) ...

... Two fairly large white pine trees were put in front and in back of the house to help create shade in summer ...

On optimal siting and daylighting:

... carefully positioned on top of the modest hill to catch the winter sun in the living room from earliest morning until late evening ...

... glass brick wall transmits natural and artificial lights both ways.

On solar strategies, i.e. winter profit, summer defense:

... more difficult to orient a house so that it avoids the effects of summer heat and humidity without an air-conditioner than it is to provide it with enough heat for the winter months. In winter the living and dining room windows towards south and west permit the sun to penetrate both rooms fully so that on clear days any artificial heat can be totally shut off during the midday hours even on cold January days. In summer, on the other hand, with the sun in a much higher position, they are shaded by an overhang on the second floor, which is calculated to exclude the sun entirely in the rooms from May to September.

On convection:

... it (the southern brise soleil) will let heated air from the flagstone terrace rise through an opening of three feet between house wall and the overhang. Most overhangs created as shelter from the sun are apt

Notes

103 (Gropius 1977, 5)
104 (Gropius 1977, 29)
105 (Gropius 1977, 9)
106 (Gropius 1977, 11)
107 (Gropius 1977, 12-13)
to collect stagnant air underneath which then moves into the rooms on windless days.\textsuperscript{108}

On material reflectivity:

... west window which offers the best view cannot, of course, be shaded in this way because the sun is too low. Therefore, a very large aluminum venetian blind, covering the full extent, is installed outside of that window, though it can be operated from within ...the metal shield, which reflects the heat away before it can heat up the window and consequently the room. In this manner it is possible to keep the temperature of the living room always 10\degree below the outside temperature.\textsuperscript{109}

On glare control:

Most people thought that the amount of light admitted to the rooms would cause constant irritation for the eyes, they were not aware of the fact that the dazzling effect of bright light in a room does not originate from the light source itself but from the contrast between window space and the wall next to it, which appears dark to the eye. When two or three windows are places at a distance from each other it can become very painful for the eye to glance in their directions unless they are well hidden by shades, curtains, or draperies, which cut off any view of the outside world and force people to turn on electric light in the middle of a summer day. But the situation is entirely different when the whole wall becomes a window, giving off bright or muted or diffused light according to preference by adding shades or see-through glass fiber curtains, which create an even, unglaring, pleasant glow because all contrasts are removed.\textsuperscript{110}

...My husband was used to thinking in frugal terms from the long experience he had had in the impoverished Germany after the first World War and also because it had always been one of his prime motivations to create maximum results with minimum means. In fact, he considered this a main factor in the producing of good architecture.\textsuperscript{111}

Notes

\textsuperscript{108} (Gropius 1977, 13)  
\textsuperscript{109} (Gropius 1977, 13)  
\textsuperscript{110} (Gropius 1977, 13-14)  
\textsuperscript{111} (Gropius 1977, 6)
It is not reasonable to cite a singular example of one architect and one building to substantiate the case that modernist architects regularly considered and employed passive strategies in the designs of their buildings, but considerable weight should be attached to the double pronged point that all of these architects were raised during the time period where comfort and convenience in buildings was not achieved by the use of modern mechanical systems and that the man who was the at the vanguard of transforming Modernist dogma into Architectural pedagogy was Walter Gropius and his design methodology was steeped with non-mechanical strategies. It is reasonable to conclude that these strategies were included with his teachings (see 1.2.6.2, “Architectural Education”).

The lack of attention to non-mechanical strategies in Modernist buildings, especially the Brutalist segment, is without difficulty attributed to the perception that these buildings are devoid of energy savings strategies as there was no need for them at a time when energy was inexpensive, climate defeating mechanical systems were the norm, comfort expectations were unchallenging, and contemporary building codes were more relaxed then today.

However, perception is not fact and an examination of the building type, referencing the above, is in order. The inventory is vast, the embodied energy enormous, and the preservation of a segment of architectural history imperative.

1.2.6.2 Architectural Education

Until about 1860, architectural education was accomplished by apprenticeship with a practicing architect. The shift to formal programs of architectural study was
complete by 1930. The transition involved two distinct methodologies of education. One was the French system’s École des Beaux-Arts where the discipline was treated as a fine art closely related to painting and sculpture. The second was the German system’s Polytechnical model where the technical sciences, especially engineering were the emphasis.

As a result of the European revolutions of the mid-nineteenth century and the lack of architectural work in the German states many graduates of Berlin Bauakademie and Polytechnische Hochschule in Karlsruhe migrated to the United States and established practices in the major cities.

*The two schools treated planning and construction as the essence of architecture, and the ornamental embellishment of the façade as a secondary matter that could be left to the individual fantasy of the artists.*

In the latter quarter of the nineteenth century early programs at Rensselaer Polytechnical Institute, Polytechnic College of Pennsylvania, Cornell University, Columbia University, Massachusetts Institute of Technology, and Harvard were formed basing their pedagogies on the German system, emphasizing the didactic study of building principles reserving design exercises until the latter years.

The pragmatism of these programs was limiting to some who desired more emphasis on design and so the preferred and more prestigious option for American

**Notes**

112 (Lewis 2012, 68)
students was to study in Paris at the École des Beaux-Arts where design was the emphasis and the practice of it undertaken in the first years.¹¹³

The subsequent impact on the American schools during the first quarter of the twentieth century was an emergence and domination of the École des Beaux-Arts system in major schools, e.g. Massachusetts Institute of Technology, University of Pennsylvania, Columbia University, and Harvard.

_Meanwhile, in Europe the modern movement solidified its formative developments, amalgamating the plastic abstraction of De Stijl, the post-Cubist vocabulary of Le Corbusier, and the rationalist idiom of Neue Sachlichkeit. Initially these developments penetrated little into America, but by the end of the decade (1920s) their impact was increasingly felt._¹¹⁴

Beaux Arts’ pedagogy reached its zenith in the 1920s as is indicated by statistics from the Beaux Arts Institute of Design (BAID) which adjudicated the national system of design competitions sponsored by the Society of Beaux Arts Architects.

_By 1922 ninety-one American cities and forty-three universities participated in its competitions or had architectural ateliers or clubs operating under its auspices; they sent 2,797 drawings to New York City, where two hundred medals and monetary prizes were distributed. Eight years later, 9,500 competition entries were submitted. To circulate information and programs for its competitions the BAID launched its own Bulletin in 1924._¹¹⁵

Notes

¹¹³ (Lewis 2012, 78)
¹¹⁴ (Alofsin 2012, 93)
¹¹⁵ (Alofsin 2012, 93)
By the end of the decade architecture students’ interest was shifting from the traditional to the new Modernist forms that were emerging from European countries made available through publications such as *L’Architecture d’Aujourd’hui*.

University of Oregon was the first to modify its curriculum, eliminating the competition system, emphasizing practical exercises requiring real responses to the same real world demands as would be encountered in professional practice. This included site-specific conditions that had never been a considered element in the Beaux Arts system. Yale followed with emphasis on collaborative projects. Then Cornell revamped the first year study from the rigors of drawing of traditional forms to a multi-disciplinary approach focusing on the design of a complete building. Other schools followed and the Beaux Arts system fell into further disfavor. University of Southern California incorporated model making in the first year at the same time discouraging copying of traditional buildings and encouraging the inclusion of practical building solutions.\(^{116}\)

The final and most radical transition involved Joseph Hudnut, the foremost early proponent of Modernist design education in the United States.\(^{117}\) Hudnut’s educational posts, interspersed with practice, began in Alabama Polytechnical Institute (1912-16), University of Virginia (1923-26), and Columbia University (1926-35), becoming Dean in 1934), and finally, Harvard University (1935-53).

At Columbia, his impact on the pedagogy reflected his own beliefs.

… *architecture of the future would be driven not by beauty and comfort but by an exigent desire to improve the environment of the*

**Notes**

\(^{116}\) (Alofsin 2012, 95-100)

\(^{117}\) (Hudnut 1949)
human race, he advocated the inculcation of scientific attitude, similar to the education of the chemist and engineer...

...make design a creative process that developed in a natural and logical manner as the expression of an integrated approach to modern materials, scientific building techniques, and the practical requirements of contemporary life.¹¹⁸

However, it was at Harvard that Hudnut would have the most impact. First, with personal programmatic modifications:

...approach to the teaching of architectural history... considered it essential to the general education of the designer he felt it should be studied in the undergraduate years; it did not belong in Harvard’s graduate program ... because of the heavy requirements and time constraints... downplaying architectural history within the graduate curriculum would have significant repercussion in coming decades at both Harvard and other schools that emulated it.

His transformation of Harvard’s architecture program would eventually become a model for schools all over the North American continent.¹¹⁹

Secondly, from the installation of Walter Gropius, founder of the Bauhaus School, as chair of the Department of Architecture. Gropius’s impact, as the primary spokesman for Modernism, along with the approximate chronological concurrence of the installations of other Modernist practitioners at other architecture schools (supported and in some cases facilitated by Hudnut and Gropius), e.g. Mies van der Rohe at (IIT), Lazlo Maholy-Nagy at the Chicago Institute of Design, and Josef and Anni Albers at North Carolina’s Black Mountain School, resulted in the final death knell to the Beaux-Arts system.

Notes

¹¹⁸ (Alofsin 2012, 102)
¹¹⁹ (Alofsin 2012, 103)
It was inevitable that all schools of architecture would have to become Modern... no one person or school could claim exclusive proprietorship of the spread of ideas it embodied. Modern was taking hold on the educational front.\textsuperscript{120}

Modernist doctrine dominated the educational arena within which the architects of Brutalism received their formal training. This is not to say that Beaux Art training disappeared at a single stroke of the Modernist pen. BAID’s presence continued, but diminish with each decade until finally in 1956 it ceased to exist in any form.\textsuperscript{121}

The effect that Modernist pedagogy’s replacement of Beaux Art pedagogy had on the curriculum is germane to our discussion as it is an educational continuation, an extension, of the earlier point that these Modernist architects having been brought up environments that fostered, in an informal manner, the understanding of techniques that influenced and optimized occupant comfort now were being exposed in formal didactic fashion to the techniques and technologies that were necessary components to the buildings that they would eventually produce.

Walter A. Taylor, director of the Department of Education and Research at the AIA from its inception in 1946 writes:

\begin{quote}
...schools should expose their students to contemporary ideas coming from the social and behavioral sciences, human physiology and earth sciences, their fundamental task was to instill a systematic and comprehensive body of clearly defined knowledge, principles and techniques.\textsuperscript{122}
\end{quote}

Notes

\begin{itemize}
\item \textsuperscript{120} (H. W. Bush-Brown 1976, 36 -39)
\item \textsuperscript{121} (A. Bush-Brown 1959)
\item \textsuperscript{122} (W. A. Taylor 1959)
\end{itemize}

> Environmental Design was not a new concept in architecture schools, at Harvard and Berkeley in the 1950’s it had stood for collaboration among different departments, and it also referred to the design of environmental control systems.  

Paul Heyer in *Architects of Architecture, New Directions in America* writes:

> The student should be exposed to many aspects of his subject during his formative years. Design is of course vital. But an architect must also be taught to sense the forces in a structure, to understand the history of architecture not as one of appearances, but as form deriving from cultural forces and from methods of construction; to be aware that aspects of heating, lighting and acoustic can enrich an architectural solution when they are a part of the design process—considered later, they almost always detract; and to have a knowledge of the natural laws of the human environment and of the individual response to them.

Alfred Swenson and Pao-Chi Chang detail aspects of the Modernist curriculum as directed by Mies van der Rohe at IIT (then Chicago Armour Institute of Technology) when he took over as the Head of Architecture in 1938 in the book, *Architectural Education at IIT 1938-1979*:

> The study of physics presents to the student such fundamental concepts of nature as space, time, gravity, statics, conservation of energy, thermodynamics, light, color, electricity and atomic structure, all having a profound relevance to architecture.

Notes

123 (Ockman and Sachs 2012, 146)
124 (Heyer 1966, 27)
The functions and types of various mechanical and electrical systems for buildings are studied in relation to human comfort, energy consumption, capital costs, and their interrelation with other building components.\textsuperscript{125}

Finally, a specific reference, made by Swenson and Chang in the \textit{Planning Sequence} section of \textit{Architectural Education at IIT 1938-1979}, mentions Ludwig Hilberseimer, brought to Armour Institute in 1938 by Mies, Hilberseimer was the former Director of Department of City Planning at the Bauhaus. From the following excerpt, the permeation throughout the curriculum relating to strategies to improve comfort and minimize energy use can be discerned. The quote is from what was the first course in the curriculum’s planning sequence and outlines the development of a building as related to site.

\textit{Winter sunlight is provided in all major spaces, and summer cooling helped by planting, overhangs, and natural cross ventilation. The organic relationship of the house to its site is also developed...\textsuperscript{126}}

1.2.6.3 Architects - Subsection Summary

The discussions in Brutalism’s final subsection concerning the informal and formal education of those architects who, depending on their date of birth, either experienced the shift to Modernism first hand or, at the least, at the hand of an earlier master who had personally experienced it, is pertinent because these were the architects whose creative souls and mastery of design had been rewarded with fantastic and multiple commissions by the establishment. These were the architects who had basked in

Notes

\textsuperscript{125} (Swenson and Chang 1980, 67)
\textsuperscript{126} (Swenson and Chang 1980, 102)
the contemporary critical accolades that had served to reinforce their visions and these were the architects who have endured and continue to endure the chill of the shift to rejection for their efforts.

Within this final Brutalism subsection is the tender that the architects of these buildings had acquired, both informally and formally, ample technical resources and foundations that allowed and encouraged them to incorporate designs and strategies into Brutalist buildings that might be relevant to both energy consumption and occupant comfort. These are important, critical contemporary topics as more and more focus is directed at the built environments’ negative impact on climate change, fossil fuel supplies, and energy costs, along with elevated occupant comfort expectations.

All of the previous subsections and subsubsections of the Brutalist section facilitated the understanding of the various societal and technological forces that resulted in the fabrication and proliferation of Brutalist buildings. Coalesced in the Brutalist section, as well as in the Modernism section, is a reduction of the vast amount of literature that is published on Modernist and Brutalist architecture, so much of which is focused on geometry and materiality as it reacted to societal and technological pressures and changes.

This final subsection, Architects, suggests a reality that the designers of these buildings had additional, little examined, arrows in their architectural quivers. These tools of technique should be inserted adjacent to any other discussion concerning the building type and its design. They are as relevant to an examination of a building as geometry, materiality, program, approach, or threshold and should be included, even if not, at first
glance, apparent. The remainder of this work is an effort to substantiate and reinforce this premise through the study of a single building.

1.3 University of Massachusetts-Amherst Fine Arts Center

In a reversal from the structure of the discussion on Brutalism, which concluded with a discussion of both the formal and informal education of its architects, this section, which undertakes using a single Brutalist building as an exemplar of the type, will address the architect of the building first. This is a more correctly linear order as it is in the mind of the architect that the building first appeared.

1.3.1 The Architect - Kevin Roche

Born in Dublin, Ireland in 1922 and raised in Mitchelstown, Ireland, Kevin Roche had an early formative exposure to architectural form. It is a similarity of experiential impact that bears striking relationship to the one discussed at the close of the previous section (see 1.2.6, “Architects”).

From Francesco Dal Co’s 1985 interview with Roche:

*KR:* Mitchelstown, where I grew up has what is regarded as one of the finest eighteenth century spaces in the country, so I had an introduction to formal architecture without realizing it.\(^{127}\)

Roche’s first disciplined exposure to architecture was found when reading John Ruskin’s lengthy essay, *The Seven Lamps of Architecture* while at boarding school. This

Notes

\(^{127}\) (Dal Co 1985, 19)
singular exposure coupled with a desire to actually build became a reality when his father, General Manager of Ireland’s largest creamery, permitted him to design and supervise the construction of a warehouse for storing cheese.\textsuperscript{128}

Enrollment followed in the architecture program at University of Dublin, which at the time of his matriculation (1940) was a Beaux-Arts oriented curriculum. The head of the program was Rudolph Maximillan Butler. Butler earned his architectural education through apprenticeships in the offices of James Joseph Farrall and Walter Glynn Doolin and eventually becoming Doolin’s junior partner, and finally carrying on the practice with James Louis Donnelly as a partner. Butler’s built work was extensive, 232 listed works in \textit{Dictionary of Irish Architects 1720-1940}. He was steeped in traditional architectural forms as can be evidenced by not only his built works, but also by his impact as adviser to the English architect Albert Edward Richardson on which Irish buildings should be included in his \textit{Monumental Classic Architecture in Great Britain and Ireland during the 18th and 19th Centuries} as well as editor of \textit{Irish Builder} from 1899 to 1935.\textsuperscript{129} Under Butler’s direction transition of the school’s pedagogy from Beaux Arts to Modernism was not a consideration and is substantiated the author’s 2015 interview with Roche.

\textit{KR}: He was a Greek Revivalist. He had done a few buildings in that manner. So we spent the first two and one half years drawing classical architecture and detailing classical architecture. Doing everything we did was that.\textsuperscript{130}

\textbf{Notes}

\textsuperscript{128} (Dal Co 1985, 19)  
\textsuperscript{129} (Dictionary of Irish Architects 1720-1940 2016)  
\textsuperscript{130} (Roche 2015)
In 1943, Butler died and the shift in Architectural pedagogy that was being experienced throughout America (see 1.2.6.2, “Architectural Education”) visited University of Dublin during the final one and one-half years of Roche’s tenure. The exposure to the contemporary architectural world’s Modernist movement was curtailed during his time at University, but it was a gathering storm as Roche articulates in the 2015 interview.

KR: ...you know I heard about Mies. During the war. Ireland was neutral, so we had no magazines, nothing, no contact with the rest of the world.\footnote{Roche 2015}

And in the 1985 Dal Co interview:

KR: ...Beaux Arts education gradually gave way, so that we suddenly discovered that there was such a thing as modern architecture. One became aware of Markelius and Asplund and Aalto in Scandinavia and, in America, Frank Lloyd Wright. There was no communication with the outside world then so it was through magazines that had been published prior to the war together with books such as Le Corbusier’s that we sought our information. I can’t describe to you what an extraordinary experience it was to suddenly discover this other architecture. It was visionary, it had to do with people and it gave hope that somehow the world could be saved. ...It was as if one woke up and felt there was a future after all. Anything was possible.\footnote{Dal Co 1985, 19}

After graduation and the end of World War II architectural opportunities exploded. Roche moved to London, where reconstruction was beginning, and worked for Maxwell Fry (Gropius had left by then) for about a year before deciding to go to America

Notes

\footnote{Roche 2015}
\footnote{Dal Co 1985, 19}
and do his graduate work in Architecture. Accepted at Harvard, Yale, and IIT, it was the lure of Mies van der Rohe that led him to IIT.

Roche stayed for only a semester, leaving because of a combination of lack of funds and a realization that Mies’ rigid deconstruction and architectural functionalism was not for him. Roche makes it very clear that it was a valuable experience for him and did not diminish his admiration for Mies, but rather underscoring, in his mind, that for him architecture might be spoken with a more flexible language.

Again, from the 1985 Dal Co interview:

**KR:** Three buildings had been built by Mies at IIT when I arrived in 1948, but I have to honestly say that I did not understand them at first. Mies was extraordinary, a formidable presence. Very intense, serious. Nice sense of humor. Somehow he had that ability to convert one in much the same way as an evangelist might do; you suddenly began to think in the way the he had ordained.

He (Mies) really created the idea of mortal sin in architecture and that there was a right way to do something and there was a wrong way. The wrong way was a loss of life. The right way was beautiful, divine. A world of absolute black and absolute white.

His influence is both positive and negative, but it is very strong.

Eventually, what one learns is that there are many languages of architecture and that there is also a universal language—a local language, and a universal language. Ultimately a building, a great building, touches in all ways; it touches in the local language, the precise and technical, and it touches in the universal language, which is emotional and intellectual. The skill is to create a language which the scholar and the artist and the common man understand without being conscious of the structure or the form and syntax; to penetrate to the ideas and emotion is the circumstance of all great art.

Mies, who focused on a relatively narrow aspect of architecture because of the depth of his investigation, produced on several
After leaving IIT in 1949 and spending several months in the United Nations Building Planning Office Roche was hired by Eero Saarinen. It was as architecturally fortuitous as could be imagined. Roche’s intellectual realization under Mies that, for him, architecture was a language of flexibility would now be given optimal opportunities to express itself in an environment that appreciated every architectural language.

Eero Saarinen’s eleven year built legacy, abbreviated by his sudden death at the age of fifty-one resulting from a brain tumor, is marked by a variety of forms and design strategies that few if any Modernist architect duplicated.

...his fresh approach and willingness to experiment with architectural vocabulary amounted to a new vision of the modern idea that offered up exciting alternatives to the strictures of mainstream postwar architecture.

...Saarinen’s architecture eschews a recurrent formal repertoire; diversity is its defining characteristic... each design was a statement unto itself, a particular, specific solution resolved by particular specific means... Rather than a mere penchant for stylistic experimentation, the diversity of his work reflects an eclecticism of procedure, an ability to adapt his method of design to a new project and a new program.

In Saarinen’s office, working side by side with Saarinen, responding to Saarinen’s confidence in him as design protégée, Roche would arrive at professional maturity and architectural mastery.

Notes

133 (Dal Co 1985, 20-21)
134 (Roman 2003, x-xi)
From the 1985 Dal Co interview:

He developed more confidence in me and gradually... I inherited more complex responsibilities... I became the intermediary between Eero and the design personnel... For the last five or six years of his life I had a very close working relationship... I sat with him eight or ten hours a day every day of the year.135

Roche would assume, at Saarinen’s death, command, along with technical and material expert John Dinkeloo.

With the above information in place it is now appropriate that we look closely at Roche’s experiences in life and education in the light of the information that has been acquired while looking at Modernist architects as a group (see 1.2.6, “Architects”).

1.3.1.1 Roche’s Personal Experiences

As noted previously, there is not a substantial body of work that details the early life experiences of these Modernist architects. Biographies, typically perfunctorily enumerate major early milestones with little elaboration, e.g. date and place of birth, names and dates of educational institutions attended, and dates and associations of professional practices. The focus is, as might be expected, their work and professional achievements. Occasionally, as in the case of the Ise Gropius monograph (see 1.2.6.1, “Architect’s Personal Experiences”) there is pertinent information to be found, but it is not plentiful.

Notes

135 (Dal Co 1985, 23)
The coincidence that the architect of the building selected for this template was Kevin Roche was a fortuitous happenstance as Roche is among the youngest, if not the youngest of the group that were the design masters of Brutalist buildings (see 1.2.6.1, “Architect’s Personal Experiences”) and is enjoying an advanced and healthy tenth decade. Roche, at ninety-four years old, is still practicing in the office that John Dinkeloo and Roche opened in Hamden, Connecticut after Saarinen’s death and graciously accommodated an interview during the summer of 2015. Roche is as vital and conversant an interview (with a hint of Ireland still in his speech) as one could hope for.

The interview provided significant substantiation to the ideas that were proposed in the previous section concerning both the impact of personal life experiences and the impact of their formal education on their mature design processes (see 1.2.6, “Architects”) and will be discussed below. It should also be noted at this time, that it is not an unreasonable expectation that the more senior members of the Brutalist group would have at the very least have experienced similar reliance on non-mechanical strategies to maintain occupant comfort and that, similar to Roche, the knowledge would have also informed their designs even as mechanical methods became available.

The following excerpts are from the interview with Kevin Roche on June 14, 2015.136

CF: You know another thing that I have followed and formed a premise of is that the first, second, and third generation of Modernist Architects were born and raised in either the late part of the nineteenth century or early part of the twentieth century, before the advent of big powerful central heating units.

Notes

136 (Roche 2015)
Do you recall when you were in Mitchelstown? Do you recall strategies that were employed in your house of maintaining comfort? Gropius's wife wrote a little monograph, "Living in the Gropius House" and she talks about how Gropius wanted the door to the basement kept open in the winter and we know about the shades on the west side and using those things and actually manipulating the environment with behavior. Do you recall that growing up?

KD: ... in a house called, Gardenhurst. We had large, about an acre, of wonderful garden; pears, and apples, and peaches all espaliered on the walls around the garden, twenty-foot-high stone walls around the garden, and two incredibly large Mediterranean palm trees...But in the house itself, of course there was no electricity, I remember as a child when the electricity came, and that was it. There was no such thing as heating or cooling. You had the fireplace and you sat by the fireplace and when it was time to go to bed you said the rosary. And that was life. My father sat on one side and my mother on the other side and we'd sit in between and you talked, you know. No television of course, obviously, hadn't been invented yet. There was no ... you opened the window if you wanted air; you closed the window if you didn't. And that was it. End of story, no mechanical systems.

Down in the basement we had a large room, which was the coal cellar. That was filled with coal, you would go in and get a shovel of coal, bring it back upstairs, put it in the fireplace.

Now I've got to switch the subject a little bit because I always like to refer to this. My mother was a member of twelve children. There were ten girls and they all grew up in a mud cottage. Mud cottage had walls about that thick (indicates about 1.5 feet), and it had a fireplace in the center, it had a kitchen and a living room, and it had a bedroom, actually it had two bedrooms. And that was it. A mud floor and it had a thatched roof. The fireplace was open. You lit the fire. It was like being outdoors.

And I've always admired it, because the simplicity of the whole thing. They got the mud right there; they got the reeds up the river. There was no water, there was no toilet. If you wanted water, you walked down to the river and got a bucket of water. They had some chickens and pigs, a cow for milk and hens for eggs, and all that. And they lived off this thing absolutely completely. There was no ... they never went anywhere to buy anything ____. And there it was - how to live in a spot - and not have to go to the store.

And it's amazing, I keep going back to it, you know, because the absurdity of our houses today with all the stuff that we have in them. And you can live simply and you can adapt.
It constantly occurs to me, how possible it is to live a full life, in very modest and readily available materials.

**CF:** Warm and comfortable.

**KR:** Warm and comfortable, growing your own stuff and she had one pot, big cast iron pot, that would swing out over the turf fire and she could cook something in that pot and at the same time bake bread on top of it. You'd get a delicious dinner, so simple, with a couple of spots of turf. That's all they had.

…it influenced me a lot in terms of how people live.

Roche’s early exposure has clearly had lasting impact on his perception of valued interior space and the attendant needs of occupant comfort, lending credence and substantive support that the impact from these experiences was retained by the designers as they executed their mid-century buildings. The final chapters of this work will offer real examples that, for at least this designer, the products of this influence exists.

### 1.3.1.2 Roche’s Architectural Education

The education that Roche experienced at University of Dublin after it made the shift from Beaux Arts to Modernist curriculum and then his time at IIT is in perfect synchrony with what was occurring in the majority of Architectural programs (see 1.2.6.2, “Architectural Education”). What is germane to this discussion is what, besides the removal of Beaux Arts design and drawing pedagogy, was added and/or emphasized in the programs. The addition and or emphasis on the curriculum has been outlined (see 1.2.6.2, “Architectural Education”), but the impact of those didactic studies concerning, light, thermodynamics, acoustics, statics, conservation of energy, color, or electricity on the designs is best heard from Roche himself.
From the interview with Kevin Roche on June 14, 2015, after explaining to Roche I felt that there were often passive strategies that had been included in the designs of Modernist buildings and that these strategies had been used during design for the purpose of occupant comfort as energy costs and fossil fuel impacts were not subjects of concern at the time and how this study, in retrospect, of these employed strategies would add currency to the value of these buildings (a debated topic) and had application to the contemporary concern of energy consumption.

**KR:** When Eero was alive and we were working on things like John Deere in Moline, Illinois, I introduced the idea of the sunshades outside. It was always a matter of how does one protect the inside of a building from the climate outside. I used them in many of the headquarters, Conoco for instance we used quite an expensive plastic cast up as awnings outside. In Union Carbide we used awnings again.

In Ford Foundation I didn't have to because the aspect of the building was such that it was protected from other buildings and I didn't have to worry about it too much. But what we did do was; we returned all the air from the building through the atrium so that the trees would regenerate that air again and recirculate back into the system. So we were probably unique in that.

Practically you'd be hard pressed to find a building of ours where we had not considered the energy aspect of it as a major factor of the design.

**CF:** I know from reading about your studies of the Fine Arts Center, and the Sun Machine name you tagged it with that you were really looking at the shadows. Are you looking at them for the impact on your geometry? Are you looking at for potential loads that those shadows might be defending?

**KR:** ... sun studies were strictly for the purpose of examining the interaction of light and shadow on the buildings geometry. The studies established the spacing between the Bridge and Main Complex. The play of shadows on the south walls along with the change of light and shadow on the pilati were of a primary concern.

Notes

(Roche 2015)
The impact of the Bridge's shading on the main complex, and its solar loads reduction on those spaces were not considered. Roche explained that the source of this shading interest resided in his Beaux Art training in Ireland. Drawing classical architecture elements, especially columns with fluting or reeding, and representing the shadow play on the column and adjacent surfaces was paramount. A vestigial influence that informed his Brutalist architecture.

Other possible strategies from a passive design perspective were not affirmed. Roche was quite candid when queried about these strategies.

**CF:** So when you started using concrete in addition to its material properties, were you thinking also of the thermal mass? I mean these buildings... there is 25,000 yards of concrete in the Fine Arts Center. It's an extraordinary amount of thermal mass.

**KR:** I have to say I didn't think about that. I didn't know about that.

Pursuant to the discussion about circulation level under the bridge I asked if shading that pathway was a factor in providing comfort to the pedestrians as the traveled that route. Roche reiterated that what he had only been interested in the aesthetics of shadows on his geometry.

Additionally, I asked if there was any consideration given to the fact that the prevailing breezes in the summer blew across the reflecting pools and would additionally cool the pedestrians as they passed by. Again, Roche was quite open and said that he had not considered that and the pools were all about aesthetics and framing the approach to the opening between the auditorium and theatre.

Notes

138 “Bridge” is the term used when referencing the 646-foot-long elevated construct that houses a series of Art Studios on the south side of the FAC.
Roche’s candor is especially important to this work as it establishes a precedent that will be necessary to keep in mind when examining other Brutalist buildings for the presence of successful sustainable strategies. Some of those strategies might have been intentionally placed in the buildings by the designer, e.g. Roche’s employment of daylighting and glare controlling techniques; but others are there only because of fortuitous coincidence, e.g. Roche’s solar defense with the building’s own geometry or thermal mass strategies for energy reduction.

It is important to remember that in a work such as this one, which attempts to establish a template for understand a building via an examination of all of its components, from design intent to construction materials; it is, in the end, the sustainable strategies that a building does possess, whether intentional or unintentional, that is paramount, no matter how these strategies happen to have been incorporated into the reality. It is their presence that adds to the building’s value.

The availability of Roche for an interview; the interest, ability, and means of Ise Gropius to produce the monograph referencing passive strategies employed by Walter Gropius will not be commonplace additions to examinations of other Brutalist buildings as the availability of the designers is, even now, limited because of the passing of the majority of them and academic and professional interest in discussing or documenting sustainable strategies used in the era of powerful mechanical systems was not a priority. However, this does not mean they are not present.
1.3.1.3 Roche and Modeling

The inclusion of this subsubsection is intended to introduce and reinforce the effort that Roche extended when investigating shading on the FAC. The extent of the effort underscores Roche’s interest in three associated impacts on the building. First, the interplay of light and dark on the surfaces of the building accentuating and adding texture to the sculptural geometry of the structure. Secondly, by studying the elevations of the building that were exposed or screened from direct sunlight he could adjust fenestration requirements to best optimize daylight usage for the program within. Thirdly, by studying the windows that received direct sunlight exposure he could work out geometric solutions to mitigate glare.

Interestingly it is Gropius that we also include in this subsubsection in similar fashion to his inclusion previously (see 1.2.6.1, “Architect’s Personal Experiences”). We have previously established Gropius’s influence on the dissemination of Modernist dogma and his impact on his students and students of his students (see 1.2.6.2, “Architectural Education”) and believe that the image of the “Model of the Gropius House” (Fig.1.59) is an early emphasis on model making for uses other than informing the understanding of building forms as it had been in the Beaux Arts system as is evidence in the following description of in *Collegiate Education of Architecture* in a section that details typical Beaux-Arts architecture curriculum in 1911-12.

*Under the caption of freehand drawing include the following subjects: drawing from casts, drawing from life, watercolor, pen and pencil, and modeling. While modeling embodied a different medium and was the one subject that was not concerned with paper techniques, yet the*
objectives were for the most part the same as in freehand drawing and it is grouped with the drawing subject.¹³⁹

...largely of exercises in copying in clay the sculptural forms most common in classic architecture. The principal objective was the improvement of the student’s visualization and appreciation of the aesthetic architectural qualities of classical masterpieces.¹⁴⁰

It had always been Gropius’s intention to use the design, construction, and occupancy of his house as a teaching tool.

_Treating their home as a showcase for Gropius’s Harvard students..._¹⁴¹

The following image (Fig.1.59), originally published in _Architectural Forum_ (1939), was also found in two works which addressed Gropius and his house; _Walter Gropius: Work and Teamwork_ by Sigfried Giedion,¹⁴² and _Walter Gropius_ by Hartmut Probst and Christian Schadlich.¹⁴³

The image is unequivocally an image of a model on a table being lit from a light source. It is not evidently from a carefully positioned model in a Heliodon, as a model of the building in Ecotect, properly geo-position and oriented, (Fig.1.60) cannot produce exactly the same shadows, but indicates that an approximation was made to duplicate early morning at summer solstice.

_**Notes**_

¹³⁹ (Weatherhead 1941, 166-67)
¹⁴⁰ (Weatherhead 1941, 169)
¹⁴¹ (Kramer 2004, 39)
¹⁴² (Giedion 1954)
¹⁴³ (Probst and Schadlich 1986, 197)
Was the model photograph only to show off the geometry of the interrupted overhangs or was this simply a photograph taken at one moment for documentation? It is far more likely that the creation of the model (not a small effort) was used by Gropius to diagnose what the geometries shading impacts on facades would be and then adjust the geometries according to load reductions and interior program while balancing the impact of the shadow aesthetics. This seems far more likely as the balance of the load reduction during summer and optimization of load gain in the winter on the large south windows of the buildings is extraordinary and was quantified in an examination of the house in the 2011 paper *Sustaining Modernity: An Analysis of the Gropius House.*

Twenty-five years passed from the creation of the Gropius House model until Modernist pedagogy completed its ascendancy in the schools of Architecture and its graduates were practicing. In the late 1950’s, in Saarinen’s office large models became the paramount technique of design. Richard Knight’s book *Saarinen’s Quest* provides

Notes

144 (Fiocchi and Hoque 2011, 9-11)
ample documentation in the form of firsthand narrative and supporting images (Figs. 1.61 & 1.62).

Knight was a junior architectural designer and photographer in Saarinen’s office from 1957 until Saarinen’s death in 1961.

*In the late 1950s, Saarinen upended the architectural profession and revolutionized the way buildings were designed by using large models to investigate the forms and functions of his intended work.*

*...mostly monochromatic, emphasizing form and effects of shading.*

Notes

145 (Knight 2008, 21)
146 (Knight 2008, 24)
When interviewing Roche in 2015 the shift in Saarinen’s office to large full-scale models and the reliance on them was brought up.

\textit{CF:} I know from, I have a copy of Richard Knight's book, Saarinen's Quest, He was the photographer...

\textit{KR:} Right.

\textit{CF:} ...photographed all those models, you're in half the pictures. And I have seen pictures of you afterwards, once you were on your own after Oakland, with great models also. And I know from reading about your studies of the Fine Arts Center, the Sun Machine name you tagged it with, that you were really looking at the shadows. Are you looking at them for the impact on your geometry? Are you looking at for potential loads that those shadows might be defending?

\textit{KR:} Well, I was the one who brought the practice into the office. Models, especially the big ones, are better than any 3D drawing, even the ones you can make with computers today.\textsuperscript{147}

The practice has continued after Saarinen’s death (Fig.1.63) and continues to this day as can be substantiated be seen in the photograph of the Model Room at Kevin Roche John Dinkeloo Associates (KRJDA) taken the day of the interview (Fig.1.64).

\textit{No effort is spared, KRJDA’s facilities allow models to be photographed, using theatrical lighting to produce real-life effects.}\textsuperscript{148}

Most pertinent to this discussion is of course the model of the FAC. When asked if he knows what happens to the models Roche replied that many are still there at KRJDA (Fig.1.64) and Yale has some in the Archives, which contain all of the KRDJA archived work. There are eleven boxes for UMass FAC alone among the total of KRDJA boxes at

\textbf{Notes}

\textsuperscript{147} (Roche 2015)

\textsuperscript{148} (Pelkonen 2011, 67)
Yale (all have been examined) and although one box is devoted to the photographs of the FAC models (Fig.1.65) there no record of one surviving.

The significance of the extensive physical modeling, coupled with Roche’s Beaux Arts background in drawing, where shadow definition is used to accentuate and study details, e.g. the fluting or reeding on columns, the shift to Modernist pedagogy while he was in school with the increased attention concerning daylight and glare strategies.

Notes

149 (Roche 2015)
along with other building physic principles (see 1.2.6.2, “Architectural Education”), and Roche’s early experience of using non-mechanical strategies relating to occupant comfort issues (see 1.3.1.1, “Roche’s Personal Experiences”) come to full and mature execution in his design of the FAC.

Verification for the above was found in the University of Massachusetts- Amherst DuBois Library Archives.

From the Fine Arts Center Theatre Season Flyer (Fig.1.66).

*The critically acclaimed Fine Arts Center, architectural gate to the campus of the University of Massachusetts at Amherst, has been named the Sun Machine for the unexpected ways light plays on its complies surfaces.*

*The shadows created by the jutting angles, expansive staircases, sweeping ramps, and shaped columns of the new Fine Arts Center progress across the building’s facade with the passage of the sun, their fluctuating patterns reflected in the campus pond to the north and the two artificially constructed ponds to the south. Which is the point.*

“We used some very conscious devices to make the building respond to the sun as it moves across the sky,” explained Kevin Roche.  

Figure 1.66: FAC Sun Machine Logo. Courtesy of UMass-Amherst Library Special Collection and Archives.

**Notes**

150 Archives of University of Massachusetts-Amherst
Although the documents from the archives all reference only the interplay of shadows on the facades, Roche has made it quite clear that while he was designing he was very much aware of the occupant’s desire for daylight, the mandate to control and/or mitigate glare, and the specificities of climate; supplying or denying, as appropriate with his geometry.

From the Pelkonen’s *Kevin Roche: Architecture as Environment*:

Roche starts his design process by identifying and analyzing all the factors and forces that influence the problem at hand. These include programmatic needs, circulation patterns, zoning laws, infrastructural requirements, building codes, traffic flows, urban morphologies, and daylight conditions.\(^{151}\)

2006 Interview with Kevin Roche conducted by *Perspecta 40* on early design:

*P40:* The prioritizing of the user brings to mind Eero Saarinen. Of course, we’ve heard the stories of when he was doing Dulles Airport in the late ’50s, for example, and interviewing every worker about how much light they needed and other details ...

*KR:* I certainly learned that from Eero.\(^{152}\)

And in the same article relating to climate considerations for the Millennia Hotel in Singapore:

*And in the bedroom/living room area there is a rectangular window with an awning—both buildings have awnings on them, because Singapore is on the equator, and a relatively small awning gives you shaded windows.*\(^{153}\)

Notes

\(^{151}\) (Pelkonen 2011, 17)
\(^{152}\) (Editors of Perspecta 40 2006)
\(^{153}\) (Editors of Perspecta 40 2006)
1.3.1.4 Roche and Concrete

Concrete’s contribution to Brutalist architecture is front and center whenever a Brutalist building is discussed. Its color and texture supplying structure and finish dominate almost all elevations planes, both interior and exterior. It has been addressed earlier in this work (see 1.2.3.8, “Brutalism’s Concrete”) and will be addressed in material detail later (see 1.3.2.3, “FAC Concrete”), but it is apropos here to address Roche’s distinct relationship with the material.

The information provided here will enhance understanding and appreciation of the FAC itself as it is dissected aesthetically, structurally, and programmatically in the following subsubsection. Understanding is also enhanced with the advantage of hindsight providing, chronologically appropriate perspectives as supplied by Roche himself in interviews.

Reiterating and expanding the point made earlier (see 1.2.6.1, “Architect’s Personal Experiences”). There should be neither criticisms nor blame attached to the use of these technologies as, at that historical moment, the availability of fossil fuels was thought to be unlimited and climate impacts not widely considered. It should now include the caveat that many of the materials (concrete being one of them) used by the Modernists were technologically new or were being pushed to their limits and have not performed as was expected by the scientists or technologist who developed them, the manufacturers who produced them, or the engineers and architects who specified them.

From 1985 Dal Co interview:

KR: The true nature of the materials we use is not always appreciated for what it is, and materials are frequently misused. For instance, concrete is exposed as a surface and it does not survive very well in
many climates. It is a frequent problem of modern buildings that cannot be maintained.\textsuperscript{154}

From 2011 Max Page interview:

\textbf{KR}: … that's where, a time, exposed concrete was coming into its own and optimistically, you know, we thought you could use it everywhere and for everything. I think time has shown that that really wasn't such a good idea.

\textbf{MP}: What, to use?

\textbf{KR}: Because of the weathering aspects of concrete, can be quite depressing.

You know, you get the stains, which you don't get with stone, in those days you wouldn't dream of cladding something with stone. You know, that was retro.

\textit{And, Paul Rudolph, of course, was trying to solve the problem by making it textured, and it does to a certain extent, but it doesn't completely resolve…}

\textbf{MP}: You mean; you think you might have done it differently in retrospect?

Reasons people are "skeptical" of the modern buildings is that they have weathered without the- they have not been maintained as well.

\textbf{KR}: That's right, modern buildings require more maintenance because, unlike classical buildings, where they faced up to that in the early days and put these cornices and drip lines and frames around things which would shed water.

\textit{And the other aspect of it, is that, in modern buildings, you have all these different materials, different coefficients that expand and start tearing themselves apart.}

\textbf{MP}: Right, but that's an important issue that people say, "oh, it leaks, it leaks," so...

\textbf{KR}: … but we were innocent of all these things. This was, 50 years ago, I guess, almost that.\textsuperscript{155}

\textbf{Notes}

\textsuperscript{154} (Dal Co 1985, 78)
From 2015 Fiocchi interview:

**KR**: And of course, a sensible use of materials is important. Now I have to qualify that by saying that when we used concrete we didn't really understand the implications of using concrete, because concrete doesn't survive as well as we all thought it would. It tends to get to crumble, it tends to crack, you know. Although there is a long history of it in use really, but one of the advantages of using stone is that it will move and ... you know that buildings are always breathing, they are always moving, they are always wanting to change. We use stone, we use brick, we use glass, and we use metal. All of these things have different components of expansion and they all eventually, any modern building is beginning to fall apart now.

1.3.1.5 Roche - Summary

From personal early experiences, through formal Architectural education, through early professional years in practice, and throughout his practice Roche was a product of the world politics (World War II), pre-mechanical system building occupancy (absence of electricity and central heating or cooling), the emergence of Modernist doctrine (in art, politics and architecture), the shift in Architecture school’s pedagogy (the demise of the Beaux-Arts system), and the availability of new architectural and engineering technologies and materials (glass, steel, and concrete). A product of his environment to be sure, but one that was tempered with design genius.

(K. Roche 2011)
1.3.2 The Building

1.3.2.1 Background

Modernism’s appearance as the dominant style during the 1960’s and 70’s at UMass-Amherst has been presented (see, “Preface”). The increased square footage required to accommodate increased student population is easy to understand along with the dynamisms driving the increased enrollment, i.e. returning servicemen from World War II and the Korean War all having access to funds directed toward college education as well as the mortgage money provided by the GI Bill.

In the peak year of 1947, Veterans accounted for 49 percent of college admissions. By the time the original GI Bill ended on July 25, 1956, 7.8 million of 16 million World War II Veterans had participated in an education or training program.156

The forces that came together that created the millions of square footage of Modernist Buildings on campus and the rejection of the traditional collegiate campus classical brick style are more complex. Certainly, the progressive leadership of Presidents J. Paul Mather (1954-1960) and John William Lederle (1960-1970) provided the instigating impetus by hiring famed landscape architect and planner, Hideo Sasaki and the firm Sasaki Associates in 1961.157

Sasaki’s master plan recommended several measures with one of special impact to this effort.

Notes

156 (U.S. Department of Veterans Affairs n.d.)
157 (Brown, et al. 2000)
Encourage building designs that reflect the University’s mission as being a place of cutting edge ideas and unimagined possibilities.

The University took to heart Sasaki’s recommendation on planning and building. The University of Massachusetts was not a small private college. Therefore, it was decided that it should not look like one. Consequently, the University made a conscious choice to erect a series of buildings that are significant example of modern architecture.\textsuperscript{158}

This was the key to what would then be built over the course of the ensuing decade.

Sasaki did not design any new buildings, but he called on the University to hire an architectural consultant to select visionaries to design signature buildings in the new plan. Sasaki and the University’s choice was Pietro Belluschi, a key figure in the modernist movement. Dean of the MIT School of Architecture, Belluschi guided several campus planning projects in these years. It was he who advised the University to hire Kevin Roche, Gordon Bunshaft, Marcel Breuer, and Edward Durrell Stone. While Sasaki and Belluschi embraced modernism, they did not seek uniformity for the campus. Far more important to them was to build shelters for the students, faculty, research, and teaching of the booming university, and to project an image of a forward-looking institution ready to take its place among the leading universities in the nation.\textsuperscript{159}

Belluschi’s designer recommendation for the premiere site on Sasaki’s master plan was Kevin Roche of Eero Saarinen Associates (soon to be KRJDA). Kevin Roche and KRJDA were actually a replacement for Minoru Yamasaki, the first acclaimed, out of state architect to be hired by the University.\textsuperscript{160} Yamasaki departed, contesting a minimal design fee.

... a budget of only two million dollars, and program specifications which were little more than a brief statement of the University’s

Notes

\textsuperscript{158} (Bernhard 2007)
\textsuperscript{159} (Miller and Page 2013, 28-29)
\textsuperscript{160} (Brown and Tepel 1976, A2)
expected needs and philosophies concerning the importance of creating a building that would be impressive enough to capture the essence of the fine arts.

...it became painfully apparent that the funds available for the building would never be enough to create a building that was large enough to house the departments adequately. It also was realized that the University wanted a monumental building to serve as a focal point and public relations object representing its emergence from an agricultural school.\(^{161}\)

This was the climate into which Roche and KRJDA were thrust and out of which emerged the FAC, almost one decade later.

1.3.2.2 Description

The Fine Arts Center is a complex massing of five separate, but linked and interconnected buildings. The interior encompasses over two hundred thousand sq.ft. (18,580.61 m\(^2\)) of space and over four hundred and fifty rooms with nine major staircases and two elevators connecting the four main levels. Additionally, over one hundred secondary staircases or ramps connect the assorted sub-levels resulting in an extraordinarily intricate plan, necessary to connect and transition through the multi-programmed spaces.

The five buildings are linked primarily along the longitudinal east-west axis. Each of the buildings houses a separate department: Music and Art at the eastern end, Drama (Speech) at the western end, Auditorium (2053 seats) and Theatre (666 seats) are located in the center separated and sharing an open plaza. The south side of the longitudinally

Notes

\(^{161}\) (Brown and Tepel 1976, A3)
connected complex is paralleled by an elevated [40 feet (12.19 m.)], 646-foot-long (196.90 m.), Bridge containing the art studios.

This subsubsection will serve the purpose of establishing site and geometric familiarity with the building (1.3.9 & 1.3.10). This is necessary, as a clear visualization of the building is a requirement for the discussion that relates the building to points already made concerning Modernism and Brutalism in the previous two sections.

Figure 1.67 & 1.68 are contemporary satellite image, which serves to illustrate the orientation of the building.

![Site Image 1](image)

Figure 1.67: Site Image 1.
Courtesy of GoogleEarth.

Figure 1.67 shows the north south axis of the building, tipping minus seven degrees from true north, along with the separate, but connected buildings (labeled in red) of the complex.

Figure 1.68 shows (red lines) the north-south site plan axes created by the Sasaki plan and how Roche oriented the FAC to orthogonally bisects those north-south axes, placing the building parallel to the University’s main entrance access road (lower red line) creating an approach from the campus’s formal access road, through the green space.
(Haggis Mall) directly and normally toward the FAC’s south elevation where the building would provide threshold, gateway, and view to the campus beyond. The threshold, gateway, and view will bear more discussion.

![Site Image 2](image)

**Figure 1.68: Site Image 2.**
*Courtesy of GoogleEarth.*

The following images (see Figs.1.69 -1.74) will aid in maintaining orientation and clarification when following the discussions that will follow. Original construction documents are available and have been accessed as will be discussed in the next Chapter, Methodology. The drawings below are the clearest and most legible of period material; however, they are not dated and were created by the University’s Physical Plant sometime after the building was built. KRJDA used a European style floor designation system, i.e. Ground Floor is equal to an American First Floor; First Floor is equal to an American Second Floor, etc. Physical Plant’s interest would have been to renumber the rooms to make them consistent with the other University’s buildings. It has, however, not
made locating rooms and synchronizing information from the original sources and references, from the University’s *Special Collection and Archives* and *Facilities and Planning Archive* with contemporary documents a simple task.

![Figure 1.69: Site Plan. Courtesy of Facilities and Planning Archives.](image1)

![Figure 1.70: Basement Level Plan. Courtesy of Facilities and Planning Archives.](image2)
Figure 1.71:
First Level Plan.
Courtesy of Facilities and Planning Archives.

Figure 1.72:
Second Level Plan.
Courtesy of Facilities and Planning Archives.
Figure 1.73:
Third Level Plan.
Courtesy of Facilities and Planning Archives.

Figure 1.74:
Fourth Level Plan.
Courtesy of Facilities and Planning Archives.
The building (Figs. 1.75 – 1.80) is a sprawling, masterful, and magnificent piece of sculpture where exterior form is the response to the programs and functions of the encapsulated interior spaces (Fig. 1.75).\footnote{162}

The massive volumes of the theatre (west center) and auditorium (east center) are both windowless as expected by programmatic dictates. Exterior geometry of the Theatre articulates the vertical cube of the stage and fly loft (rising 75 feet (22.86 m.) above the stage floor) adjoined by the hexagonal total of wing space, house, and lobby (Fig. 1.76).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{image.png}
\caption{Figure 1.75: View of FAC from the North. Courtesy of UMass-Amherst Library Special Collection and Archives.}
\end{figure}

\section*{Notes}

\footnote{162} Note: Although photographs are available and could be taken at this time, disseminating photographs that document the deterioration and discoloration to the concrete, the elimination of the reflecting pools, the occluding of the opening between the Theatre and Auditorium, and other disfigurations and insults to the FAC is not desirable. Finding period photographs that celebrate the building’s sculptural and monumental characteristics, while at the same time illustrating a particular point is limiting. The solution, when a period image was not available, was to use images from the models of the building to help illustrate a point.
The Auditorium’s (Fig.1.76) geometry responds to internal acoustical criteria with the four tiered balconies advancing as elevation increases, rather than receding as was more typical, resulting in a more egalitarian view, i.e. as elevation from the stage level increased (a higher balcony), the balcony brought the viewer closer to the stage rather than farther away (Fig.1.77).
Figure 1.78: FAC East Façade: Morning Glare Defending Geometry (see red square). Courtesy of KRJDA.

Drama to the west and Art and Music to the east have similar geometries, i.e. narrow footprints containing double-loaded corridors accessing perimeter offices, all with access to ample daylight. Glazing orientation (Figs.1.73 & 1.74) and building geometry defending each office from glare (Fig.1.78) (see 3.3.1, “Daylight Maximization”, Glare Control” & 3.4.3, “Window Direct Solar Gain Defense”).

Insinuated into each department were the requisite programmatically demanded spaces. Classrooms, rehearsal spaces, green rooms, dressing rooms, lobbies, and storage spaces for the Theatre and the Auditorium; a practice theatre, workshop spaces, and prop and scene storage for Drama; soundproof rehearsal spaces, performance venues, and practice studios for Music. Singular spaces responding to program requirements, e.g. a common library for the three programs, an Art Gallery lit by a pyramidal skylight was located beneath the terrace between the Theatre and Auditorium, and office space for the Auditorium and Theatre staff, adjacent to the ticket lobby, were inserted appropriately.

Each program received the additional attendant necessities of bathrooms, maintenance closets, mechanical rooms, etc. The majority of these spaces were located below grade or, if above grade, capped with terraces as their interiors were focused on
their internal programs and exterior views were discounted. In addition to the office and classroom space, Art was supplied with a continual row of studios located along the length of the Bridge, all lit by north facing light monitors (Fig.1.79) and each opening out into a single corridor (10-foot-wide) supplying “pinup” space for the student work (Fig.1.74).

![Figure 1.79: Bridge Art Studio’s: North Facing Light Monitors. (see red line).](image)

One feature, in this general description, bears special emphasis, that of the elevated Bridge, which completes the southern façade (Fig.P.18). The construct not only houses the Art Studios, it also provides a sheltered walkway crossing and connecting the east and west sides of the campus. The regularly spaced dihedral pilotis supporting the Bridge present a uniform façade as the FAC is approached from the south, but when the final two hundred feet (60.96 m.) of the approach is reached the two reflecting pools (Fig.1.80) narrow the approach and funnel the visitor toward the opening between the Theatre and Auditorium, where the entrances to both are located, and direct the view to the north over the campus pond and into the center of the campus. This is Roche’s skillfully crafted formal and magnificent entrance to the University of Massachusetts-Amherst.
1.3.2.3 FAC Concrete

Concrete as a material, a construction process, and its related psychological associations has received much attention thus far (see 1.2.3.4, “Construction Module Scale”, 1.2.3.5, “Lack of Ornamentation”, 1.2.3.6, “Maintenance”, 1.2.3.8, “Brutalism’s Concrete”, 1.2.5.2, Tadao Ando’s Concrete”). It will receive still more attention as the discussion continues, but now the focus will be specifically on the concrete the FAC was formed with.

Reviewing the original Specifications for Massachusetts State Project No. U-63-5 document (Fig.1.81) in the Facilities and Planning Archives the following very specific entries (Note: Specifications Document, has been categorized to allow easier comparisons with construction practices experienced by the FAC in the following subsubsection, underscores are for emphasis).
Color of Concrete:

3-04. Materials

.1 Cement shall

AA: Use a warm buff-color cement for all concrete which has an exposed face in the finished work: Penn-Dixie Nazareth, Pa or Howe’s Cave, N.Y. plants or Coplay Saylor’s Light or another of the same color.

BB: Use a matching color shrinkage compensating cement in concrete for exposed work schedule in Table A and as manufactured by a licensee of chemically prestressed concrete corp.; Chemcomp Cement or equal.

(b) Be the same brand throughout the entire work, unless otherwise approved in writing by the architect.
.5 Aggregates shall

(A) Consist of graded natural sands and gravel or crouched stone having clean, uncoated grains of hard and durable mineral, of uniform light color.

(B) Be free of organic impurities, so that the standard test will show a color not darker than Figure 2 of the Standard Color Chart, ASTM C 40.

Installation of Concrete:

3-08. Depositing Concrete

BB. Begin vibration as soon as concrete has been placed and continue until the entire section being placed has been thoroughly consolidated...

The time of vibration at one point shall be sufficient to accomplish thorough consolidation of the concrete around the inclusions and against the forms and to eliminate all air bubbles and voids.

Construction Joints:

3-09. Construction Joints

.1 Construction joints shall be located as herein specified and where shown on the drawings. Construction joints shall be made only where show on the shop drawings.

.2 Exposed joints shall be straight and true.

Curing of Concrete:

.1 All concrete shall after placement

(A) Be kept in a continuously moist condition for a period of not less than 7 days.

Exposed Formed Concrete:
3-11. Exposed Formed Concrete

.1 ... shall be smooth, dense concrete with a uniform mortar surface, which shows no coarse aggregate, without voids or stone pockets and without fins, projections or any irregularities or abrupt change in plane, as the concrete come from the forms.

.2 ... shall be cleaned by washing down with water and detergents of dilute acid, using fiber brushes. Remove all stains and discolorations. After drying, the concrete shall be uniformly clean and of uniform color.

Metal Reinforcement:

(E) Be placed so that the clearance from concrete surfaces exposed to the weather is not less than 2 inches.

Forms:

.5 Exposed concrete formwork - lay out the form panels in a regular pattern and at a uniform spacing. The pattern shall be repetitive for the full length of each wall surface and within slab soffit panels. Conform to the approved form panel layouts. Ties shall be uniformly and regularly spaced in straight lines in both directions. Make all field cuts in forms square and true without damage to form surfaces which will contact concrete. Form square internal and external angle corners without chamfer strips. Butt adjacent panels tightly together in continuous uniform contact, which will prevent the passage of air and water. Maintain a true surface across all joints.

.8 Forms may be reused if in the opinion of the architect their condition is such as to give the specified results.
The above are only selected extracts of the *Plain and Reinforced Concrete-Formwork* section of the *Specifications Document*, which encompasses nineteen pages in all. It is an exacting and specific specification detailing the process from material selection to the care of the finished surfaces after form removal. Is Tadao Ando’s process more rigorous?

Ando’s process has evolved over time, as material deficiencies were revealed and technology innovations to combat those deficiencies discovered and put into practice. Perhaps Ando’s control of a jobsite and construction process are more scrupulous, and his budget more luxurious; but Roche’s design intent and construction demands were similar, if not identical. Roche freely admits that the way that he and his contemporaries used concrete was not without fault. It was a new material and did not perform, in every respect, as they had anticipated. (see 1.3.1.4, “Roche and Concrete”).

Thus, some fault lies there, but the real problems with the FAC’s concrete lies in the construction process as the following subsubsection will explain.

### 1.3.2.4 Design and Construction

In the 1950’s The University was still a primarily oriented agricultural school with a limited fine arts faculty and a legitimate question exists as to whether there was anyone available who could competently define a program sufficiently adequate to initiate the process of designing and building a multi-million dollar Fine Arts Center. Paired with this inexperience was the University’s uncertainty as to whether such a large complex was necessary at all.
unwillingness to contract a consultation and research team to make an in-depth and accurate study seems to have set the pace for the building.

The grossly underestimated allocation of $2,000,000 for the building was evidence of the administration’s inexperience with large building projects of this type.

We see this also in the initial programs sent to the architects, which was little more than a brief statement of the University’s expected needs and philosophies concerning the importance of: creating a building that would be impressive enough to capture the essence of the fine arts. Accompanied with the University's philosophies, was a chart listing space usages, approximate dimensions, net areas, and finally total areas, which combined to be around 200,000 sq. ft. From this information, and some minimal additional information from the various departments involved, the architect was expected to be able to give the University a complex housing - three departments, a 4000 seat Concert Hall, and a 900 seat Theatre - all of which was meant to be a focal point on the campus.¹⁶³

See also two sample pages of the September 30, 1960, twelve-page, mimeographed copy of a document found in the University’s Facilities and Planning Archive (Figs.1.82 & 1.83). It is unsigned and uncredited, but shows evidence of the indecisiveness, even at that late date, of what programs should be housed in the building (Landscape Architecture is included), along with woefully underestimated square footage requirements

Notes

¹⁶³ (Brown and Tepel 1976, A2)
It was not until the early 1960’s when forces conjoined (see 1.3.2.1, “Background”) that the possibility of the building became a reality.

... appropriation of funds which were now more accurately estimated to total $4,500,000 for construction.\textsuperscript{164}

After the exit of Yamasaki and the aforementioned recommendation of Belluschi Kevin Roche and KRJDA became the designers of record.

\textit{On December 4, 1963, Belluschi recommended the firm of Eero Saarinen and Associates (later named Kevin Roche John Dinkeloo and Associates) because of “their wide experience and authoritative knowledge in the design of fine arts buildings, theatres, music halls, and other similar projects.”}\textsuperscript{165}

For Architecture, for Modernism, for Brutalism, for UMass-Amherst this was a result that is regarded as enormously fortuitous by the former three and should be

\textbf{Notes}

\textsuperscript{164} (Brown, et al. 2000, A3)
\textsuperscript{165} (Brown and Tepel 1976, A4)
regarded in that identical light by the fourth as the remainder of this subsection will support, but time has not proven it to be so.

Brown and Tepel’s narrative continues and includes, designated by quotation marks, a quote from Richard Galehouse.

Through the next eight months Roche and Dinkeloo worked diligently to arrive at a rough interior plan coupled with a highly sculpted exterior plan for a linked, but segregated department complex located at the southern end of the pond.

Their initial presentation of the preliminary plans to the University was heralded as "the most brilliant, professional architectural presentation that I've ever attended” by Richard Galehouse of Sasaki…

As is often the case in research, although not as often as one could wish, good fortune can sometimes visit. As was the case when a Project Manager at the University, Douglas Marshall, mentioned in passing that early in his career he had worked at Sasaki Associates. I inquired if he had known Galehouse. The response was an affirmative and I was put in touch with Galehouse, informing him of the reference, and asking him to clarify it if possible.

The background to my and Stu Dawson's involvement is that I was the project planner and Stu the project designer for our master planning and design work at the University beginning in the early 1960s.

Notes

166 Note: At the time of Brown’s and Tepel’s research and writing on the University’s campus, 1976, the year after the dedication of the Fine Arts Center, they had access to documents and people that forty years hence are no longer available. This work is indebted to their diligence as researchers and to the University’s archive in preserving this single typewritten copy of their effort.

167 (Brown and Tepel 1976, A4)
Pietro Belluschi who was Dean of Architecture and Planning at MIT and Hideo Sasaki who was Dean of Landscape Architecture at Harvard were our senior advisers and served on a design review committee of new projects along with myself.

As you noted, starchitects were designing buildings at the time. I can tell you that they were all competing with each other as well. In trying to maintain a pedestrian academic core in our master plan we had to solve the vehicular circulation problem on the campus where all roads ran north south thru the heart of the campus.

Stu came up with the idea of the boulevard between the face of the campus and the town to collect the various streets and to utilize the old football field as a "front door" to the central green. This left the building site at its head.

We were very concerned that an architect would plant a building at the head of this gateway site blocking the view into the central green. The University had already selected Minuoru Yamasaki to design the building and we were not enamored with his delicate white buildings that he was designing at the time. So our master plan illustrated a transitional space, an open paved plaza space at the head of the lawn of the mall leaving open the view to the central green. The building site for the fine arts center was shown on the side of this plaza space.

My comment about the "brilliant presentation" came from the fact that Kevin Roche understood what we were trying to accomplish with the master plan including protecting the integrity of the central green and that the design form of the building was drawn from the site location and the critical urban design orientations illustrated in the master plan.

He designed his building as a contemporary "gate" to the symbolic heart of the campus, the central green, rather than imposing a known architectural style. The building also served to "bridge" at the same time to the east and west sides of the campus. His brilliant, beautiful solution was better than anything that we could have imagined. My comment therefore was all about the beautiful fresh form he created from his consideration of the site and the master plan. 168

Notes

168 (Galehouse 2015)
It was not until 1968 that the FAC was finally approved and then not until 1971 (funding problems) that construction was begun. Since the introduction of the idea of creating a Fine Arts Center for the University in the mid 1950’s, through the inadequate, in-house programmatic research and efforts in the late 1950’s, through the sophisticated professional studies spearheaded by Lederle in the early 1960’s, and on through the finally approved construction documents of 1968 the original parti of a monumental, blatantly modern, future evoking building had never been waivered from.

The critics followed Galehouse’s lead and heaped praise and accolades on Roche’s design (see 1.3.2.6, “Initial Reviews”), but problems were attendant at the University as enrollment had dramatically increased, tripling over this period (see, “Preface”). This had a proportional, impact on the three programs to be housed in the new facilities and there would be seven more additional years of increased enrollments between the final approval for construction and building occupancy.

"The Fine Arts Center is a masterful and magnificent piece of sculpture”, says Friedman, whose office is in the building. However, while he claims the building is beautiful, he says "It doesn’t work.”

The building suffers because it is "rigid and inflexible”, he says, and, because it was so long in construction, the departments it houses have grown larger than anticipated and do not have sufficient operating space.169

Some observers have noted that the expensive and expansive new facility still won’t be large enough for all the art, music, and theatre department people and their activities.

Notes

169 (Alumnus 1976)
But the building was planned in the mid-1960’s and since then these departments have more than doubled in students, graduate students, and faculty.\textsuperscript{170}

Roche dealt with these obstacles as best as was possible given the administration’s intransigency.

These problems were particularly troublesome since it was painfully obvious that the building was far too small for the rapidly increasing department needs. To alleviate the problem of space limitations the communications department was omitted, as was approximately 50\% of the art department. All along it was realized that this sort of monumental building was meant to be non-expandable and complete in itself. In short, the designers were faced with creating a highly flexible building functionally, but not allowed to deal with this problem efficiently through the design of an expandable structure.

...special difficulties involved with the concert hall, which was eventually to shrink from 4000 to 3000 to 2200 finally, while the theatre shrank from 900 to 700 at the request of President Lederle. This seems to have been a result of financial problems...\textsuperscript{171}

Finally, with design begun in 1964, design approved and budget estimated on in 1965 (Fig.1.84), design modifications finalized and approved in 1968, funding finally attained and bid awarded in October of 1970 (Fig.1.85), construction was started in 1971.

Notes

\textsuperscript{170} (Chastain, Fine Arts Center at End of Long Gestation Period: Eleven Years from Conception to Delivery 1974)

\textsuperscript{171} (Brown and Tepel 1976, A5)
The space issue was a problem of administrative planning and unwise inflexibility not of architectural design, but nonetheless not an endearing environment for the new occupants of this building and would be the one that has colored perception of the building over the ensuing years. Time has been spent on this point because an in-depth
study of a building should examine its shortcomings and understand the origins of those shortcomings. This knowledge enables a more empathetic and instructive analysis than would otherwise be possible.

To that point, one final discussion is added to this subsubsection. One of the actual construction of the building and its contractor’s performance. Roche’s concrete will be discussed in detail in the following subsubsection; for our present discussion it will suffice to say that the construction and successful completion of a concrete building is intimately attendant on the care and quality of the construction process (see 1.2.5.2, “Tadao Ando Concrete”) and deviation from those procedures compromise buildings aesthetics, occupant comfort, and building durability.

It is evident from the records of minutes, *Meeting Notes and Field Inspection Report*, found in the Facilities and Planning Archives that compliance was an ongoing issue. These records were created to document the meetings, attended by all stakeholders, after the bimonthly KRJDA site inspections.
One image of a page from the minutes is reproduced (Fig.1.86) and is followed by a series of typical entries from the recorded minutes illustrating the constant battle for proper concrete construction as specified in the FAC Specifications Document

February 25, 1971

4. The following items were noted in reviewing recent concrete work in the field:
   
   d. The architect advised that absolutely no stoning or rubbing of concrete work was to be done after stripping of forms. Only specified cleaning is to be performed on concrete work.
   
   e. The Architect also advised that the top of concrete wall lifts are to be formed straight. The Contractor explained he intended to use wood strips secured to the wall forms at the top of each lift to produce straight lines at the face of concrete walls.

5. The Architect advised that the first wall pours of the Music Building and Speech Building may proceed using Penn-Dixie Type II cement, however, the sample walls are still to be cured for final review before issuing formal overall approval.

May 20, 1971

1. The Architect again emphasized the importance of Fontaine preparing and submitting concrete design mixes for Type I cement concrete and any other concrete they may propose to use.

June 3, 1971

4. The following items were noted in reviewing recent concrete work in the field:

   f. The washes in a number of cases outside exterior windows adjacent angled walls on the First Floor slab of the Music Building were not well defined and did not provide the specified wash. In one case, water was being trapped against the exterior wall. The incorrect conditions will be corrected and revised methods incorporated to ensure proper washes.

   g. Numerous outside corner conditions contain continuous vertical stone pockets. The formwork must be made tighter in order not to lose the matrix through the joint and specified vibration performed. If proper vibration cannot be performed due to box-out sat the top of forms – holes may be drilled in the box-out form to allow the vibrator to penetrate. Continued occurrence of the condition will result in rejection, removal and replacement of the concrete.

   h. A minimum of 1” cover for slab reinforcing steel is still not being maintained due to incorrectly sized slab bolsters. The Contractor will see that correct slab bolsters are installed.

   i. A dark horizontal line exists around the entire first lift of the studio Theater (“H” Building). Any future walls that contains cold joints will be rejected, removed and replaced.

   j. The Architect once again advised he Contractor that concrete work was not to be patched.
June 10, 1971

5. The following items were noted in reviewing recent concrete work in the field:

k. Vertical corner conditions at walls still show stone pockets and loss of matrix. The Contractor is attempting to correct this condition by tighter formwork and better controlled vibration.

l. Edges of slabs at exterior walls show numerous signs of lack of vibration and wide form joints producing air pockets and stone pockets. The Contractor will take measures to correct these conditions in future work.

m. A large stone pocket was observed on the interior surface of one splayed wall in the Music Building, Frist Floor. This condition will be covered by gypsum board in this instance, however, if a condition of this nature develops in an exposed area the concrete will be rejected.

6. The Architect once again cautioned the Contractor against patching any concrete work. No concrete work is to be patched.

July 1, 1971

4. In reviewing slab curing procedures, it was suggested by the Architect that covering the slabs with PVC after placing concrete and curing for 7 days without the use of additional water would be acceptable. The Sisal Kraft paper and hosing with water does not work effectively.

5. The Contractor advised he would commence corrective work on concrete washes on the First Floor of the Speech ("A") Building at once.

7. The contractor was instructed by the Architect to commence patching of concrete work. Areas and conditions when reviewed in the field to establish guidelines for patching. Any questionable areas should be brought to the attention of the Architect before commencing work.

10. The Architect advised Fontaine Bros. of the following conditions regarding concrete work:

b. Concrete truck tickets are to clearly indicate from which batch plant the concrete is shipped and also to have a time clock stamp indicating the time the truck left the plant in lieu of a hand written time.

c. All concrete for any one day’s placing is to be supplied from one plant – not two as has been the practice in the past.

d. The Testing Laboratory is to start plant inspection at once and continue until further notice due to inconsistencies in concrete strengths.

August 13, 1971

1. The Architect and the Contractor reviewed concrete patching on the Music Building (J) and established guidelines to be used in future concrete patching. In general, concrete patching is to be minimized and the concrete surfaces simply cleaned of all latence.
August 26, 1971

1. Preparation of the First Floor slab, south wing in the Music (J) Building for placing concrete was reviewed and the following conditions called to the attention of the Contractor:

   a. Joints between plywood forms and the concrete walls below must be pulled up tight and/or filled.
   b. Electrical conduits tied to reinforcing steel is pulling steel up and must be untied and supported independently.
   c. Additional reinforcing steel required under fan coil slab depressions was missing and must be installed.
   d. Several pieces of top reinforcing steel were bent and must be straightened.
   e. Forms must be cleaned out thoroughly prior to placing columns.

September 9, 1971

1. The Architect requested Fontaine Brothers clarify their request for a revision to the concrete design mix if they intend to change mixes.

2. The Architect again requested that all exposed concrete wall corners be protected from damage.

3. Formwork for the First Floor walls of the Music (J) Building South Wing were reviewed and the following conditions brought to the Contractor’s attention:

   a. In several instances the wall reinforcing steel was not spaced in the forms properly or was bent out of shape.
   b. A number of plywood panel joints were not aligned properly and were open at the top.
   c. Several wall panels contained plywood, which had raised grain and were swelled up. These panels will be replaced with new plywood forms. The Contractor was cautioned not to use plywood forms beyond a point where they will not produce the specified concrete work.
   d. The architect also pointed out to the contractor numerous conditions where nails had not been reset and plywood had not been repaired since previous use of forms. Plywood panels must be carefully inspected and repaired or rejected prior to reuse.

October 15, 1971

3. The Contractor was advised that the top of concrete dwarf walls in the Auditorium, including the Orchestra Pit walls should have a trowel finish. Also the top of parapet walls should have a trowel finish.

December 22, 1971

1. The Architect again observed improper cold weather protection of concrete.

   a. The north parapet wall of the Library has no cold weather protection other than plastic sheeting over the forms. The wall was placed two (2 days ago).
   b. A number of slabs on grade in the Auditorium have not been covered and protected against cold weather. The contractor was instructed to correct these conditions immediately and to
January 27, 1972:

3. The Contractor was again cautioned to take extreme care in laying out form panels in exposed areas. Any question should be brought to the attention of the architects well in advance of erecting formwork.

The accumulated aggregate of these comments is sufficient to establish that it was an ongoing effort for KRJDA to enforce the standard of performance relating to the concrete installation of the FAC. It should also be noted that these site visits were only bimonthly. One can only hypothesize at what might have occurred and was undetected during the interims between visits or what inadequacies went undetected on the massive site during their visits.

Each one of the construction deficiencies would have either short-term or long-term impact on the FAC’s aesthetics and durability. The impacts of these deficiencies and the problems of addressing and correcting them, or the inability to correct some at all, has been discussed previously (see 1.2.3.5, “Lack of Ornamentation”, 1.2.3.6, “Maintenance”, 1.2.3.8, “Brutalism’s Concrete”), but deserves further clarification as they have become the realities that blemish the FAC.

The list of defects resulting from construction deficiencies (in no particular order) is a lengthy one:

- Steel reinforcement too close to the surface, e.g. June 3, 1971; Item 4h, leads to rust stains bleeding through and staining the finished surface in the short-term. In the long-term, the corroded steel expands and cracks the concrete allowing water to penetrate, efflorescing the concrete salts disfiguring the surface still more, and finally, the freeze-thaw cycles cracks and spalls the concrete.
• Forms used too often, e.g. September 9, 1971; Item 3d, wherein the surface of the form that contacts the concrete has deteriorated or if a form is not properly cleaned or coated with releasing oil, e.g. August 26, 1971; Item 1e, results in aberrant patterns in the finished surface of the concrete.

• Stoning of concrete, e.g. February 25, 1971; Item 4d, after removal of forms and imperfections are found results in deviation from the intended uniformity of texture and the finish that was meant to cloak the building in uniformity.

• Concrete mixes from different plants, e.g. July 1, 1971; Item 10b, c, d, results in dissimilarities of color from one formed panel to another or within a single panel itself, e.g. the dark horizontal line mentioned, e.g. June 3, 1971; Item 4i. This negatively affects the visuals similar to the last point, only with color rather than texture.

• Concrete made with cement from different manufacturers, e.g. May 20, 1971; Item 1, other than specified or approved results in similar color disparities to the previous point.

• Horizontal planes in geometric buildings such as the FAC, e.g. June 3, 1971; Item 4f, are often pitched slightly so that although they appear flat they are not. The few degrees off of the horizontal allows them to shed water away from any vertical intersect. A pitch in the wrong direction defeats the strategy and directs water at the building rather than away. Attendant water related issues of staining and leaking are the result.

• Absolutely straight formwork at parapet termination are critical, e.g. February 25, 1971; Item 4d, to maintain the critical geometric intent of the design.

• Invisible repair via patching of concrete is effectively impossible so stone pockets with absence of matrix are extremely problematic when uniformity of finish is a requirement, e.g. June 3, 1971; Item 4j.

• Improper curing procedures, e.g. July 1, 1971; Item 4, prevents the concrete from coming to its full specified strength.

• Improper cold weather protection, e.g. December 22, 1971; Item 1a & b, prevents the concrete from coming to its full specified strength.
• Inadequate vibration results in stone pockets and absence of matrix at various locations (edges of slabs, vertical corners, e.g. June 3, 1971; Item g, results in not only patching problems, but attendant weaknesses where patching materials is joined to original pour resulting in continual vulnerability to water invasion and associated issues.

• Joints between forms not being tight or properly aligned, e.g. September 9, 1971; Item 3b, or “taking extreme care in laying out form panels” e.g. January 27, 1971; Item 3, all result in assorted loss to the precise geometry of the designed panel layout pattern.

In fairness to the contractors it appears that at the completion of construction aesthetic compromises were dealt with. No evidence of unresolved issues concerning the finishes or visuals of the building’s exterior have been found in the archives and the photographic evidence (see Figs.P.18, 1.75, 1.78) supports that observation.

Over the ensuing years Physical Plant has resolved leaks and concrete failures as can be evidenced by the selective over-cladding of original concrete surfaces with lead-coated copper, numerous concrete patches, and poorly selected colored caulking of control and expansion joints. Some interventions are blurred under the years of grime and mildew, but not all. These are the legacies of the construction deficiencies.

There is, however, clear evidence that the scope of the project and the expected completion were difficult to achieve. From a meeting on June 3, 1971

_The Architect pointed out that to date approximately 1600 yards of concrete had been placed. Based on the General contractor’s schedule there remains 17 months to place the remaining 23,400 yards of concrete, which is an average of approximately 1300 yards a month or approximately 300 yards a week. To date the maximum quantity of concrete place in one month is 1100 yards (May)._

_The contractor must improve his concrete progress considerably to average 300 yards of concrete per month for the next 17 months and meet his construction schedule._
In hindsight, with the complexity of the project, the imposed time constraints, the aesthetic and finishing demands of a material, intolerant to post-pour corrections and adjustments, the FAC joins its Brutalist brethren in suffering from either what, at the time of construction, were unsuspected or unrecognized aesthetic or durability issues of the material or construction errors and omissions.

This subsubsection has addressed two of the negative associations with the FAC, i.e. space inadequacy and concrete degradation. Neither was an intended design intent; both could have been addressed and remedied. The space issue addressed during design process by relaxation of the geometric constraints Roche was held to as program changed. The concrete degradation addressed by extended funding and schedule adjustment during construction and maintenance after construction. This does not remove the resulting onuses attached to the FAC, but it does foster an understanding of these shortcomings.

1.3.2.5 FAC Systems

Construction of the FAC was in the final phases by October of 1973 nearing completion when the Yom Kippur war, beginning on October 6, 1973, precipitated a series of events leading to the first oil crisis of the 1970s.

First, the Arab oil producers hastily convened at the Sheraton in Kuwait and announced the imposition of production cuts, an embargo on the US, and a price increase from $3 to $5 a barrel of oil. And this regional cable was quickly wound up with the international ones. In part because OPEC already had engaged in a series of price increases between September 1970 and September 1973. In fact, just the month before the Yom Kippur war, OPEC had already extracted an additional 70% price increase from the multinational oil corporations.
In October 1973, the non-Arab members see what the Arab members are doing and they think this is a good idea and so they also increase prices. And they do so intermittently until agreeing in January of 1974 to freeze the price of oil per barrel at $11.65. So the energy crisis in short is the fact that in course of just three months the global price of oil had more than quadrupled.\(^{172}\)

Concerns regarding energy consumption had not as yet been raised by the general membership of the AEC community. Energy was plentiful, available, and inexpensive. The systems, previously specified and now installed in the FAC by January 1974, were typical of systems that met the programmatic needs and maintained occupant comfort without thought to energy consumption or reduction:

- Lighting for the majority of building was supplied by the industry standard fluorescent T-12’s. The Auditorium, Theatre, and practice spaces received the requisite theatrical lighting required. Task lighting was supplied as required and inventoried, room by room, in the 1974 Movable Equipment Inventory document.

- Cooling was accomplished with two 327-ton electric motor driven centrifugal water chillers and distributed by variable air volume units (VAV).

- Space heating needs were met with district steam supplied from the coal-fired central heating plant. Distribution varied throughout the building and included: wall mounted convectors, hydronic radiators, individual fan coil units, or variable air volume (VAV) systems.

- Plug loads were less demanding than today absent the assorted electronic equipment available and required today and were appropriate for the various programs entertained in shops, mechanical rooms, offices, rehearsal spaces, etc.

As they were the systems typical of the day, criticism can only be levied if they have not been updated, as technology evolved and climate concerns were substantiated.

**Notes**

\(^{172}\) (Rose 2015)
This would be the responsibilities of the stakeholders responsible for operational costs and maintenance -- not the designers of the building.

In the case of the FAC, the original coal-fired steam plant has been replaced by a combined cycle Central Heating Plant in 2008,\(^{173}\) T-12 florescent lighting was replaced with T-8 bulbs and new ballasts during a campus wide lighting retrofit (117,000 bulbs and ballast replaced) in 2005,\(^{174}\) and the original chillers were replaced with a district chiller (Whitmore District: FAC, Herter Hall, and Whitmore Administration Building) in 2003.\(^{175}\)

### 1.3.2.6 Initial Reviews

As early as 1966, five years before construction was to begin, the FAC was receiving accolades from the architectural press. A nineteen page, comprehensive article in *Architectural Record, May 1966* titled *Distinguished Architecture for a State University* analyzed and extolled both the planning and the architecture that was changing the Western Massachusetts campus.

> The administrators of this rapidly expanding institution, once a modest agricultural college referred to by nearby Smith girls and Amherst boys as "Mass Aggie," are handling its physical planning and design problems with great skill. This is attested by the participation of leading architects who work only for clients who give them a real chance.

### Notes

\(^{173}\) (Sustainable UMass n.d.)
\(^{174}\) (Parkin 2004)
\(^{175}\) (RMF Engineering 2015)
When the article was printed: Skidmore Owings and Merrill’s McGuirk Stadium was finished, Hugh Stubbins’ Southwest Dormitory and Dining Complex was nearing completion, Campbell, Aldrich, and Nulty’s Administration Building’s construction was just beginning, Marcel Breuer’s Lincoln Campus Center’s design was complete, Campbell, Aldrich, and Nulty’s Graduate Research Center design was also complete through construction phases, and Edward Durrell Stone’s Library Tower had been located and was near design completion.

At the conclusion of the article Roche’s FAC was introduced and completes the article:

Theaters, auditoriums, studio space and other elements of a typical university arts program might, in the hands of another architect- have produced five buildings. But these elements have been resolved by Kevin Roche into one brilliantly organized structure, which Pietro Belluschi believes, will be the most distinguished fine arts complex to be built on any campus in the United States.

...Richard Galehouse, “In most cases it is now a mistake to design a campus building with a front and a back. Such structures are becoming large enough to be multi-faced. One of the wonderful things about Roche’s building is that you can enter it from many paces.”

After completion of the project the critical acclaim continued:

Of all today’s architects, the one who always seems to come up with the biggest, boldest, most original ideas is Kevin Roche...

A boldly sculptured bridge of art studios...

Urbanistically, it’s a brilliant concept. The straight line of the bridge gives a firm edge to the central campus and ties together the varied sizes and shapes of the auditoriums and theatres, which in turn reflects the variety and scale of the older buildings nearby.

Notes

176 (Architectural Record 1966, Study 358)
Great attention has been paid to realizing the potential of every interior space. The large auditorium, with balconies sweeping forward instead of back is a wonderful space; so are the studios.  

The highest architectural marks went to the Fine Arts Center, which opened in October 1975. The arts center is a sprawling Kevin Roche and John Dinkeloo building lauded by critics as “brilliant” and “a joy.”

Like a magical coin, the obverse side, toward the mall, is classical in nature; the reverse side, toward the pond, is almost wholly romantic. Because you cannot visually separate one side from the other and because each intermittently suggests the presence of the other, they evince special tension - saying, among other things, that while the classical and romantic traditions may be different roads to the same Rome, intersections are possible and constitute yet another tradition.

Roche Dinkeloo Associates have fused the traditions of classical order and romanticisms at Amherst. Visually, there is a constant give and take between both qualities of composition while they have created functional, ample spaces for students and faculty to slog away in. Inside, the auditorium and theaters derive from technical requirements and acoustical properties an engaging, unadorned esthetic. In fact, Amherst derivation throughout, its drama a studied extension of program and place – the new virtuosity.

Supplementary to the above reviews are two additional sources of support for the FAC’s architectural magnificence and deserved position as a Modernist icon. The first is the evidence offered by the cover image for KRJDA’s retrospective, Kevin Roche John

Notes

177 (Campbell 1974)
178 (Alumnus Magazine 1976)
179 (Architectural Forum 1974)
180 (Two Splendid Fine Arts Centers by Roche Dinkeloo And Associates 1975, 101)
Dinkeloo and Associates Vol. One 1962-1975. For the 1977 publication, from an inventory of over two-hundred major buildings, built for clients such as John Deere, Metropolitan Museum of Art, Union Carbide, and Ford Foundation; it was one single image of a portion of the FAC’s southern façade, as viewed from across the eastern reflecting pool, showing the Bridge in full sunlight, with shadow play visible on the supporting piloti and on the west side of the Art Building beyond, that was selected to represent their work (Fig.1.87).

The second supporting observation is from the book, The Pritzker Architecture Prize: The First Twenty Years. The committee selected three buildings for each of the twenty architects to highlight their achievements. For Roche the three buildings were Ford Foundation Headquarters, Union Carbide Corporate Headquarters, and the Fine Arts Center at University of Massachusetts Amherst.

Notes

181 (Roche, Dinkeloo and Futagawa, Kevin Roche, John Dinkeloo and Associates, 1962-1975 1977)
182 (Thorne, et al. 1999, 70-75)
Every review was not without criticism as evidenced by Robert Campbell’s 1974 review in the Boston Globe

Yet one can’t be completely enthusiastic. The building suffers from a quality that is often pointed out in Roche’s work. Entirely made of concrete, which is hand rubbed to make it as uniform as possible, the building is completely lacking in detail or texture.

A building like this raises the whole puzzling question of how a human being, looking at a building, senses a relationship to it, understands it as something more than an inert mass of material. It helps if you can see where you go in, or where, if you were inside, you could be looking out; if you can perceive, from the shape and detail of the exterior, what some of the activities are that take place inside; if, as you move toward the building, you can see a gradual unfolding of smaller and smaller details that step the building down to you in scale – from the whole building, to the room, to the window, the brick, the texture of the brick. All these things help you to building as a container of human activity as something different from outdoor sculpture.

Enough of these qualities are missing in the UMass Fine Arts Center to leave it with a curiously blank quality. If it isn’t too anthropomorphic to say it, you get the feeling that when you look at the building it isn’t looking back. It’s faceless.\textsuperscript{183}

Additionally, there were initially some reservations about the internal acoustics of the auditorium, but they proved to be unfounded as explained by Jim Shea, project engineer for UMass.

Shea says reverberation testing by Bolt, Beranek, and Newman of Cambridge has proved the acoustics “too live” so far.

There is a four-second lapse in sound from the stage to the back of the auditorium. This will be remedied by special acoustical hangings or panels until the reverberations are timed exactly right.

Notes

\textsuperscript{183} (Campbell 1974)
It’s better, at this point, he says that the acoustics should be a bit on the “live” side, because there are things that can be done about it. If they were too dead now it would be virtually impossible to correct.\textsuperscript{184}

The last criticism, related to acoustics, is a type of criticism that can often emerge and hover around new forms - whether architecture, art, or music (see, “Preface”). The suspicion and skepticism that often appears has its origins in the fear of something not understood and can produces various negative observations, not always ill-founded, but in this case they were.

Campbell’s criticism is a valid one and is supported by discussions in the various subsections and subsubsections of the Brutalism section where concrete, materiality, scale, approach, entrance, and view were all examined with respect to their impacts on the perception of Brutalist buildings. Campbell’s 1974 criticism is an excellent segue into this chapter’s final subsubsection, “Contemporary Issues” and can be regarded as canny fortune telling.

\textbf{1.3.2.7 Migration of Reviews and Perceptions}

Although the FAC initially received glowing reviews from the architectural press the administration, and the community at large; with each corner of the triad reinforcing the other two; there was an interesting piece of research and a resulting paper produced by two graduate students in 1976, the year after the FAC had been completed. The work was another foreshadowing of issues that would come to visit the perception of the FAC.  

\textbf{Notes}

\textsuperscript{184} (Chastain, Fine Arts Center at End of Long Gestation Period 1974)
as a single entity and Brutalism in broader context over the forthcoming years. The work’s goals were the following:

... to assess users’ and non-users’ perceptions of how well the building met the original program points: 1) functionality and flexibility; 2) front door/back door focal point of campus; 3) human relationship to material; 4) esthetic influence on campus and community.\(^{185}\)

The research involved a three-part survey. The first part was discussed previously (see 1.3.2.4, “Design and Construction”).

The first part of the survey involves the analysis of the program's development, which includes the University's administration, Massachusetts legislature, department members, architects, and various consultants. Interviews were done with many of people concerned with the building's conception, development, and current use. Careful checking of department letters to the architects, administrative directives, and various other pertinent data was done.\(^{186}\)

The second and third sections are germane to the present discussion.

The second part of the survey involved the nonusers and outside viewers not directly related to the building. Approximately 200 computer-readable questionnaires were recovered from the initial 300 handed out across the campus. From this it was hoped to gain an unbiased, purely visual response to the building’s size, material, location etc.

The third phase centered around the interior spaces, and user perceptions of the building. A different questionnaire was used in this section ... This information would then help us understand the building’s weaknesses and strong points. From this we could then make some suggestions and corrections to the design process...\(^{187}\)

Notes

\(^{185}\) (Brown and Tepel 1976, Cover Page)  
\(^{186}\) (Brown and Tepel 1976, Cover Page)  
\(^{187}\) (Brown and Tepel 1976, 1-2)
The questions asked on the questionnaire for the second survey were as follows:

- Is the building a focal point?
- Is it a satisfactory expression of the arts?
- Is it a representation of the front door of the University, a magnet?
- Does it represent the step into the future--the change from an agricultural school to a modern university?
- Is the building aesthetically pleasing?
- Is the building functional; does it work?188

The protocol followed for handing out the questionnaire, which only took five minutes to complete, was to hand it out to passersby, only on sunny days, on the north side of the FAC, near the campus pond, where the FAC is readily observable.

The results were reinforcing with respect to the previous subsubsection’s “Initial Reviews” findings and aid in validated the conclusions of discussions and observations relating to this topic (see 1.2.3.2, “Building Geometry”, 1.2.3.3, “Building Scale”, 1.2.3.5 “Lack of Ornamentation”, 1.2.3.7, “Transparency”, 1.2.3.8, “Brutalism’s Concrete”) found in the Brutalism section of this chapter.

Most respondees felt that Fine Arts Center was impressive by an overwhelming majority, more impressive than the other two buildings surveyed (Library & Campus Center) ...

... most respondees did not think that any of the three buildings were beautiful (the FAC rated highest of the three) ...they thought the FAC and the Library cold, uninviting and unlikeable.

Respondes thought that the FAC was indeed a very good idea even though they did not like the building itself. This seemed to be very much colored by the fact that concrete was very much disliked—so many suggestions wanted to change the material in some way, by painting it,

Notes

188 (Brown and Tepel 1976, b1)
by camouflaging it etc. even though it is this facet that gives the building its strong sculptural effects which is overwhelmingly acknowledged.

Many people’s expressions of what they felt the building symbolized expressed that this building was representative of some sort of expression of the future, whether that expression be positive or negative. Perhaps this sensation is because the building is so radically different.

Suggestions for improvement strongly requested landscaping, graphics, or means to prevent people from getting lost inside, windows, and improved functionality. Secondarily, there were requests to soften the building’s impact and methods to add a sense of humanity to it.¹⁸⁹

A remarkable observation of Brown and Tepel was made possible by the survey mandate that the respondees identify their affiliation with the University and was noted at the conclusion to their analysis of the second questionnaire.

There were some interesting observations regarding who was relating what feelings. People in the arts seemed most positive about the building’s beauty; people in education seemed to think most strongly that it was a good idea though they didn’t much like it; people in business administration and Stockbridge school were most negative about it.¹⁹⁰

Brown and Tepel advocate further exploration of this observation and it is beyond the scope of this work to do so here. However, there does seem to be a distinct correlation with the various positions taken by the three individual academic disciplines that are in accord with Dewey’s writings on aesthetics judgements and beauty (see 1.2.4.3, “Aesthetics”). The observations also add currency to the position that education is a key that can open the door to appreciation of Brutalist constructs. Certainly all three sectors

Notes

¹⁸⁹ (Brown and Tepel 1976, b3)
¹⁹⁰ (Brown and Tepel 1976, b3)
defined by Brown and Tepel are educated, but only one pedagogy, Art, had included the requisite studies necessary to assess the beauty of Brutalism.

The third investigation also broached problems associated with Brutalist buildings separate from aesthetics.

This segment ... involving the user’s perception of the facility was undertaken to draw a comparison between (1) the original programming and (2) the resultant environment created for the arts.

... an attempt to find out what the students, faculty and support staff actually felt about the building as an environment, which affects them. 191

The population sample was intended to include students, faculty, and support staff, but due to incompleteness of interior finishes and furnishings at the time many of the faculty were not available as they were still teaching in other locations. This part of the study is (as admitted by the investigators) of a more general nature, but inferences that apply to Brutalism’s perception can be drawn from the findings.

Throughout the study, users appeared more distinct in their perceptions, either positive or negative, which may be a reflection of artistic attitude or heightened artistic appreciation and environmental awareness.

In considering the Fine Arts Center as a focal point, users’ did perceive that it was a dynamic and a focal point, but they did not see it as being in scale with the rest of the campus.

...in response liking the material used in the interior, 55% definitely disliked the interior material. The exterior was found to be more successful than the interior.

Notes

191 (Brown and Tepel 1976, C-1)
... having the exterior shape frozen before programming for the interior spaces was finalized is also incredible since the exterior and the interior are not inseparable or independent.

The Fine Arts Center as an aesthetic influence produces mixed support in the findings. Users felt it impressive but not particularly beautiful. The judgements on aesthetic outweighing functionality or structural problems. People see it as aesthetically pleasing and striking but not functional or stimulating. The area of aesthetics also supports the findings on relationship to materials in that the users find the Center interiors rather dull and 50% actually found them ugly.¹⁹²

The issues of scale and materiality appear again and for the first time, it will not be the last, we have the use of the word “ugly” being attributed directly to the FAC,

A second document from the time periods of construction and immediately post construction was found in the University Archives. It is a memorandum from the Director of Fine Arts Center, Frederick Steinway, dated 28 August 1974, and references, “Center Guided Tour”. The reason for including this document in the present discussion is because an examination of the document reveals and underscores one particular problem that Brutalist architecture possesses and was discussed earlier (see 1.2.3.3, “Building Scale” and 1.2.3.9, “Negatives - Subsection Summary”) which was the long circuitous routes necessary to navigate these buildings and the exacerbation to that task caused by the absence of exterior views. Steinway’s memorandum (Fig. 1.88) is a preemptive strike in an attempt to aid tour guides for the new building. He recognizes the difficulty and writes:

*I have made up a “Friendly Tour Guide to the Fine Arts Center”: which covers most of the salient features of the building. I can walk it in 15 minutes... Use the guide for a dry run.*

Notes

¹⁹² (Brown and Tepel 1976, C-4)
It is a two-page document that gives step-by-step instructions with all appropriate reference points for the guides to follow. The first page is uncannily similar to the format that Google Maps would use, thirty years later, when providing step by step directions. It is accompanied by the cover page of the memorandum and offers visual support to Brutalism’s and the FAC’s disorientation issue.

The term “active neglect”, a visitor to many Brutalist buildings, also visits the FAC. It has been discussed at length (see 1.2.3.5, “Lack of Ornamentation”, 1.2.3.6, “Maintenance”, and 1.2.3.8, “Brutalism’s Concrete.” In point of fact, two of the images used to reinforce the points made are illustrated with images of the FAC (Figs.1.43 & 1.45).

A leap of imagination is not required to realize that what was negatively problematic regarding materiality, i.e. concrete, which the Brown & Tepel study brought attention to in 1976, has increased exponentially over the past forty years as “active
neglect” continues and is typified by occasional entries in University’s newspaper, The Massachusetts Daily Collegian.

The Fine Arts Center is ugly, especially when it rains, and its layout is bizarre to say the least. Herter Hall is equally as ugly, and a creepy tunnel connects it to the unattractive Bartlett Hall. In fact, most of the buildings on campus – the Campus Center, Worcester and Franklin dining commons and the concrete jungle, Southwest – aren’t very pretty.193

The specifics of the negative impact imposed on the FAC by “active neglect” will not be regurgitated here, but it is enormous as can be discerned whenever the building is observed in person.

There are two other factors that have negatively colored the perception of the FAC and both involve separate, but related interventions that have not only altered the geometry of the complex, but also impacted and in fact destroyed significant elements of Roche’s design parti.

Roche’s design intent was that the 646-foot-long (196.9 m.) FAC would serve the formal entrance way to the University’s central campus and core. Its length defined the southern bounding element to the campus core. The elevated Bridge supported by the regularly spaced V-shaped piloni provided a classically sourced modernist entablature. The opening between the Theatre and Auditorium was threshold and gateway, opening out to the campus pond and campus core beyond, framing a view that included the pond and surrounding buildings, i.e. the UMass-Amherst Chapel, Edward Durrell Stone’s Library, and Marcel Breuer’s Campus Center. Two reflecting pools flanked the final one.

Notes

193 (Sparks 2012)
hundred and forty-five-foot approach to the campus’s formal entrance; funneling and focusing the visitor’s attention to the Theatre’s and the Auditorium’s respective entrances and to the pastoral scene and its amalgamation of architecture’s past and future beyond.

Both the opening between the Theatre and the Auditorium and the reflecting pools are gone. Victims of disrespectful design decisions for the former and maintenance decisions predicated solely on financials.

In 1999, the opening between the Theatre and the Auditorium was occluded by a cluster of glass constructs.

The new lobby sports several kinds of glass and surfaces designed to reflect color and light. German channel glass, high in the south entrance to the lobby is coated with an energy-efficient layer that turns the glass pastel purples, pinks and greens in daylight. White synthetic terrazzo tile in the floor of the vestibule reflects light and color.

A square flared structure of bright red panels at the center of the ceiling, called "the lantern", casts pink reflections on the floor by day and sends color onto the roof, through more glass, at night. On the north side of the building a tall channel glass structure, known as "the lighthouse,"... goal for lighting the FAC lobby ... "was not one of even illumination. but rather one of drama and focus reinforced through the controlled use of shadow, light and the powerful use of color. Much as a theatrical set is brought to life through the use of unseen light source. this lobby will be similarly illuminated, controlling what the viewer sees and creating a strong emotive response. The result is a heightened sense of drama to prepare the theatergoer for what lie ahead."

It is acknowledged that the glass addition did give a token nod toward Roche’s focus on shadow play on the exterior surfaces with the shadows and light play the

Notes

194 (Fitzgibbons 2001)
illuminated constructs create at night, but the violation of the dominating principle elements to Roche’s gateway parti was flagrant.

This criticism does not ignore the changes in sensibilities and expectations of theatregoers at the turn of the twenty-first century from what they were in the early 1960s. Waiting in line for tickets or admittance to a theatre exposed to the elements: sun, wind, rain, cold, etc. was no longer tolerated. Comfort expectations had changed.

When the University made the decision to accommodate the not unreasonable request for protective enclosure from the elements for the plaza space, Pritzker Prize winner Kevin Roche was not approached. Instead the University requested design solutions and from only Massachusetts based design firms.

*Jurors chose the winners from 122 submissions of work by Massachusetts architects.*

Could the original parti have been respected? In researching the KRJDA Archive at Yale University an early undated longitudinal sectional perspective of the building was found (Fig.1.89). The drawing clearly shows a roof over the plaza between the Theatre and Auditorium. Not enclosed, but roofed. At the turn of the twenty-first century, curtain wall technology was far advanced from the 1960s and 1970s. Narrow mullion profiles, thermally broken integrated glazing panels, and weatherized entrance doors would have supplied the technology necessary for a conditioned interior while adhering to the original design parti of gateway, threshold, and view - all supplied with transparency.

**Notes**

195 (Fitzgibbons 2001)
In the case of the elimination of the reflecting pools there is a consistency of public opinion that supported repairing and maintaining the pools and is refreshing for those who value the building’s iconic status.

Despite that sentiment, both pools have vanished. The western triangular pool has been transformed into a landscape feature complete with bridge over sunken gardens. The eastern rectangular pool has been replaced by bollards and accessible parking spaces for the patrons of the theatre and auditorium.

If the only solution to Americans with Disabilities Act (ADA) compliance was the complete eradication of the eastern rectangular pool, then correctness and fairness would have made it an unfortunate, but justifiable necessity. It does not, however, seem reasonable that compliance with the ADA criteria of number and size of parking spaces, distance of travel from parking lot to entrance, etc., was so draconian that the only resolution was eliminating the eastern pool in its entirety, rather it seems an unimaginative value-engineered decision.

The support for and controversy surrounding the pools is chronicled through the following articles dating from 1987 through 1999:
As an employee in Herter, my office faces the reflecting pools, and I would like to say that unfilled, I feel that they are very ugly. When they are filled, they look so nice.\(^{196}\)

As the administrator of the University’s only formal public art program and the manager of three current large-scale public art projects, one of which is in conjunction with the Physical Plant department, I would like to take this opportunity to strongly endorse the repair of the pools so that they can be used as originally intended by the architect/designer, Kevin Roche. Not only would their use greatly enhance the building, but they would make both a strong aesthetic and symbolic statement about the way we envision our campus and take pride in it.

The site of the reflecting pools was originally one of the six sites earmarked for a public art project in the next 10 to 12 years in a long range plan for public art. \(\ldots\) The Physical Planning Committee requested that we postpone any future planning for that site until a full-scale engineering, feasibility and budgetary study could be conducted. I would be ecstatic if we could simply return the pools to their original intended use, rather than try to make a work of art or landscape design conform to the pools. There is no possible way that such a project could be more successful and fitting for the site than the original design and it usage.

There is no question that it is embarrassing to leave the pools as they are at one of the two centers of the campus where thousands of people visit.\(^{197}\)

The reflecting pools haven’t been filled regularly since the Amherst water shortage of 1980. Since then, the pools have been filled for special occasions or by rainfall, and leaks were detected.

Physical Plant recently repaired the known leaks, and filled the pools last week. Since then a leak has been detected from the triangular-shaped pool, which lies above the Theater Department end of the building. The other pool—which is a square-shaped pool on the east end of the plaza—seems not to leak.

Notes

\(^{196}\) (Nwokoye 1987)

\(^{197}\) (Tuttle 1987)
Operations director Peter Wozniak says Physical Plant is considering keeping the pools filled by the feeder pipes built for that purpose. He will first examine the issues of maintenance: empty pools attract skateboards; full pools attract rubbish.

Fine Arts Center operations director Jim MacRostie, who has wanted to see the pools filled regularly, is asking for comments. “We want to know if people would like to see the square one filled all the time,” MacRostie said. “If there is enough interest, we could try to get the money to keep them filled and maintained.”

Whenever I walk to and from Hill from my office in Goodell, I take the promenade inside the reflecting pools. And I wonder why those never reflect anything except the intentions of their design.

I’ve heard the theories: “Liability if an inebriated individual drowns”; “Too much maintenance”; “A waste of precious water through evaporation”; and even “the building is so ugly that we shouldn’t reflect it”. But I always thought it was more a matter of not caring.

Then, a couple of weeks back – apparently in preparation for some visiting dignitaries – the pools were filled! They reflected the sky and the actions of the wind magnificently. The came alive, and I was proud that the rejuvenation of the campus and finally come this far. …Today on my walk, they were once again drained to their cold asphalt floors – and my spirits ebbed with the water.

Are we to conclude that the reflecting pools are to be used only during days when past and potential donors of sufficient means may be around in significant numbers? Is risk and waste OK during those times, balanced by the benefits of creating an expansive mood before the pitch is made? Is the maintenance task of daily wrapper skimming and occasional bike removal greater than pumping vast gallonage in and out of a cement pond kept water tight for a day or two of use each year?

…Or are the pools also there for the regular residents of and frequent visitors to this campus? Are we somehow less worth investing in? Does soothing overtaxed spirits not matter so much? Are they only gala ponds – announcing as they fill and drain that bigger fish have come and gone?

Notes

198 (Morton 1987)
199 (Chandler 1999)
The reflecting pools at the Fine Arts Center have long been a maintenance problem. The pools; initial design was poor; now that they are well over 25 years old, the poor design creates a myriad of problems: when the pools are filled, water evaporation is quick, especially in the summer months; the pools are a magnet for windblown trash, juice and soda bottles, among other debris; and despite cosmetic repairs (with maintenance costs extremely high), the pools; aesthetics leave much to be desired.

Last year, in an effort to implement an interim solution-and based on advice from experts in the private sector, the University repaved the reflecting pools. Even though the pools still leak, this re-paving provided a needed new base for sealcoating (which will occur next spring). The new sealcoating will allow the reflecting pools to hold water for a longer period of time.

A committee including representatives from the FAC, the Facilities Planning Division and the Physical Plant will be meeting in the future to develop a long-term solution to the reflecting pool problem. The committee will take into account the diverse aesthetic, artistic, financial, and maintenance needs, which need to be addressed. It is an extremely controversial subject, with some people anticipating a landscaped garden in this area and other wishing to retain the original architect’s reflection pool vision, but with a refined design.

In the meantime, the Grounds Management and FAC staffs will work together with our limited resources to make the reflecting pools look as attractive as possible throughout the year.\(^{200}\)

Over a decade had passed since the first of the above articles calling for maintenance and maintaining the reflecting pools as they were originally intended. It is doubtful that the water evaporated from the pools any faster in 1999 than it did in 1975 and more than likely trash and debris issues were always a problem. Repair and maintenance costs are clearly the issues. The consequences of the failure of the University to repair and maintain the pools are insults that the FAC must suffer and they are additional degrading factors that contribute to negative public perception.

Notes

\(^{200}\) (Fournier 1999)
The FAC is a recapitulation of all of the negative perception problems visited by the Brutalist buildings as a group that were delineated earlier:

- The negative association with the monikers, Brutalist and Brutalism.
- The building’s monumental scale and convoluted footprints leading to exhausting approaches and confusion in identifying entrances and thresholds.
- The internal directional disorientation created by complicated program, exacerbated by limited and limiting exterior views.
- The concrete construction module scale contributes to a loss of human connection with material and process followed by the resulting sense of dehumanization felt by users and viewers.
- The material concrete’s monochromatic association with coldness and sterility.

It is possible that the FAC might have endured, defeated, and emerged victorious in the battle for public approval, if these had been the only opponents. Roche’s brilliant design, the uniqueness of geometry, the encapsulation of Sasaki’s Master Plan, and the embodiment of the University’s vision of the future were potent weapons with which to succeed. However, the additional obstacles of active neglect and disrespectful geometry interventions proved to be insurmountable and the FAC, an iconic exemplar of a building type succumbed and accolades of the past are now only fading articles in archives.

1.4 Architecture Summary

The inclusion and sequencing of the three sections, Modernism, Brutalism, and University of Massachusetts-Amherst Fine Arts Center in this first chapter, Architecture, was intentional. The understanding of the facets and aspects of architecture discussed in the third section, “University of Massachusetts-Amherst Fine Arts Center”, is sequentially dependent on understanding the aspects of architecture discussed in the
second section, “Brutalism”; and it follows that understanding the aspects of architecture discussed in the section, “Brutalism”, is sequentially dependent on understanding the aspects of architecture discussed in the first section, “Modernism”.

Modernism’s paradigm shift did not eradicate traditional architecture; rather it created new tectonic forms that emerged from the cauldron of artistic and social upheavals visiting the western world’s reassessments of society, government, and the arts coupled with the concurrent availability of new materials and new technologies. Modernism supplied the genetic material that would be passed on to Brutalism in general and ultimately to the FAC, one of Brutalism’s exemplars.

It was these Modernist forms and tenets, forecasters of mankind’s assault on the future that inspired the University to embark on their Modernist building boom defining the campus’s vision of its future as a major teaching and research center. All of these Modernist ideals are encapsulated in Brutalism and by extension the FAC. They must be understood when viewing and evaluating a building, without that understanding the view is partially obscured by the clouds of ignorance.

As Brutalism emerged it inherited all of those Modernist genes, but similarly to processes in the natural world assorted mutations evolved the physical forms of the buildings, e.g. materials, geometry, program response. It was a Darwinian type response to the social pressures and technological innovations of the time, but the core genome of Modernism remained intact. The FAC is not the ultimate or even penultimate specimen of this genetic line, but it is one of the last that inherited all of the qualities of Brutalism, infused with Modernism, which with the additional inspiration of a master designer, Kevin Roche, resulted in a specimen of architectural genius.
The understanding of a building's metaphysics, i.e. the reality that is beyond what is perceptible to the five senses, is absolutely critical to understanding and evaluating a building. Without the addition of that information it would be an incomplete and inaccurate evaluation. Dewey understood.
CHAPTER 2

METHODOLOGY

To arrive at the objective of achieving a calibrated or validated energy model of an existing building the challenge is to recapitulate all aspects of the building’s reality, e.g. geo-position, ordinal orientation, building geometry, envelope materiality, construction details, local weather and climate, program activities, mechanical systems, occupancy schedules, etc.

One purpose of simulation is to explore the impacts of potential interventions and their impact on economics or energy use. As such, all appropriate building data sets are inserted into the model. Simulated results are then compared to actual historical data, if the building is metered and/or energy records are available. At that time, if the simulated results compared to the actual energy consumption fall within the standards set by the National Renewable Energy Lab (NREL) methodology and adopted by other organizations, including ANSI/ASHRAE Standard 140 (ANSI/ASHRAE 2007, 2004, 2001), Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs, the first codified method of test for building energy software in the world, then the model is considered calibrated (see 2.12, “Calibration and Validation”) and can be used to determine the potency of potential interventions, for purposes of improved economics and/or reduced energy consumption.

For the purposes of this work, a period examination, a different approach was necessary, as the focus of interest was not as the building exists presently (2016), but

Notes

201 (Polly, Kruis and Roberts 2011, 35)
rather as it existed in 1976, the first year of full occupancy. This effort involved including not only original geometries, materials, construction details, and mechanical equipment specifications, but also excluding all subsequent interventions. It also required inputting appropriate 1976 schedules and occupant behaviors, which in some cases were quite different from those of 2016.

As energy consumption was not of particular concern in the early 1970’s (see 1.2.6.1, “Architect’s Personal Experiences”), buildings at UMass-Amherst were not individually metered for steam usage, nor were individual building’s electrical consumptions recorded. It was, therefore, necessary to develop a methodology to validate the energy model representing this earlier time period with the currently available contemporary energy consumption data (see 2.12, “Calibration and Validation”).

Once the energy model was validated then the building could be studied as to the 1976 potencies of passive strategies existing in the building; whether included intentionally in the design, as in the case of daylighting and glare control, or unintentionally (but fortuitously) present in the design as in the case of thermal mass and albedo effects. Finally, the impact of addressing the buildings most apparent weakness, the thermal conductivity of concrete, and its impact on total energy consumption could be measured.

After the methodology was in place, the model robust and energy analyses performed, a detailed and thorough evaluation of the FAC could finally be made.

Notes

202 Note: 1976 was the year used for whole building energy analysis. While the FAC opened in the Fall of 1975, it was not until the year 1976 that it experienced a January 1 to December 31 calendar year, which is necessary for DesignBuilder inputs.
available to the AEC community. Additionally, the building could be examined simultaneously within the frameworks of:

- Architectural History.
- Regional, National, and Global Architectural Significance.

Existing scholarship and literature has always made the first two available, but technology has only recently made the latter possible. It is only with this third framework that a building can truly be understood and correctly and completely evaluated.

2.1 Original Documents

There were three sources that had retained assorted elements of the original documents relating to Kevin Roche’s Fine Arts Center at UMass-Amherst, i.e. “UMass Amherst Library Special Collection and Archives”, “UMass Amherst Facilities and Planning Archives”, and “Kevin Roche John Dinkeloo and Associates Records at the Yale University Library’s Manuscripts and Archives”. Each source contributed elements that, when assembled together, substantially completed a whole. Specific to the physical building these elements included conceptual design drawings, design development drawings, construction drawings, construction meeting notes, construction specifications, contracts, mechanical system balancing reports, and post occupancy equipment inventories. Together they supplied all of the necessary information to construct the geometry and input the mechanical systems into the energy model.

Additionally, and most invaluable, were numerous letters, memos, journal articles, and press clippings, which clarified or added information that informed the
model, especially relating to schedules and occupant behaviors. For example, a letter/memo from the administration to the faculty reminding that during the January break between semesters, even though students were not present, faculty was expected to be in their offices (working from home before cell phones and computers was not tolerated).

Finally, there was the building itself, which helped to make the creation of the model possible. The three years I spent inside the FAC, in its architecture studios, helped in understanding its geometric convolutions, and if memory did not serve and more clarification was needed, the FAC was less than one half-mile’s walk away.

2.2 Modeling Geometry

In the future, the burgeoning technology of laser scanners and point clouds will make the work of reproducing an existing building a possibility from the points of view of accuracy and economics. Now, 3D laser scanning is not always a precise and accurate or affordable option.203 The necessary process to create the geometry for a 3D digital model of an existing building, especially a large complex one, is therefore time consuming and arduous, often seeming to be anachronistic in light of some of today’s push-button technologies. The procedure at its most elemental involves a combination of entering data obtained from original hand-drafted construction documents (plans, sections, elevations, perspectives, and detail drawings) with accompanying dimensional notations and then, if further clarification is necessary, visiting the site and physically

Notes

203 (Foster 2013)
measuring and clarifying any element of the building that is unclear in the available drawings.

2.2.1 Hand-Drafted Drawings

In the case of the FAC, UMass-Amherst Physical Plant created six AutoCAD drawings (DWGs) in 1998, which to some extent facilitated the process. Inserting the six DWGs as underlayments in Autodesk Revit was far superior to inserting image scans of original drawing sheets. Points and lines in DWGs are available to “snap to”, which lends greater precision and ease to the procedure, although not without some idiosyncratic problems as discussed below.

In the absence of the DWGs, the process is still possible as was demonstrated in two similar, but smaller studies done for the Walter Gropius House,204 (Fig.2.1) and Paul Rudolph’s Milam House,205 (Fig.2.2). It is not typical that AutoCAD drawings of any sort exist for an older building, designed and built before digital drawing technology became the growing norm in the late 1980s and 1990s.

Notes

204 (Fiocchi and Hoque 2011)
205 (Fiocchi, Shahadat and Hoque 2011)
More often, a set of hand-drafted original drawings exist. Provided they are available; the process would involve the following:

- Scan the documents via flatbed scanner and save as TIFF or JPEG files at 300 dpi, minimum resolution.
- Import the images into Adobe Photoshop or similar image editing software and optimize brightness, contrast, and sharpness for readability.
- Import the scanned and enhanced files into Autodesk Revit or similar 3D digital drawing program.
- Observing dimensional references on drawing, use the digital software’s scaling and measuring tools to adjust the drawing’s plans, sections, elevations, etc. so that program’s drawing tools will produce correctly scaled model elements.
- Insert adjusted digital drawing plans as underlayments at coinciding levels in the building model, which will then serve as footprint templates for each digital 3D level.
- Information extracted from original sections and elevations will inform vertical component dimensions.

The challenges that arise from this process are with both the condition of the available drawings and the underlying nature of hand-drawn, dimensionally annotated drawings. Notably, the original construction drawings are pen and/or pencil on paper or vellum and then, since 1923, and until the modern plotter of the late twentieth and early twenty-first century, were most often reproduced using the “Diazo Print Process” on paper. Copies were then distributed to the appropriate parties, e.g. stakeholders, contractor, subcontractors, building departments, etc.

The treatment that these documents then endured as they traveled from construction sites to job meetings to questionable archival storage was neither a clean nor coddled journey and the abuses of this life, along with the age and quality of the original
support material, render them considerably less legible than a contemporary digitally plotted drawing. This makes the reading, even with digital zoom tools, difficult. Drawing sheet, A-6, Auditorium Floor Plans from the FAC Construction Document set serves as a typical example (Fig.2.3).

![Figure 2.3: A-6: Auditorium Floor Plans. Courtesy of UMass-Amherst Physical Plant.](image)

There is also the difficulty of the density of the information on a pre-digital drawing sheet. There are no digital layers to be turned off, allowing the viewer to more clearly see specific information. Finally, there is the biggest obstacle, which is that because the underlayment is an image and not an AutoCAD file there are no lines or points to “snap to”. Compounding this, the hand-drawn pencil lines have thicknesses and inconsistencies that must be synchronized with the precision of the digital model.

Therefore, to ensure accuracy as a model is constructed, measurements must be repeatedly checked with the drawing program’s measuring tools and compared with the annotated dimensions written on the original drawing sheets. Throughout the process, constant cross-checking is required in order to ensure that correct dimensions of
insertions and positions of components are being made. As the annotated dimensions on
the original drawing sheets are not always legible, it is sometimes necessary to verify a
plan dimension on an elevation sheet or another plan sheet. If still in doubt, the
dimensions can then be rechecked with a scale ruler on a printed sheet. Finally, if
uncertainty is still present, a site visit with tape measure might be required. The result
will be a digital model that is a robust geometric representation of a building, but not
without considerable time and effort.

2.2.2 Digital Drawings

The availability of the six DWGs (Fig.2.4) for the FAC eliminated considerable
challenges given the density and condition of the available original 132 sheet
Construction Document set. Use of the DWGs (Basement Level, 01 Level, 1M Level, 02
Level, 03 Level, 04 Level) were not without difficulties.

![Figure 2.4: FAC DWG: Ground Floor. Courtesy of UMass-Amherst Physical Plant.](image)

Inconsistencies and inadequacies were inherent in the six DWGs, as these six
drawings are meant to represent all of the over 100 levels and approximately 450 rooms
contained in the FAC. The original 132 sheet Construction Document set contains ten
plan sheets, two elevation sheets, six section sheets, and nine detail sheets - all Arch E
sized with tremendous detail. Without the original drawing set and the possibility of site visits, the DWGs would have proven inadequate.

The DWGs were created in January 1998. The date was discovered (see red line in Fig.2.5) when reviewing the “Properties” of the original DWG files and observing the date “Created”. Total editing time was also available in “Properties - Statistics”, which showed that each file took over 400 hours (see blue line in Fig.2.5) to create. Clearly, a substantial amount of time was spent inputting the data to create each DWG (over 2400 hours for the set of six), but there is no information available about how the information and measurements for the DWGs was obtained.206

Comparing random measurements with site visits and dimension notations from the original drawings set indicates that while accuracy of the measurements is good, precision varies.

Notes

206 (Pourshadi 2015)
Although Autodesk Revit is the software program referenced here, this discussion is not limited to Revit, but to any 3D drawing program, e.g. ArchiCAD, SketchUp, etc. However, for the remainder of this chapter, I focus on Revit and the use of that program to export via gbXML protocol into an energy modeling program.

Measurements supplied by the DWGs within individual spaces are accurate. These measurements can be taken from one interior plane to another interior plane. The dimensional discrepancies appear with the collective aggregation of the measurements and are related to wall thickness.

Wall thicknesses in the FAC are not always as expected, e.g. concrete walls for structure respond to load demands, drywall partitions comply with varying fire codes or acoustic demands. As there are approximately 450 rooms distributed in an extremely complex layout these discrepancies combine for error in overall measurements.

The lack of overall accuracy is apparent when, for instance, DWGs of first and second floors are overlaid upon each other. In this situation, the positions of exterior envelope walls, staircase walls, or elevator shaft walls should align in a vertical plane – they do not.

This inaccuracy affects the building’s Gross Square Footage (GSF) and attendant Energy Use Intensity (EUI) (see 2.3, “Energy Models” & 2.11 “Energy Use Intensity and Square Footage”) and precipitates a digital construction obstacle. The modeler is no longer able to use “snap-points” on all of the DWGs. As a model is constructed the process typically begins at the lowest level (similar to the way an actual building is constructed) creating all of necessary geometry for that level, then moving to the next level. If the modeler draws using only the data and “snap-points” embedded in the second
level DWG, then this level’s exterior walls, structural walls, mechanical chases, etc. will not line up vertically with the level below, as they should, and Room/Space volume geometries are compromised or incorrect.

2.2.3 Room/Space Volumes

Although Revit will allow the above to be drawn, inaccuracies will appear when Revit calculates volumes of these Room/Spaces, i.e. Rooms for Revit Architecture, Spaces for Revit Mechanical. Room/Space volumes are the basis for transferring the Revit model geometry via gbXML format into DesignBuilder and Ecotect (see Appendix A, “Hint, Techniques, and Obstacles Encountered”). The “vertical jogs” created by the misalignment of walls between levels will result in unintentional voids within a Room/Space volume leading to an inaccurate import into the energy model, which will incorporate these voids (where none exist) and incorrect Room/Space volumes result (Fig.2.6).

Figure 2.6: Void (shown in red) created by vertical misalignment, “jog”, of walls in elevator shaft at Level 4.
The vertical perimeter of the Room/Space must be consistent with the perimeter of the footprint’s Room/Space. A section taken through an elevator shaft in the FAC (Fig.2.7) illustrates how a Room/Space volume (elevator’s Room/Space is shaded in blue) is properly defined. The shaft wall alignment must be exact from one level to another in order to accurately and precisely represents the volume. Following the “snap-points” on each DWG would not have resulted in this section, but rather one where each level of shaft wall would be in a different vertical plane.

This means that when creating a 3D model using DWGs that lack precision from level to level, the modeler must decide which position to establish for each wall level. The modeler must disregard the “snap-points” on the subsequent levels (or alternatively select a middle or top level deemed more correct) and match the position and thickness of each level’s structural walls with the structural wall position of the designated level, above or below. Use of Revit’s “Underlayment Tools” makes this possible, as underneath a view of any level can be placed an additional underlayment to the initially underlayed DWG.

Figure 2.7: Section of FAC West Elevator Zone (blue shading) illustrating correct vertical wall alignments.
Although there are “work-arounds” for the above within Revit, i.e. moving the Room/Space volume base level to a higher level and extending the lower limits of the new Room/Space volume base level below to the original Room/Space volume base level, it is not a desirable remedy as the additional “jogs” create unnecessary energy modeling complexity with attendant increased simulation times, plus they do not exist in the reality of the building.

Whenever there are “jogs” in the planes of the geometry of a 3D building model intended to be exported to an energy model, whether the “jogs” are vertical in section as outlined above or horizontal in plan there is increase in energy model complexity, which impacts simulation time. If the “jog” has importance to the geometry and/or performance of a building it should be drawn, but if the “jog” represents a small articulation in a wall and can be eliminated then it should be; as every plane of a model will be analyzed individually in an energy model and simulation time can be decreased if the model has only the required planes to represent the building.

Simulation time can be very lengthy if a large building is not constructed cleanly. Extraneous surfaces might increase the simulation time to a point where analyses become inconvenient at best or unproductive at worst. In the case of the final FAC model, WBES simulation time on hardware with a 16.0 GB 64-bit Operating System and Intel® Core(TM) i7-4700MQ CPU @ 2.40Hz was approximately ten hours. Reducing simulation time is always a desirable.

It is a vastly preferred technique to create a model of a complex building in a sophisticated 3D drawing program such as Revit and then export a gbXML file created
with that program into an energy modeling “frontend”\textsuperscript{207} such as DesignBuilder or Ecotect, rather than to attempt to create the geometry of the building within the energy modeling program itself. The drawing tools within energy modeling programs are primitive when compared to the sophistication of the tools in dedicated drawing programs such as Autodesk’s Revit. The drawing tools within frontends work effectively for simple schematic exploration, but for a complex building they are wholly inadequate.

The sophistication and capabilities possessed by Revit to create a geometrically accurate and minutely detailed complete building must, however, be tempered by the energy modeling mantra, “Keep the model simple”,\textsuperscript{208} in order to minimize the demands of simulation.

The scope of this work does not include the step by step instructions necessary to produce a robust 3D energy model. However, in an effort to add to the body of information that presently exists relating to the process of creating a large complex building in Revit with the intent of successfully exporting the 3D geometry into an energy modeling program via gbXML format,\textsuperscript{209} a series of hints, techniques, and obstacles encountered that were discovered in the process of producing the FAC model and not discovered elsewhere in modeling literature are included see Appendix A, “Hint, Techniques, and Obstacles Encountered”)

\textbf{Notes}

\textsuperscript{207} Note: An energy model “frontend” is a digital software that provides access to an energy simulation software, e.g. EnergyPlus or DOE-2; in a more user-friendly fashion than inputting with text and code directly into the simulation software itself.

\textsuperscript{208} (J. Mumford 1993, 358)

\textsuperscript{209} Note: This information is specific to DesignBuilder and Ecotect. It may or may not be appropriate for every energy modeling frontend.
2.2.4 Modeling Geometry – Section Summary

Following the generally available geometry creation protocols for constructing 3D models for gbXML export that can be found in the instructional or help manuals of each energy modeling program, e.g. *DesignBuilder Revit – gbXML Tutorial*,\(^{210}\) or from information available in scientific papers in topic specific journals, addressing individual software’s WBES model creation techniques, e.g. *Envelope retrofit analysis using eQUEST, IESVE Revit Plug-in and Green Building Studio: a university dormitory case study*,\(^{211}\) coupled with the information provided by this project should facilitate the creation of robust geometric imports of large models. These models will still require some adjustments and modifications, but all will be possible to execute within the constraints of the energy model’s editing and drawing capabilities (see 2.3, “Energy Models” & Appendix E, “Model Square Footage Reconciliation”).

2.3 Energy Models

The term “energy model” includes an assortment of software programs. The outputs of the programs embrace an assortment of results, e.g. whole building energy simulation, mechanical system sizing, daylighting analysis, electric lighting analysis, acoustical performance, water consumption, wind flow analysis. etc. At present, in

Notes

\(^{210}\) (DesignBuilder 2013)  
\(^{211}\) (Mostafavi, Farzinmoghadam and Hoque 2015)
“Whole Building Energy Simulation” (WBES) alone, there are thirty-nine analysis software tools available.\(^\text{212}\)

The decision as to which tool to select is based on several variables:

- The project’s intent.
- The capabilities and capacity of the hardware that will use the program.
- The project’s level of development (concept or existing) and building type (residential or commercial).
- The selected software’s interoperability with other programs (import and export capabilities).
- The formatting of the program’s simulation results (spreadsheets, graphics, and visual displays).
- The software’s energy simulation engine, and the cost of the software.

DesignBuilder was the software of choice for whole building energy simulation in this work.

A second energy modeling program was selected for this project, Autodesk Ecotect Analysis, which offered some additional or improved analyses other than those offered by DesignBuilder and, as will be shown, has proven to be very valuable for this project.

2.3.1 DesignBuilder

DesignBuilder is an advanced and intuitive frontend that uses *EnergyPlus Energy Simulation Software* (EnergyPlus) as its simulation engine. The link with Autodesk’s Revit through the DesignBuilder Add-In or through direct gbXML import from a Revit

\(^{\text{212}}\) (BEST Directory n.d.)
exported gbXML file (see Appendix A, “Hint, Techniques, and Obstacles Encountered”) allows complex geometries to be examined within the software’s environment. The software then facilitates evaluations of heating loads, cooling loads, fossil fuel consumption (space heating, domestic hot water (DHW) usage), electricity loads (lighting, plug, process, etc.), etc. in annual, monthly, daily, or hourly increments. Performance indicators such as load sources, thermal comfort, solar shading impacts, daylight availability, etc. are options that can be extracted from the analysis. Results of simulations are output in not only “comma separated value” (csv) spreadsheets, but in charts, graphs, and tables that aid in communicating findings in a clear and decipherable manner; an important feature, as the data produced when simulating a large building is extensive and any aid in parsing and communicating the data is appreciated.

EnergyPlus is a console-based program that reads input and writes output to text files. It is an open-source whole building energy modeling engine produced by the Department of Energy (DOE) and the most recent of a line of DOE funded modeling engines that first appeared in 1977, i.e. DOE-1 and DOE-2.

In 1996, the programs, Building Loads Analysis and System Thermodynamics (BLAST) and DOE-2 were merged into the single program, EnergyPlus.\textsuperscript{213} EnergyPlus has been under continuous development since then and has come to be recognized as the state-of-the-art simulation engine within the sphere of building energy modeling.

\textit{EnergyPlus implements detailed building physics for heat, air, and moisture transfer, allows flexible HVAC and refrigeration configuration options, and has a programmable interface for modeling control sequences. EnergyPlus is rigorously tested according to}

\textbf{Notes}

\textsuperscript{213} (Center for Building Science Newsletter 1998, 6)
ASHRAE 140 methodology and includes comprehensive engineering and user-reference documentation.\textsuperscript{214}

The potency of the program is impressive with features and capabilities as follows:

Integrated, simultaneous solution of thermal zone conditions and HVAC system response that does not assume that the HVAC system can meet zone loads and can simulate unconditioned and under-conditioned spaces.

Heat balance-based solution of radiant and convective effects that produce surface temperatures, thermal comfort, and condensation calculations.

Sub-hourly, user-definable time steps for interaction between thermal zones and the environment, with automatically varied time steps for interactions between thermal zones and HVAC systems.

Combined heat and mass transfer model that accounts for air movement between zones.

Advanced fenestration models including controllable window blinds, electrochromic glazings, and layer-by-layer heat balances that calculate solar energy absorbed by window panes.

Illuminance and glare calculations for reporting visual comfort and driving lighting controls.

Component-based HVAC that supports both standard and novel system configurations.\textsuperscript{215}

Additional advantages of EnergyPlus are:

- Expert users can access source code allowing third party validation adding to the software’s credibility and long term reliability.

Notes

\textsuperscript{214} (Office of Energy Efficiency & Renewable Energy n.d.)
\textsuperscript{215} (U.S. Department of Energy 2015)
• It has been validated by the comparative *Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs* BESTEST/ASHRAE STD 140.

• EnergyPlus’ use of an Integrated Solution Manager EnergyPlus, which overcomes the most serious deficiency of the BLAST and DOE-2 – sequential simulations – inaccurate space temperature prediction due to no feedback from the HVAC module to the loads calculations. Accurate prediction of space temperatures is crucial to energy efficient system engineering, occupant comfort, occupant health, system size, and plant size.

• Loads calculated (by the heat and mass balance engine) are passed to the systems simulation module. The building systems simulation module calculates heating and cooling system and plant and electrical system response. Feedback from the building systems simulation module on loads not met is reflected in the next time step of the load calculations in adjusted space temperatures if necessary, and not just reported as unmet hours.²¹⁶

The two methods of importing 3D geometry into DesignBuilder have been discussed (see Appendix A, “Hint, Techniques, and Obstacles Encountered”)

DesignBuilder Add-In to Revit 2015 is the most efficient of the tools that are able to inspect large complex building geometries (Fig.2.8) after preparation has been done in Revit and before the final insertion into the DesignBuilder program (see Appendix C, “Revit’s DesignBuilder Add-In”). This process is also aided by the additional two spreadsheet files related to the geometry that accompany the export from Revit to DesignBuilder and are accessible in the “DesignBuilder Export” window (see 2.11, “Energy Use Intensity and Square Footage”).

Notes

²¹⁶ (Ibarra and Christoph 2009)
Tools within the ‘DesignBuilder Export” window to select and isolate a single Room/Space (termed “Block/Zone” in DesignBuilder) enable detailed checking of the geometry of a Room/Space geometry before the final import (Fig.2.9).

There are, however, reservations related to an import through this methodology. DesignBuilder imports the gbXML model as a model with shading surfaces only for “Building Blocks/Zones”, i.e. elements that enclose conditioned space. Objects that were created in the Revit model that are important to the building’s performance, separate from the conditioned spaces, are not imported. These elements, when created within
DesignBuilder are termed, “Component Blocks”, objects that are treated simply as shading/reflection surfaces in simulations without any other properties save geometry and materiality.

Elements that are important to the model’s energy performance must now be drawn within DesignBuilder as “Standard or Ground Component Blocks” using the drawing and editing tools supplied by DesignBuilder. Examples in this project are the FAC’s twelve pilotis that support the Bridge and defend the long southern façade of the building from solar loading (Fig.2.10) or adjacent topographical features, e.g. asphalt parking lots, concrete terraces, reflecting pools, or grassy expanses.

There are also a very substantial number of surplus of elements imported as shading surfaces to all of the “Building Blocks” that should not be there. These extraneously imported shading surfaces, which are BIM transfer artifacts, prevent radiation heat exchange between the Room/Space elements (Building Blocks) and the sky.

![Figure 2.10: FAC Shading Element: Pilotis (red arrow).](image)

There are also a very substantial number of surplus of elements imported as shading surfaces to all of the “Building Blocks” that should not be there. These extraneously imported shading surfaces, which are BIM transfer artifacts, prevent
radiation heat exchange between the Room/Space elements (Building Blocks) and the sky.

In the case of the FAC there were over 3400 hundred shading surfaces created, many of which would negatively impact the simulation results. They are primarily the roof and wall shading surface planes of all the conditioned zones. Allowing them to remain in the model would have prevented the actual exterior geometries of the Room/Spaces from exchanging radiation with the sky and would result in incorrect heating loads, cooling loads, operative temperatures, etc. etc.

Deleting these items is not difficult within the program as DesignBuilder’ GUI allows multiple selections per single deletion command and the main exterior roof and wall planes are not difficult to discern in the GUI where they are shown in yellow for roof shading surfaces and red for wall surfaces (Fig.2.8).

After this series of deletions, the modeler must evaluate the importance of the remaining shading surfaces and adopt a technique to eliminate the ones that are either incorrect or inconsequential to performance. In the case of the FAC, even after deleting the larger and obvious shading surfaces for major roofs and walls there would still be over 3000 surfaces left to assess. DesignBuilder’s selection tools and deleting sequence for multiple small elements is tedious; if there are many elements to delete it is not productive. This was the case for the FAC.

A more viable alternative is to use the “DesignBuilder Add-In” to examine the model closely, but then import the file without shading surfaces (option is available in the DesignBuilder Export window) or by using Revit to create gbXML file with the “Export Complexity Tab’s” drop-down menu set at “Simple” (Fig.2.11). The desired shading
surfaces can then be created using the drawing and editing tools supplied by DesignBuilder.

![Figure 2.11: “Export gbXML-Settings” Window: Export Complexity (red line).](image)

This was the case when modeling the FAC and the twelve massive dihedral pilotis that support the Bridge and afford solar defense to the long southern façade of the building (Fig.2.12).

Without question every detail of a building’s shading geometry that exists in the building’s reality and reduces solar gain has impact of some consequence, but the degree of importance of the impact must be evaluated by the modeler and weighed against the impact to the simulation time and results. As an example, the extension of the roof geometry on the north side of the FAC’s elevated row of Art Studios creates a one-foot (30.46 cm) projection over the 13 ft. (3.9 m.) high, 646 ft. (196.9 m.) long series of light monitors (Fig.2.7). The projection does not have any impact when shading is considered, as the orientation is to the north. It would have impact when considering surface albedo and reflectance, but the scale of that impact is so minor that the addition of these shading surfaces can be excluded from the model without detriment. If the modeler is in doubt, add or subtract surfaces and observe the impact in the simulation output.
It can also be observed (Fig. 2.10) that additional elements besides the pilotis have been added to the model of the FAC, i.e. perimeter concrete and asphalt hardscape surfaces, grass surfaces, and the two reflecting pools. The purpose is to explore the impact of these elements’ shading and reflectivity on the loads of the building in total or individual Room/Spaces within the building. Note that the colors in the GUI “Edit Screen” (green for “Ground Component Blocks” and purple for “Standard Component Blocks”) are only for visually differentiating object block types in the GUI. Data inputted into the various “Component Block” surfaces defines each surface’s singular material properties. The “Component Block” is programmed with the materiality of its various surfaces, e.g. a reflecting pool is programmed with the materiality of water and a parking lot with the materiality of asphalt. Although they appear as the same color in the GUI “Edit Screen”, they are not the same materials and respond appropriately during simulation. The GUI’s “Visualization Screen” differentiates the surface materials and is useful for a policing of “Component Blocks” to be certain correct materiality has been assigned (Fig. 2.12).
The reason that there are so many extraneous shading planes is related to the complexity of the model in Revit (even with as many simplifications as possible). Some individual sections of geometry, e.g. a roof plane will be composed of five shading planes as it is in a construct with a top and four sides. Additionally, there are many long walls made up of shorter segments, and each of them would have a shading surface. The numbers add up quickly.

Complex intersections with close tolerances of window edges to wall returns can create additional DesignBuilder geometry elements. Non-orthographic angles can create superfluous wall segments in the import. This necessitates a final geometry edit within DesignBuilder. Each Block must be isolated and checked to ensure that simplicity and accuracy of geometry is achieved. DesignBuilder’s block, zone, and zone component editing tools are adequate for the task, but a substantial amount of time must be allocated for the inspection and geometry revisions.

One example is shown below (Figs.2.13 & 2.14) in the FAC’s Music Wing’s First Floor North Zone. The exterior wall geometry around the west facing windows lining this exposure is similar in geometry to the exterior windows walls on other facades where the interior Room/Space activity is an office or small studio. The geometries of these facades and the impact on daylighting and defense from glare will be discussed later (see 3.1 “Intentional Sustainable Strategies Employed”). The windows are designed to substantially fill the wall they are inserted in, with the return angles of this wall to each adjacent wall at 45 degrees, but in opposite directions.
Constructed as simply as possible in Revit there is still considerable geometry and close tolerances involved with these intersections. DesignBuilder’s interpretation of the tight connections was to add an additional window (see yellow window outline in pink shaded wall in Fig.2.13). The solution is to delete the extraneous window (see pink shaded wall in Fig.2.14 without the window). Note that there is an additional window to delete in two offices to the west (see red arrow in Fig.2.14).

One additional idiosyncratic feature in DesignBuilder must be addressed, which is the issue of how DesignBuilder interprets the perimeter envelope location line when importing geometry through gbXML protocols.

In the case of creating a building entirely within the program itself, DesignBuilder accommodates the modeler’s intent and allows flexibility as to where the location lines of the building elements will be placed (Fig.2.15). The placement of the lines impacts both the GSF and the volume of a room.
The options at the extremes (all inner or all outer) allow the user to define Building Blocks (Rooms/Spaces) using external measurements for floor area and zone volume calculations including actual surface thickness; or using internal measurements, in which case the zone geometry dimensions are the same as block geometry dimensions.

The option most consistent with traditional mechanical engineering conventions, when calculating loads, is to take zone geometries and surface areas from the exterior planes of the external envelope and to centerlines of internal partitions.217

Traditional mechanical engineering conventions:

- Room/Space height begins at the floor level and rises to include thickness (depth) of the ceiling assembly, i.e. plenum (if present) and structural intermediate floor or the top floor, i.e. in the case of a flat roofed building, the roof assembly depth is included.
- Plan area dimensions include the thickness of exterior envelope walls and are measured to the center line of partition walls between rooms or zones.

This convention insures traditional GSF totals when the aggregates of Room/Space areas are totaled. DesignBuilder’s alternative geometry option choices allow for internal air volumes to be calculated or per square unit occupancy and other internal gains to be reported in different area/volume metrics, which can vary with the intent of the modeler or the report’s destination requirements (code compliances, rating agency parameters, etc.).

To test the DesignBuilder outputs of “Geometry, Areas and Volumes” command options, a simple “Twenty-foot Cube of a Building” model with .5 ft. (15.24 cm.) floor

Notes

217 (Siegenthaler 2004, 27-33)
slab, 1 ft. (30.48 cm.) walls, and 1 ft. (30.48 cm.) flat roof assembly was created within the program using only the program’s drawing and editing tools (Fig.2.16).

![Figure 2.16: Footprint of Twenty-foot Cube of a Building.](image)

Instructions in DesignBuilder Interface:
“outer” (blue square) and “inner” (red square).

When the outer dimension options were selected (blue square in Fig.2.16), square footage was reported at 400 sq.ft.\(^{218}\) (37.16 m\(^2\)). Using the inner dimension options (red square in Fig.2.16) square footage was reported at 324 sq.ft. (30.10 m\(^2\)). The 76 sq.ft. (7.06 m\(^2\)) loss is accounted for by the adjusted interior floor area dimensions of 18 ft. x 18 ft. (5.49 m. x 5.49 m.) minus two 1 ft. (30.48 cm.) wall thicknesses, rather than the 20 ft. x 20 ft. (6.09 m. x 6.09 m.) overall exterior dimensions. Note that volume measurements can also be controlled.

As demonstrated by the above example, when a model is created within DesignBuilder, it can be controlled. In the case of a gbXML import, this is not the case. An identical model to the model created in DesignBuilder, i.e. a twenty-foot cube, was

Notes

\(^{218}\) 401 sq.ft. rather than 400 sq.ft. is program metric to imperial conversion rounding error.
constructed in Revit and exported to DesignBuilder by both the “Revit to gbXML to DesignBuilder” protocol and the “DesignBuilder Add-In” protocol. In both cases the interior dimensions were the dimensions used by the imported model and the square footage reported was again the 324 sq.ft. (30.10 m²) number. The impact of this is significant when determining GSF and EUI numbers and will be discussed (see Appendix E, “Model Square Footage Reconciliation”).

2.3.2 Ecotect

The visual nature of Ecotect’s calculation and simulations results, which help to clearly communicated the various results of Ecotect’s many simulation tools and wizards. have been valued for their well-recognized graphics within the AEC community.

*Acquired by Autodesk in June 2008, the software combines a wide array of analysis functions -- including shadows, shading, solar, lighting, thermal, ventilation, and acoustics -- with a highly visual and interactive display that presents analytical results directly within the context of the building model. This visual feedback enables the software to communicate complex concepts and extensive datasets, and helps designers engage with multifaceted performance issues -- at a time when the design is sufficiently 'plastic' and can be easily changed.*

The original Ecotect software was written by Dr. Andrew Marsh at the School of Architecture and Fine Arts at The University of Western Australia and progressed from

**Notes**

219 (Rundell 2008)
the first commercial release (version 2.5) in 1996 through several versions until 2008 when the final version (version 5.6) was acquired by Autodesk.220

The program’s contributions to this project are significant (see Chapter 3, “Analysis”):

- Displaying of complex shadows and reflections on the building’s geometry.
- Generating interactive 3D sun-path diagrams for overshadowing analysis.
- Calculating the incident and reflective solar radiation on designated surface and percentages of shading on interior and exterior planes.
- Evaluating daylight factors spatially and at specified points within an area or volume.

However, it does not compare in the area of simulating building energy use to a dedicated WBES program such as DesignBuilder using the industry standard EnergyPlus engine (see 2.3.1, “DesignBuilder”).

One of the main shortfalls of Autodesk Ecotect is its inability to simulate the dynamic nature of thermal performance of buildings. This is perhaps not an issue in case of parametric studies that aims to investigate the relative effectiveness of design options, but hinders the use of Ecotect in research and practice, when thermal performance detailed analysis is required. Ecotect inherited this limitation from the Chartered Institution of Building Services Engineers (CIBSE) Admittance Method it uses. Autodesk Ecotect uses this method to calculate internal temperatures and heat loads. Admittance Method is a pseudo-dynamic method based on variation about the mean value. It also has the disadvantage of not taking in consideration the effect of solar radiation when it enters the space. Solar radiation is considered a space load the moment it hits a window and is not traced to check which internal surface it hits and accordingly heats up. Equally important, Autodesk Ecotect cannot calculate thermal lag for composite elements that are not included in its library. This either prevents the representation of certain cases or forces approximation leading to inaccuracy in simulation. To this end a detailed thermal

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220 (Raines 2011)
Importing a large geometric model into Ecotect from Revit follows a similar path to the insertion into DesignBuilder with a few notable additions and deviations. The process begins with the gbXML export command in Revit, use Revit’s “Export gbXML-Settings” window and tools to police the model, and is finished with a thorough inspection of the geometry in the “DesignBuilder Export” window accessed via the “DesignBuilder Add-In”.

Once the modeler is satisfied with all aspects of the gbXML file, return to Revit’s “Export gbXML-Settings” window, set the “Export Complexity Tab’s” drop-down in the “Export gbXML-Settings” window to “Simple with Shading Surfaces” (see below), and export and save the new gbXML file.

This file is now a valid gbXML file, but it cannot, at this point, be interpreted by Ecotect as it is not encoded in a format Ecotect recognizes. Revit exports in UTF-16 format whereas Ecotect requires UTF-8 format.

To convert the format: open the gbXML file in “Windows Notepad”, use “Save as” / Text Documents (*txt), change the encoding format to UTF-8 (Fig.2.17), and save the file. The reformatted gbXML file may now be used to import into Ecotect.

The reason that the import was changed in the “Export gbXML-Settings” window to “Simple with Shading Surfaces” from “Simple”, which was the selection for the

Notes

221 (Gado and Mohamed n.d., 9)
DesignBuilder import, is that Ecotect does not import the multitude of extraneous shading surfaces that DesignBuilder does.

What Ecotect does import though is many of the shading surfaces (if they had been created in Revit) that will be impacting the building model, e.g. the twelve pilotis that support the Bridge. It will not, therefore, be necessary to spend the time creating these objects in Ecotect. Selecting and deleting any extraneous objects in Ecotect is not a time issue, so any imported object that is not desired can be addressed quickly.

There are some additional idiosyncrasies with the Ecotect import to be followed:

- When importing gbXMLs into Ecotect Select: File / Import / Model Analysis Data rather than File / Import / 3D Cad Geometry.
- Imported file type is Green Building Studio gbXML (*.XML).
- At the bottom of the “Autodesk Ecotect–Import XML Data” window check the tick box, “Import Only Surface Geometry”.

Just as in DesignBuilder, there will still be editing necessary to complete a robust model. The editing is slightly less critical in Ecotect than DesignBuilder as there is no
intention of performing any energy performance simulations for which exact geometry is absolutely critical; but rather, to study solar, shading, daylight, glare, and albedo impacts, both on the building as a whole and selected areas of the building. Nevertheless, unexpected and unforeseen problems can be prevented with a thorough edit.

Ecotect has excellent isolation and selection tools to facilitate the process and reduce the visual clutter in the “Edit Screen” of the GUI to a more manageable view when single zones (Rooms/Spaces) or small multiples of zones are isolated (Fig.2.18).

![Figure 2.18: FAC Auditorium in Isolation: Ecotect Edit Mode.](image)

Additionally, the gbXML import has also transferred the numbers and names of the “Rooms/Spaces” assigned in Revit to the “Zones” in Ecotect. Just as the names were transferred to the “Blocks/Zones” in DesignBuilder, a feature that in models with large numbers of Room/Spaces is critical.

The final tasks, after the zone by zone geometry edit of the building in Ecotect is complete will be, just as it was necessary in DesignBuilder, to construct, using Ecotect tools, the surrounding topography, i.e. terraces, grass surfaces, parking surfaces, etc. (Fig. 2.19). All of these surfaces will be programmed with respective material properties (see
2.4, “Programming”). The effort is not always easy as Ecotect’s drawing and editing tools are antique and idiosyncratic, but it is a manageable effort.

![Figure 2.19: FAC Ecotect Model in Visualization Mode.](image)

2.4 Programming

When constructing a period energy model there is little difference in programming the model with the methodology employed for a newly constructed building. Deviations and exceptions are obvious. If an addition has been added, then it must be removed. If insulation has been added to a cavity or after a new roofing system installation, it must not be included. If windows were upgraded or glazing changed as new technologies became available, the inputted specification needs to be identical to the original specifications. If a mechanical system has been updated, the specifications of the original will be the inputs. If lighting systems have been upgraded to more efficient performance, they must be returned (digitally) to the original. If activities or program for the building are different, the original activities or program for the spaces must be used.

In a related fashion to how the geometry of the building was examined for digital recreation, the correct inputs for the above are sourced from original drawings, original Specifications Documents, archival miscellany, the existing building itself, and from
information gleaned from any persons who might have knowledge of original fabric, systems, program, or traditions. The more exact is the recreation of the first year of full occupancy after completion, the more credible the model.

The majority of the above requisite information can be substantiated through the various sources. What is more difficult to define, with any certainty, is occupant behavior in the building. Just as in a new building, occupant behavior can distort a building’s energy performance profile.

*People and building performance are intimately linked.*

Thermostats in spaces can be changed to higher setpoints in the winter and lower setpoints in the summer, dictated by occupants’ personal thermal whims and quite different from originally designed parameters. Lights and equipment can be left on when spaces are unoccupied. Mechanical systems might not receive the scheduled specified maintenance and lose efficiency. The number of ways that a building’s expected and intended user behaviors can be and are disregarded is unlimited.

Still, just as when modeling a new building, assumptions for reasonable and expected behaviors are made and are the entered inputs. There is also the need in period modeling to recognize that some behaviors are not dictated by the individual, but rather by administration or societal expectations and protocols, which might be quite different from contemporary ones. The impact on schedules and activities within certain spaces can be dramatically different for some program spaces when decades of time have passed from the original occupancy to the creation of the energy model. Again social research

**Notes**

222 (Yao and Lim 2013, 279)
can be done and interviews with original building contemporaries are sometimes possible; but it is not as exact and certain an input as entering an original mechanical system’s heating curve.

The following subsections on the programming process focus on DesignBuilder as DesignBuilder is the program that will produce the whole building energy simulation where the programming entries are most involved and most critical in order to recapitulate the reality of the building. The necessary programming entries, e.g. emissivity, reflectance, absorptance, that will be needed in Ecotect to examine the desired specific impacts of solar loads, shading defenses, daylighting strategies, etc. will be duplicates of the data entered in DesignBuilder and will be discussed in the appropriate subsection in the “Analyses” chapter.

2.5 Zoning

In Revit the zones are defined as Rooms or Space depending on the Revit program used. In DesignBuilder they are defined as Blocks and Zones, and in Ecotect, as Zones. All refer to the same segregated conditioned volume of a building that has specific constructions, occupant comfort demands, mechanical system inputs and responses, and environmental force impacts.

There are three rules that need to be applied when zoning an energy model. One, the number of zones should be kept to a minimum for the purpose of reducing simulation time. Two or more identically programmed spaces, side by side in a building, with all inputs identical, should be combined into one single zone. In large models there is ample opportunity to employ this technique, which because of the multiple opportunities will
reduce simulation time dramatically, e.g. the FAC model, with almost 450 individual partitioned spaces was reduce to 128 zones. Two, program, activities, occupancy, and schedules must be consistent within the zone. Three, cardinal and ordinal orientation must be consistent throughout the zone, e.g. perimeter offices in areas of the FAC, all with identical program with the same occupancy and activity were segregated into North Zones, Northeast Zones, East Zones, Southeast Zones, etc. as solar loads vary with orientation (Fig.2.20).

![Figure 2.20: FAC’s Music Wing Offices: Ordinal Zoning (see Room/Space Labels).](image)

### 2.6 Constructions

Construction elements in a Brutalist building such as the FAC are among the simplest to program. Sizes, layers, and materials are clearly defined in details within the original Drawing Set and the original Specification Document.

**Roofs:**

- Flat: layered assembly, i.e. ballast, built up roofing, expanded polystyrene (EPS) insulation, structural reinforced concrete deck (Fig.2.21).
- Flat: monolithic reinforced concrete.
- Sloped: monolithic reinforced concrete.
Figure 2.21: FAC: Typical Roof Detail.

Walls:

- Exterior (above and below grade): monolithic reinforced concrete.
- Interior Structural: monolithic reinforced concrete.
- Interior Partition: layered assembly, i.e. drywall or acoustic material, steel framing, drywall or acoustic material. Outside layers determined by Fire Codes or Function.

Floors:

- Basement: monolithic reinforced concrete.
- Raised Exterior: layered assembly, i.e. monolithic reinforced concrete, EPS insulation, monolithic reinforced concrete.

Windows, Skylights, Exterior Doors:

- Single pane; Aluminum frame; no thermal break.

Exterior Doors:

- Single pane; steel frame
- Steel flush with or without glass panels

Interior Doors:

- Single pane; steel frame.
- Steel flush with or without glass panels.
All aspects of the material properties can be entered within the “Construction Data Window” (Fig.2.22), i.e. conductivity, specific heat, density, emissivity, solar absorptance, visible absorptance, etc. It is not necessary to include surface resistance (film coefficient) layers to represent the resistance of the air films adjacent to the inner and outer surfaces. These are included automatically by DesignBuilder.

Included in the “Construction Template” is the model’s Air Tightness input for establishing infiltration and exfiltration rates. Blower door tests for large buildings are logistically, technically and economically problematic. There is not a database for large building air leakage metrics, which are impacted by construction type, geography, climate, and exposure. While not quite as “modeler-influenced” as defining schedules, air leakage data inputs require documented research in order to associate a reasonable air tightness metric to the model. An important input as air leakage rates can account for up to 40% of the energy a building uses for heating & cooling.223

Figure 2.22: DesignBuilder: Edit Construction Data Window: FAC Built-up Flat Roofs.

Notes

223 (Building Codes Assistance Project n.d.)
The paper most frequently referenced in discussions of commercial building air leakage is *Airtightness of Commercial Buildings in the U.S.* written in 2005.

In 1998, Persily published a review of commercial and institutional building airtightness data that found significant levels of air leakage and debunked the “myth” of the airtight commercial building. This paper updates the earlier analysis for the United States by including data from over 100 additional buildings. The average airtightness of 28.4 m<sup>3</sup> air/minute 75 Pa is essentially the same as reported by Persily in 1998. This average airtightness is in the same range as that reported for typical U.S. houses and is also similar to averages reported commercial buildings built in the United Kingdom prior to recent airtightness regulations. Additionally, the trend of taller buildings being tighter and the lack of correlation between year of construction and building air leakage observed are consistent with the earlier report. This new analysis also found a trend (with considerable scatter) towards tighter buildings in colder climates. Although this study more than doubles the number of buildings in the air leakage database, any conclusions from this analysis are still limited by the number of buildings and lack of random sampling.\(^{224}\)

In the absence of a definitive metric, the inputted data for the FAC is .3 ACH\textsuperscript{nat}, which is a relatively modest number and is based on a 33\% weighted average \[ (0.65 + 0.25) \times 0.33 = 0.3 \] from the *CIBSE Guide for Estimating Infiltration Rates* for an Air Conditioned Office Building (4000 - 20,000 m\(^2\)) (Fig.2.23).

Qualities the FAC possesses that give credibility to the .3 ACH metric are:

- Window-to-wall ration of 5.82\% is extremely low; therefore, there is a considerably reduced linear perimeter interface between the window assembly and wall opening where leakage most typically occurs.
- Monolithic roof and wall assembly construction has far fewer joints then layered assembly construction and therefore has less possible total leakage areas.

**Notes**

\(^{224}\) (Emmerich 2005)
All windows are inoperable with aluminum frames sealed to concrete surrounds. Reduction of operable sash reduces linear leakage areas.

Possessing a substantial volume of core spaces reduces the total ACH of a building:

*Core Flow Rate – Half of Perimeter - Infiltration flow rate input for all zones assuming the building level air change in core is half that of the perimeter zones.*

A substantial surface area of the exterior envelope is underground minimizing air leakage as the envelope’s exterior surfaces are surrounded by earth.

Finally, one material property - solar and visible absorptances - deserves special attention as its impact on the FAC is substantial and will be demonstrated (see 3.3.4, “Unintentional Sustainable Strategies Included”).

Thermal absorptance represents the fraction of incident long wavelength radiation that is absorbed by the material. This parameter is used when calculating the long wavelength radiant exchange between various surfaces and affects the surface heat.

**Notes**

225 (Gowri, Winiarski and Jarnigin 2009)
balances (both inside and outside as appropriate). Values for this field must be between 0.0 and 1.0 (with 1.0 representing “black body” conditions).

The visible absorptance field in the material input syntax represents the fraction of incident visible wavelength radiation that is absorbed by the material. Visible wavelength radiation is slightly different than solar radiation in that the visible band of wavelengths is much more narrow while solar radiation includes the visible spectrum as well as infrared and ultraviolet wavelengths.

In EnergyPlus, this parameter is used when calculating the amount of incident visible radiation absorbed by various surfaces and affects the surface heat balances (both inside and outside as appropriate) as well as the daylighting calculations.\(^\text{226}\)

Excluding the ballasted flat roofs of the FAC the entire exterior consists of the buff-colored concrete mix specified by Roche (see 1.3.2.3, “FAC Concrete”).

Establishing the solar and visible absorptance (SA) values for the FAC model is based on a survey of concrete material properties available from multiple sources:

- Engineering Tool Box: Absorbed Solar Radiation.\(^\text{227}\)
- Portland Cement Association: Solar Reflectance Values of Concrete.\(^\text{228}\)
- DesignBuilder Material Library: Concrete Default Values.\(^\text{229}\)
- CRC Handbook of Tables for Applied Engineering Science.\(^\text{230}\)
- Concrete mixtures vary in color depending on the cement color, which varies from manufacturer to manufacturer. One company’s “Grey Portland Cement” will be slightly different than another company’s “Grey Portland Cement”. Consequently, the absorptance numbers vary from reference source to reference source.

**Notes**

\(^\text{226}\) (DesignBuilder n.d.)
\(^\text{227}\) (Engineering ToolBox n.d.)
\(^\text{228}\) (Marceau and VanGeem 2008)
\(^\text{229}\) DesignBuilder Software, v.4.7.0.27, 2016
\(^\text{230}\) (Bolz and Tuve 1973, 211-212)
To establish the absorptance of the FAC’s Buff Concrete (no values were found from any source for this product) an extrapolation was made between white concrete (SA .25) with grey concrete (SA .5). Based on the buff concrete’s color being closer in value to the grey; the extrapolated value for the buff concrete was weighted toward the grey concrete by approximately seventy percent – SA .375 (Table 2.1).

Table 2.1: FAC Concrete Solar Absorptances.

<table>
<thead>
<tr>
<th>Concrete Color</th>
<th>Solar Absorptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Concrete</td>
<td>.25</td>
</tr>
<tr>
<td>Weathered White Concrete</td>
<td>.55</td>
</tr>
<tr>
<td>Buff Concrete</td>
<td>.375</td>
</tr>
<tr>
<td>Weathered Buff Concrete</td>
<td>.675</td>
</tr>
<tr>
<td>Grey Concrete</td>
<td>.5</td>
</tr>
<tr>
<td>Weathered Grey Concrete</td>
<td>.8</td>
</tr>
<tr>
<td>Dirty Buff Concrete</td>
<td>.8</td>
</tr>
</tbody>
</table>

Similar to the SA increase of .3 for both white and grey concrete the identical SA increase was given for weathered buff concrete (SA .675).

An identical value was given to dirty buff concrete (SA .8) as was reported in tables for weathered grey concrete. This final SA .125 increase is a necessary accommodation for the substantially blackened areas of mold and mildew that cloak significant areas of the FAC’s concrete (Figs.1.43 & 2.24).

Figure 2.24: FAC: Dirty Buff Concrete.
2.7 Activities

Zones are defined by their solar exposure and by the activity that occurs within the zone’s space and are programmed within DesignBuilder by an “Activity Template”. The FAC’s zones were programmed using twelve different “Activity Templates”, i.e. Art Studios, Assembly Areas, Auditoria, Circulation, Display and Public Areas, Mechanical Rooms, Music/Speech Studio’s, Office and Consulting Areas, Reception Areas, Restrooms, Storage Rooms, and Workshops.

An “Activity Template” is the controlling template for all of the zones programed for that activity, e.g. Restroom. However, a single zone within this group can receive individual, unique modifications to its data, if necessary, without affecting the other zones programed by the same “Activity Template”. There is a hierarchy to inputs.

The Activity Template within DesignBuilder involves many inputs (Fig.2.25) and deserves discussion especially in relating to the multiple unique inputs required by the FAC’s multiple programs.

Figure 2.25: DesignBuilder Activity Window (partial view).
The impact of good activity data on an accurate simulation result is as critical as accurate geometry. All of the data inputs entered in this project, up to this point, have been quantifiable and verifiable, i.e. orientation, geometry, construction details, materials, zoning. Many of the data inputs that follow, e.g. occupancy schedules, metabolic rates, DHW usage, lighting and equipment usage, etc. are based on research, experience and judgement.231

Occupancy density is entered as people/ft². In the case of the FAC, a review of the original drawings showed that two people occupied each Faculty Office, rather than the norm of today, where each office is typically private and occupied by a single person. At first it was thought that perhaps this was a direct result of the demands created by the increased program sizes that occurred from the time of the FAC’s design to its much later start of occupancy (see 1.3.2.1, “Background”). Discussion with H. Dennis P. Ryan, Professor Emeritus, who was at the UMass in the 1970s informed that at that time shared offices were not uncommon. Note: With the exception of the above office density issue, the other spaces in the FAC have remained faithful to the original program. Densities were calculated with original drawing designated occupancies and space square footage.

Metabolic activity can be a significant contributor to space loads especially when factored with density. In FAC Auditoria, the Metabolic Factor is 0.9 for Men with Occupant Density of .096847 people/sq.ft. (.08997 people/m²). In FAC Offices, there is a slightly higher Metabolic Factor of 1.0 with Occupant Density of .009849 people/sq.ft.

Notes

231 The possibility exists for dynamic statistical modeling, which would account for random time dependent changes within the modeled system, but is outside the scope of this project and my knowledge.
(.000915 people/m²). Occupant driven loads are considerably less in the FAC Office Spaces.

Schedules have enormous impact on the building’s energy use and there are many schedules to be entered (over 70 schedules were constructed for the FAC). They are, however, the most problematic to enter correctly. In an existing building, occupant surveys can be taken and data loggers can be placed that, depending on the thoroughness of the surveys and the time span and type of data collected by data loggers, can determine behavior patterns in a building with increased certainty. This is not the case with a period building, and an alternate strategy must be used.

While research can suggest the schedule that an administration imposes, e.g. on a campus, an Academic Calendar, it can only be a guideline. Some occupants might choose to come into the building on a holiday or on a Saturday or Sunday and without a detailed survey of behaviors there is no way to make a reasonable prediction. For that reason, it is useful to use the Library of “Schedule Templates” that DesignBuilder has accumulated and are installed in the program as a starting point. The “Schedule Templates” within DesignBuilder that are coded in the color green, are derived from a national or international sources, e.g. American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) or Chartered Institution of Building Services Engineers (CIBSE). From there, the modeler can modify the schedules with information discovered in research.

Notes

232 (Wolfe, Malone and Heerwagen 2014, 3.4)
233 Note that only data coded in green was used in programming the FAC model.
234 (DesignBuilder n.d.)
Some examples, all of which informed data input modifications to the FAC’s "Schedule Templates”, which began as “DesignBuilder Library-Schedule Templates” were pertinent pieces of information found in “UMass-Amherst Library Special Collection and Archives”:

- Saturday morning classes, a longtime, traditional academic practice had been discontinued by the time the FAC opened in the Fall of 1975. Saturday meeting dates last appeared in the University’s Fall of 1969-70 Schedule of Courses booklet, which was distributed to students for the purpose of enrolling and scheduling classes for themselves. The option had disappeared (no doubt to the delight of students) with the publication of the University’s Spring of 1969-70 Schedule of Courses booklet.

- Availability of the 1975 and 1976 performance schedules in the FAC’s Auditoria and Theatres aided programming of the Auditoria spaces (Fig. 2.26).

- A memo to faculty reminding them that they were expected to be present in their offices after Christmas and New Year’s break even though student’s were not on campus informed office schedules during that period.

![Figure 2.26: FAC Auditorium Schedule: 1975-76.](image)

Entering data into schedules is time consuming and harkens back to earlier times when frontends did not exist and all data was entered as text or code into energy
modeling programs. DesignBuilder uses a slightly modified version of the standard EnergyPlus Schedule/Compact Format (Fig.2.27).

The format does not suffer errors lightly, but DesignBuilder has an error message that appears, if an error is made (not an uncommon occurrence) in punctuation, spelling, redundancy, etc. That is very helpful in parsing out the mistake.

Schedules take into account all of the yearly/seasonal changes that occur, which are many in an Academic Year, e.g. schedules when classes are in session, schedules during reading and exam periods, schedules during vacations and summer breaks, etc.

Schedule inputs are not only daily, but also hourly, which is most relevant as occupancy levels vary in spaces depending on the hour of the day.

![DesignBuilder: Office Occupancy Schedule (partial view).](image)

The schedule that is the overriding schedule for a building is the Seasonal and Holiday Schedules. The seasonal and holiday schedule at the University for the year 1976 was able to be determined from the 1975 – 1976 and the 1976 – 1977 Academic Calendars (Fig.2.28).
Occupancy Schedules, DHW Schedules, Lighting Schedules, Office Equipment Usage Schedules, all are in synchrony with the Seasonal and Holiday schedules, but each allows individual modifications. For example:

Example 1: It is a reasonable expectation that on major holidays, e.g. Christmas or New Year’s Day that office occupancy will be 0%.

Example 2: It is not a reasonable expectation that on Saturdays when classes are in session that offices are unoccupied. Occupancy might be entered as (twenty-four-hour clock format) from 8:00 - 16:00 as 0.1 (percent) and 16:01 to 7:59 as 0.0 (percent); reflecting 10% occupancy for eight hours of the day and 0% occupancy for the other sixteen hours.

Example 3: It is reasonable to expect that on Saturdays during intercessions between semesters that the schedules in the offices are similar to the Holiday schedule and there is 0% occupancy.

The use of datalogger recordings are not possible with a period examination of a building. It is up to the modeler to establish and program the schedules. Since it is
sometimes not a possibility to find archival data supplying clues to the answers of the myriad of questions that arise when schedules are being inputted, the modeler is forced to rely on, at least for beginning reference points, the “DesignBuilder Library Files”. These files are based on years of accumulated data, segregated by building type.

Occupancy schedules direct the usages for DHW, Lighting, and Equipment. The same occupancy schedule will also direct the zone Setpoint Temperature and Setback Temperature oscillations for the Heating, Cooling, and Ventilation Systems.

It is also in the Activity Templates that the metrics for various systems are inputted:

- DHW consumption rate (gal./ft²/day).
- Cooling and Heating Setpoints and Setbacks (°F).
- Relative Humidification and Dehumidification Setpoints (%).
- Minimum fresh Air Requirements (cf./min./person).
- Target Illuminance (fc).
- Office Equipment Gains (w/ft²).

In the FAC model, the sources for the above design levels were varied:

- DHW consumption rate (gal./ft²/day). Source: DesignBuilder Library Default. DHW consumption in a building with programs and activities such as the FAC located in a heating dominated climate typically demonstrate low percentages of DHW energy impacts when total energy consumption is the targeted concern.
- Cooling and Heating Setpoints and Setbacks (°F). Source: original Specifications Document, from archives.
- Relative Humidification and Dehumidification Setpoints (%). Source: original Specifications Document, from archives.
- Minimum fresh Air Requirements (cf./min./person). Source: 1970s Building Codes.235
- Office Equipment Gains (w/ft²). Source: DesignBuilder Library and 1975 Fine Arts Moveable Equipment List.237

### 2.8 HVAC

The FAC utilizes several different heating, ventilation, and air conditioning systems throughout the building, based on the Room/Space programs and the location within the building:

- Perimeter Offices used individual fan-coil units located below each window.
- Internal spaces were heated, cooled, and ventilated with constant volume air handlers. Hot water heating coils supplied warm air, chilled water coils supplied cool air, with dry-bulb economizers integrated into the ventilation requirements moderating energy consumption.
- Perimeter spaces with high design space heating loads were augmented with hot water radiation, e.g. the elevated Art Studios and corridor of the Bridge.
- Stairwells with exterior access were supplied with convector units.
- Restroom were heated with hot water radiators and supplied with isolated mechanical ventilation.
- Core Areas, elevator shafts, storage rooms, and mechanical rooms were designed to float without any mechanical system intervention.
- Heat source was steam from the coal fired Central Heating Plant. Cooling source were two 237-ton Electric Motor Driven Centrifugal Water Chillers located in the lowest level.

### Notes

235 (Walsh, Dudney and Copenhaver 1983, 101)  
236 (Illuminating Engineering Society 1972)  
237 Courtesy of Facilities and Planning Archives
Information for all of the mechanical systems was provided by the seventeen sheet, “H Drawing Set”, included with the original “Construction Drawing Set” (Fig.2.29), the *Balancing Report: Air-Water-Sound* prepared by Greenleaf Associates, the mechanical contractors responsible for the FAC’s systems (Fig.2.29), and the *Specification Documents*.

All system setpoints, setbacks, humidity setpoints, etc. as found in the documents are programmed into the model (see 2.7, “Activities”).

2.9 Lighting & Plug Loads

Lighting was one of the most straightforward of all the data inputs to enter. All of the twelve different Activity Templates were programmed with the lighting levels.

**Notes**

Note: This project is indebted to Jason Burbank, Campus Engineer and Sandy Beauregard, Facility Engineer at UMass-Amherst, who clarified issues and matters related to the FAC’s mechanical systems.

Lighting levels in 1976 were achieved principally with the use of T-12 Florescent technology and the impact of this now antique technology is addressed in the section, “Calibration and Validation”.

With the exception of the offices within the FAC, the DesignBuilder ASHRAE Library files were used to input plug loads (Table 2.2). It is acknowledged that there have been changes in equipment over the past forty years. Shop equipment options have increased resulting in more pieces of equipment and power tools, but portability and efficiency counters the proliferation. Plug loads for the building represent only 5.13% of total electric load and 2.07% of the total energy loads in the DesignBuilder “FAC 2016 Baseline Model” (see 2.12.2, “FAC Model” & 2.12.4, “FAC 2016 Baseline Model Calibration”), so reliance on the DesignBuilder ASHRAE Library files was elected as small deviations within a small percentage could be tolerated.

A subset of total plug loads is “Offices Plug Loads”. These were far more problematic. The equipment that has become typical in modern offices and their inherent electrical consumption is reflected in the metrics contained in the DesignBuilder ASHRAE Library files. The proliferation of computers and related equipment has been tremendous since the mid-1970s.

...for every piece of wired hardware on your desk, two or three pieces of equipment lurk in the network beyond — office hubs and servers, routers, repeaters, amplifiers, remote servers.\textsuperscript{239}

Notes

\textsuperscript{239} (Huber 1999)
The 1975 Fine Arts Moveable Equipment List supports this finding as can be seen in a typical office’s inventory of equipment (Fig.2.30), i.e. there is an absence of any electric or electronic equipment.

<table>
<thead>
<tr>
<th>Room/Space</th>
<th>Illuminance</th>
<th>Fc</th>
<th>Plug Loads w/ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art Studios</td>
<td>1076</td>
<td>100</td>
<td>.4051</td>
</tr>
<tr>
<td>Assembly Areas</td>
<td>753</td>
<td>70</td>
<td>.1700</td>
</tr>
<tr>
<td>Auditoria</td>
<td>200</td>
<td>15</td>
<td>.1654</td>
</tr>
<tr>
<td>Circulation</td>
<td>215</td>
<td>20</td>
<td>.1700</td>
</tr>
<tr>
<td>Display and Public Areas</td>
<td>323</td>
<td>30</td>
<td>.3252</td>
</tr>
<tr>
<td>Mechanical</td>
<td>54</td>
<td>5</td>
<td>5.5049</td>
</tr>
<tr>
<td>Music/Speech Studios</td>
<td>323</td>
<td>30</td>
<td>.0451</td>
</tr>
<tr>
<td>Office and Consult Areas</td>
<td>323</td>
<td>30</td>
<td>.1139</td>
</tr>
<tr>
<td>Reception</td>
<td>215</td>
<td>20</td>
<td>.4301</td>
</tr>
<tr>
<td>Restrooms</td>
<td>323</td>
<td>30</td>
<td>.4301</td>
</tr>
<tr>
<td>Storage</td>
<td>54</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Workshops</td>
<td>538</td>
<td>50</td>
<td>.4645</td>
</tr>
</tbody>
</table>

To compensate for what would have been an excessively high plug load level, if the DesignBuilder ASHRAE Library files for office plug loads had been used (given the changes in office equipment loads over the past forty years), the FAC’s “Office Plug
Loads” were reduced by 90%, i.e. 1.1139 w/ft² to .1139 w/ft². According to the FAC Moveable inventory list there were not any electrical devices in the offices, which would mean a 0 plug load. A reasonable expectation is that a few electrical devices could be brought in by the occupants, e.g. a task or desk lamp. In light of that a small plug load 10% was inputted.

In support of the above, the “FAC 1976 Baseline Model” (see 2.12.2, “FAC Model” & 2.12.4, “FAC 1976 Baseline Model Validation”) was simulated with the ASHRAE Plug Load Library Template value (1.1139 w/ft²) loaded in the offices. A second simulation followed with all conditions identical excepting the plug load reduction to .1139 w/ft² in those offices

The second simulation shows a reduction of plug loads from the DesignBuilder ASHRAE Library levels of 42.29%, with the following associated load impacts:

- Cooling Loads decreased by 0.30%.
- Fan loads decreased by 0.03%.
- Pump Loads decreased by 0.14%.
- Total Electric Loads decreased by 1.8%.
- Heating Loads increased by 0.96%.

However, whole building annual energy consumption was only reduced by 0.04%. The impact of modeler justified program data inputs will be discussed further (see 2.12, “Calibration and Validation”).
2.10 Weather Files

2.10.1 Background

This subsection includes a recapitulation of the discussion in the paper, *Matching Building Energy Simulation Result against Measured Data with Weather File Compensation Factors*\(^{240}\) presented at the 2014 ASHRAE Annual Conference.

Building modeling protocol calls for the insertion of the geographically nearest and most recent Typical Meteorological Year (TMY) file, optimally a TMY3 file. While the file format of the weather data input may vary; the original data before the conversion (EPW, WEA, BIN) — is from the TMY File.

A TMY data set provides annual hourly meteorological values typifying conditions at a specific location over a long time period—as much as thirty years. Although not designed to include meteorological extremes with global weather impacts (catastrophic events are excluded from the data set, e.g. the 1991 eruption of Mt. Pinatubo), TMY data have natural diurnal and seasonal variations that represent a year of typical climatic conditions for a specific location. Each TMY data set is composed of twelve typical meteorological months (January - December) that are concatenated essentially without modification to form a single year with a serially complete hourly data record for primary measurements.\(^{241}\)

Notes

\(^{240}\) (Fiocchi, Hoque and Weil, Matching Building Energy Simulation Result against Measured Data with Weather File Compensation Factors 2014)
\(^{241}\) (Wilcox 2008)
Data for the files is compiled by the National Climatic Data Center and is freely accessible via the internet at the National Solar Radiation Data Base.\textsuperscript{242} The site contains 1020 locations of TMY3 Files and 239 additional locations for TMY2 files. The TMY3 are preferred as they contain the most current and complete data available and are the file type that most contemporary building energy modeling programs are designed to import, but where geographically appropriate, TMY2 files are usable.

Each TMY3 file contains hourly data compiled over either a fifteen-year period (1991-2005) or a thirty-year period (1976-2005) depending on the weather station. The file includes 68 different elements recording data principally from the following categories:

- Global Horizontal Radiation.
- Direct Normal Radiation.
- Total Sky Cover.
- Dry Bulb Temperature.
- Dew Point Temperature; Relative Humidity.
- Wind Speed and Wind Direction.
- Surface Albedo.
- Liquid Precipitation.

Using a yearly file compiled with months from different years is conservatively valid, even with the recent warming trends in certain geographic regions, for building design and energy use analysis.\textsuperscript{243,244} This is confirmed in a 2007 study simulating office buildings in five major climate zones in China using multi-year (1971–2000) weather

\textbf{Notes}

\textsuperscript{242} (National Renewable Energy Lab. 2015)
\textsuperscript{243} (Crow 1981)
\textsuperscript{244} (Colliver and Gates 2000)
databases as well as typical meteorological years. The energy simulation results from the TMY files (and the long-term means) fell well within the maximum and minimum ranges of the 30 year individual predictions.\textsuperscript{245} Simulation results were also compared using a variety of typical weather year selection approaches (TMY, IWEC, and TMY2) and those obtained by averaging the results for 30 years for ten U.S. climates, finding a 5% maximum difference.\textsuperscript{246}

The importance of using accurate weather files to program a building energy modeling program cannot be overstated. The most carefully oriented and constructed energy model in terms of geometry, material data, assembly/construction data, space zoning, building activities and usage, internal loads (lighting, plug, and equipment), occupancy schedules, etc. will result in incorrect outputs, if the weather file imported into the simulation program does not coincide with weather experienced by the building being analyzed.

2.10.2 Obstacles to Overcome

2.10.2.1 Distance & Topography from nearest TMY File

For the FAC simulation, the geographically closest weather station with a TMY3 file is Chicopee Falls-Westover Air Force Base, 14 miles (22.6 km) away and is the one used in the DesignBuilder and Ecotect simulations.

Notes

\textsuperscript{245} (Yang, et al. 2008)
\textsuperscript{246} (Seo, Huang and Krarti 2010)
This file would serve the simulation well with one exception. In the course of modeling other buildings on the UMass-Amherst campus it was discovered that there were significant differences in the HDD embedded in the Chicopee Falls-Westover Air Force Base TMY file and the HDD experienced on the UMass-Amherst campus from 2010 thru 2015.

The energy use data that was recorded for the FAC by the UMass Physical Plant and would be used to calibrate the model (see 2.12, “Calibration and Validation”) was a response to weather factors including HDD totals. There was need of a protocol to reconcile the disparities.

The HDD experienced by the FAC are most correctly taken from a South Deerfield, Massachusetts weather station (KMASOUTH15). The station is 8.95 mi. (14.4 km) from the FAC. The South Deerfield station does not have a TMY file, but its record of Heating Degree Days (HDD) is more representative of the HDD experienced by the FAC as not only is it in closer proximity, but it does not have the Holyoke Mountain Range separating site from weather station (Fig.2.31) Even relatively nearby weather stations may report significantly different weather than the modeled building due to variations in topography, geography, microclimates, water bodies, or land cover characteristics.247

The impact of HDD on the simulation of a model in the Northeast (ASHRAE Climate Region: 5a Cool-Humid) is significant as space heating loads are a major contributor to energy consumption. HDD are based on Dry Bulb Temperatures (DBT)

Notes

with reference to a building’s “Balance Point” temperature, i.e. the temperature at which a building begins to use mechanical means to meet the prescribed mechanical system setpoints.\textsuperscript{248}

Figure 2.31: FAC Distance to Weather Stations. Holyoke Range (red line).
Courtesy of GoogleEarth.

Since heating energy use constitutes the dominant energy load in a building in the Northeast U.S., the singular focus on DBT and HDD is justified. Other data supplied by the weather file either have more direct connections to other energy loads or do not vary over large geographic distances:

- **Insolation** affects solar gains through transparent surfaces and sol-air temperatures, which relate to passive solar heating, and are important for calculating cooling loads. However, the primary determinant of insolation is latitude, which is likely to be very close to the same as even a relatively distant TMY weather file-originating weather station.

- **Cloud Cover**, has larger effects on daylighting and lighting electrical loads, but also affects direct insolation and is, like insolation, typically a large-area effect.

**Notes**

\textsuperscript{248} Note: TMY files use 65°F (18.3°C) Balance Points; all HDD in this work is consistent with that protocol.
- **Relative humidity** is used in calculating latent cooling loads.

- **Wind speed** can drive air leakage which can impact the heating load, but in DesignBuilder, air leakage is inputted into the program as air changes per hour (ACH) and is not impacted by wind speed. Wind speed does change the exterior air-film R-value impacting conductive heat loss, but the effect of even a large difference between the TMY3 file and the actual site weather is minimal in context of the entire assembly R-value. In the present case, average wind speeds for the site and the TMY3 file respectively were 5.5 and 6.6 mph (8.8 and 10.6 km/h) respectively. While relatively large (20% difference) and statistically significant (T = -4.25, p < 0.0001), in absolute terms a difference in wind speed of 1 mph is not detectable in a heat loss calculation and is consistent with the emphasis being placed on dry bulb temperature.

A “HDD Compensation Protocol” for resolving the disparagement has been adopted (see Appendix D, “HDD Reconciliation”) to provide a means of comparing actual metered energy data from with the simulated results of a model of that building located on the UMass-Amherst campus using the Chicopee Falls-Westover Air Force Base TMY file.

### 2.10.2.2 Custom TMY File

The previous energy modeling efforts to which the “HDD Compensation Protocol” had been applied had always involved the modeling of an existing building in its contemporary condition (geometry, systems, and program) and time frame. The annual energy consumption simulation results were then compared to annual metered data. The protocol was effective, but now the task was to model a building as it existed forty years ago at a time when there were no records of energy consumption.
An additional concern was that the Chicopee Falls-Westover Air Force Base’s TMY file’s data was from the fifteen-year period, 1991 – 2005, i.e. data that began over fifteen years after the targeted first year of occupancy, 1976.

An attempted solution was to have a Custom TMY file created by Weather Analytics, the industry leader in supplying custom TMY files. There were, however, limitations on the file that was produced. The smallest TMY that Weather Analytics are able to produce is seven years, so ideally a file chronologically surrounding 1976 (1973 – 1979) would have been preferred, but Weather Analytics data only extends back in time to 1979. The decision was to have a custom file produced at the limit of their data, i.e. 1979-1986 and simulate with that file.

The results were very disappointing. Weather Analytics had warned that data from those years is all observational and the file would have extrapolated missing data, sometimes hourly and sometimes daily. When testing the file using the “Twenty-foot Cube of a Building” model described previously (see 2.3.1, “DesignBuilder”) total annual energy use was 29.54% higher when the Custom TMY file was substituted for the Chicopee Falls-Westover Air Force Base’s TMY file.

Opening up the two files in Ecotect’s “Weather Manager” showed that HHD totals (outputted as Heating Degree Hours in “Weather Manager”) were 18% greater in the Custom File (Fig.2.32). It is possible that the file is more accurate than at first thought, but substantiation for just how accurate or inaccurate is the data in the file is difficult to ascertain.
One paper that supported the custom file’s HDD extremes was found in a National Oceanic and Atmospheric Administration (NOAA) Technical Report, *Regional Climate Trends and Scenarios for the U.S. National Climate Assessment*. However, it was too imprecise to use as validation, only providing an indication that the data might have been consistent.

*Figure 5 shows annual and seasonal time series of temperature anomalies for the period of 1895-2011. Across the Northeast temperatures have generally remained above the 1901-1960 average for the last 30 years, both annually and especially during the winter.*\(^{249}\) (Fig.2.33)

The algorithm’s used in the creation of the Chicopee Falls-Westover Air Force Base’s TMY file would have eliminated extremes as they selected which months within the fifteen years range to concatenate into the TMY file. Apparently this was not the case with the Custom file as the extremes in a seven-year period were frequent enough to seem typical. No further investigation was done after the HDD discrepancy was

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**Notes**

\(^{249}\) (Kunkel, et al. 2013, 20-21)
determined, but a similar discrepancy could be predicted from observing the similar summer temperature deviations (see Fig.2.33) only now in Cooling Degree Days (CDD).

![Figure 2.33: From Figure 5: 1979-1985 Northeast Temperature Deviations: Winter (blue); Summer (red).](image)

The failure of the Custom TMY file required the project to resort to the use of the Chicopee Falls-Westover Air Force Base’s TMY file including the previously established “HDD Compensation Protocol”. Additional rationales then needed to be applied in order to verify that the models were calibrated and validated (see 2.12, “Calibration and Validation”)

### 2.11 Energy Use Intensity and Square Footage

Energy Use Intensity (EUI) is the defining metric in whole building energy analysis. It is the single metric that the AEC industry has to evaluate and compare buildings’ yearly energy consumption. EUI is expressed as energy per square foot per
year. It is calculated by dividing the total energy consumed by the building in one year (measured in KBtu) by the total gross floor footage (GSF) of the building.

Traditionally the sum of the annual total amount of energy (fossil fuel and electricity) consumed by the building and inserted into the numerator of the metric has been “Site Energy”. This number was determined by either building’s installed meters (gas, steam, electricity, etc.) or energy records or bills. More recently the Environmental Protection Agency (EPA) has determined that “Source Energy” is more representative of a buildings performance. Source energy represents the total amount of raw fuel that is required to operate the building. It incorporates all transmission, delivery, and production losses.

*By taking all energy use into account, the score provides a complete assessment of energy efficiency in a building.*

The EPA has established national standards for the conversion factors necessary to convert a building’s “Site Energy” usage into “Source Energy” usage.

*The efficiency of secondary energy (e.g., electricity, steam) production depends on the types of primary fuels that are being consumed and the specific equipment that is used. These characteristics are unique to specific power plants and differ across regions of the country. For example, some states have a higher percentage of hydroelectric power, while others consume greater quantities of coal.*

*Because Energy Star is a national program for protecting the environment through energy efficiency, EPA has determined that it is most equitable to employ source-site ratios at the national level. As such, there is only one source-site ratio for each of the primary and secondary fuels in Portfolio Manager, including electricity. The use of national source-site ratios ensures that no specific building will be*

Notes

*250* (Energy Star n.d.)
credited (or penalized) for the relative efficiency of its utility provider.251

The shift is a laudable effort, as it is far more reflective of a building’s impact on the environment. Until this recent transition, all EUI numbers have been reported using “Site Energy”, since this work involves a 1976 building, which will be compared to other period buildings; it is more appropriate to continue to use “Site Energy” as the metric.

When comparing EUIs from one building to another it is important to consider the building’s construction type, occupancy and activities, and local climate. Buildings with different construction types conserve energy at different rates depending on their envelope’s conductive resistance and air sealing abilities. Buildings with different programs cannot be compared, e.g. the activities in a hospital use far more energy than the activities in a dormitory even if the buildings are of similar size and occupancy numbers. Heating loads in the Northeast U.S, far exceed an identical building’s heating loads in the Southeast U.S. because of climate, with the inverse being true for cooling loads.

EUI figures for various building types in assorted climates have been collected by the U.S. Energy Information Administrations (EIA) since 1979.

*Commercial Buildings Energy Consumption Survey (CBECS) is a national sample survey that collects information on the stock of U.S. commercial buildings, including their energy-related building characteristics and energy usage data (consumption and expenditures). CBECS includes building types that might not traditionally be considered commercial, such as schools, hospitals, correctional institutions, and buildings used for religious worship, in addition to*

**Notes**

251 (Energy Star n.d.)
traditional commercial buildings such as stores, restaurants, warehouses, and office buildings.252

It is through comparisons with the assorted data sets collected by CBECS that will enable and enrich the discussion that will follow related to the FAC (see Chapter 3, “Analysis”).

The energy value, the numerator in the EUI, is a definite in the physical world of buildings as the meters and energy records or bills provide the definitive and detailed data in British Thermal Units (Btu, KBtu) or Watt-hours (wh, kwh). It is the GSF number in the denominator that can be at times the most problematic and is not always the easiest to measure once a building is built.

The methodology of determining GSF is defined by Building Owners and Managers Association International (BOMA), the leading source for information on the commercial real estate industry. BOMA’s standards and research reports have been property professionals’ primary resource for insights and guidance for more than 100 years.253

Gross Areas of a Building: Standard Methods of Measurement (ANSI/BOMA Z65.3—2009) provides a uniform basis from which to compute, communicate and compare the measurement of buildings by gross areas, and offers the industry’s first direct measure of the physical size of a building. The standard meets growing industry demand for a true methodology for measuring gross area.254

Notes

252 (U.S. Energy Information Administration n.d.)
253 (BOMA International: Building Owners and Managers Association International n.d.)
254 (BOMA International: Building Owners and Managers Association International n.d.)
This is the standard for measuring the building’s GSF as used by CBECS and defined by Energy Star Portfolio Manager,\textsuperscript{255} which refers to GSF as Gross Floor Area (GFA).

\textit{The Gross Floor Area (GFA) is the total property square footage, as measured between the principal exterior surfaces of the enclosing fixed walls of the building(s). This includes all finished areas inside the building(s) including supporting areas, e.g. Lobbies, Tenant Areas, Common Areas, Meeting Rooms, Break Rooms, Atriums (count the base level only), Restrooms, Elevator Shafts, Stairwells, Mechanical Equipment Areas, Basement, Storage Rooms.}\textsuperscript{256}

If the building has an uncomplicated orthographic footprint with similar geometry for the upper and below grade levels then determining the GSF is not a complicated task, either from measurements taken directly from the building or from an architectural drawing set.

In the case of buildings such as the FAC determining the actual square footage is far more problematic:

- There is not a single footprint, but rather multiple footprints of the various sections of the building requiring the complete footprint to be collected from separate footprint components, e.g. Music Building, Art Building, Arts Studio Building, Theatre Building, Auditorium Buildings, Speech Building (Fig.2.34).
- Underground spaces spread out beyond the observable footprint at grade, adding to the GSF.
- Within each component’s footprint there are multiple levels, some are below grade, some are upper levels. Some of the levels expand their floor to ceiling heights impacting levels above or below. Some of those expanded heights divide into additional levels, e.g. in the Auditorium

\textbf{Notes}

\textsuperscript{255} Energy Star Portfolio Manager interfaces with CBECS allowing EUI comparisons.
\textsuperscript{256} (Energy Star n.d.)
there are orchestra pits, orchestra level, stage, balconies, and catwalks. Many of the additional levels are irregularly shaped individualistic areas.

- Multiple ramps, staircases, and elevators transition between all of the multiples of levels.

Accurately determining each area’s geometry without excluding a singularly individual area is extremely challenging, especially given the multiples of these types of conditions in a large building. The sum total of these omissions can be significant, a problem seen in the preparation of the six DWGs for the FAC (see 2.2, “Modeling Geometry”).

Figure 2.34: FAC Multiple Component Footprints. Courtesy of Facilities and Planning Archives.

The importance of GSF accuracy cannot be understated. An under reported GSF distorts the EUI in a negative manner; an over reported GSF distorts the EUI in a positive manner. Only an accurate GSF resulting in an appropriately correct EUI can be used with confidence and authority in comparing a single building to another building or to a group of buildings.
Determining the GSF of the FAC was difficult as totals from sources for the building’s GSF varied significantly.\textsuperscript{257}

1. From “UMass-Amherst Library Special Collection and Archives”:
   - 1975 Document recommending, “Acceptance of the facility by the Board of Trustees subject to satisfactory completion”: 214,500 sq.ft. (19,927.70 m²).

2. From “UMass-Amherst Facilities and Planning Archives”:
   - Undated Document titled: “Fine Arts Project – Budget”: Gross Area: 200,00 sq.ft. (18,580.608 m²).

3. From “UMass-Amherst Facilities and Planning Department”:
   - 2011 Document titled: “Space Use Document 101.2 Building Space Profile by Department”; Authors: Crystal Decisions: Grand Total 168,617 sq.ft. (15,665.03 m²).
   - 2015 Document titled: “Building Space Profile Fine Arts Center (420)”: Grand Total 201,839 sq.ft. (18,751.46 m²).

\textbf{Notes}

\textsuperscript{257} Note: For all “Square Footage Documents” created after the 1999 Perry, Dean, Rogers & Partners, “FAC Lobby Addition” the appropriate deduction of, 4742 sq.ft. (440.45 m²), was made. The deduction is not included in this section’s totals.
4. From UMass-Amherst Physical Plant:


The significant discrepancies between the reported values was of concern as the final resolution would impact the FAC’s EUI and comparison to other buildings. It was a reasonable assumption to make that the final GSF was somewhere in the vicinity of 200,000 sq.ft. (18,580.608 m²), but the exact number was not apparent. All of the above sources required examination in order to determine a method to calculate the final totals.

- Documents from the “UMass-Amherst Library Special Collection and Archives” and “UMass-Amherst Facilities and Planning Archives” were judged as either early unrealistic projections or anecdotal (uncited quotes) and discounted. Exceptions were the “1970 Fine Arts Center Building (U63-5 Contract 1)” and “1975 Document, Recommending acceptance of the facility by the Board of Trustees subject to satisfactory completion”, as both referred to a very specific number, 214,500 sq.ft. (19,927.70 m²).

- Documents from the “UMass-Amherst Facilities and Planning Department” were suspect because of missing Room/Spaces that were found in one documents, an exceptionally high GSF reported in one document, and the recognition that the documents were prepared as “Building Space Profiles”, rather than GSF documents and would not necessarily been following BOCA or CIBECs protocols.

- A single exception existed, “2015 Fine Arts Center Space Data”; Author: Negar Pourshadi: 201,838.86 Total sq.ft. (18,751.46 m²). An interview with Negar Pourshadi, UMass-Amherst Facilities Space Information Analyst, on April 3, 2015 supplied the information that the six original DWGs (see 2.1,”Digital Drawings”) had been updated and two additional DWGs had
been added. Inspection of the file’s “Property Statistics” revealed that the new files were
based on the originally created files from January of 1998 and had received additional editing
since the previous edits of 2010-2011 as noted in the “Statistics Editing Time.” The Pourshadi
document “2015 Fine Arts Center Space Data” greatly improved on the previous “2011 Space
Use Document 101.2 Building Space Profile by Department”. It no longer was missing spaces
and was accompanied by a spreadsheet that validated the areas extracted from the DWGs.
However, because it was contained measuring inaccuracies inherited from the originally
created DWGs (see 2.1, “Digital Drawings”) it was discounted. It was a perfectly adequate
document for space planning, but for EUI calculation it was suspect.

- No source could be determined for the “UMass-Amherst Physical Plant: 2010 thru 2015
  UMass Energy Usage: Fine Arts Center Bldg. No. 420”: GSF 220,094 (20,447.40 m²).

A second visit to the “Kevin Roche John Dinkeloo and Associates Records at the
Yale University Library’s Manuscripts and Archives” and the examination of one final
set of drawings in Box 67 provided a solution. Each of the ten “Plan Drawing Sheets”
from the Original 1969 Construction Set were assessed for all pertinent area take offs
(Fig.2.35).

- Assignable Area of Instructional and Library Facilities in Project.
- Assignable Area of Instructional Related Facilities in Project.
- Assignable Area not in Project.
- Nonassignable Area.
- Total Net Area.
- Gross Area in Proposed Facilities.

Inspection of the document using a scale ruler and the document dimension
notations concluded that Gross Square Footage complied with BOCA and CBECs
protocols (Fig.2.36).
Figure 2.35: Example: A-6 Drawing Sheet with Square Footage Takeoffs. Courtesy of Kevin Roche John Dinkeloo and Associates Records at the Yale University Library’s Manuscripts and Archives.

Figure 2.36: A-6 Drawing Sheet Detail with GSFs. Courtesy of Kevin Roche John Dinkeloo and Associates Records at the Yale University Library’s Manuscripts and Archives.
All numbers were rounded to the nearest whole number, so some rounding errors would exist, but a reliable GSF for the FAC during the year 1976 was tabulated. Total GSF was 206,641 sq. ft. (19,197.58 m²). This would be the value that was used to calculate EUI for the FAC after reconciling the square footage numbers that both the Revit Model and the DesignBuilder model produced internally (see Appendix E, “Model Square Footage Reconciliation”).

2.12 Calibration and Validation

2.12.1 Background

Within the AEC community the accuracy of an energy model is an ongoing topic. Inevitably, the frequently reported discrepancy between real building metered and documented energy use versus the simulated results is brought into the conversation.

_For as long as predictive models of any sort have been prepared, there has been a (sometimes raging) discussion about how accurate they are. Essentially, they’re all wrong if you consider accuracy as “matching reality exactly.” They can be very useful, however. The challenge is to recognize where and why models diverge from reality and when it matters for the purpose at hand. In other words, how can we maximize “usefulness?”_259

A major use of whole building energy modeling in the recent past has been to create a reasonably creditable digital representation of a proposed building to test assorted siting options, siting orientations, fabric and system options, window-to-wall

Notes

258 Note: Ecotect’s use in the project did not involve EUI calculations, so precise GSF within Ecotect was not a concern.
259 (Dirkes II May 2016)
ratios, etc. This is needed to evaluate the potential impact of the selected choices on energy usage and energy usage’s related economics.

A related, but alternative purpose has been to create a reasonably creditable digital representation loaded with minimum ASHRAE standards and code limitations. This model is then simulated to establish a “Baseline Model”, which informs the user of a prescribed minimum energy performance for the proposed building. The “Baseline Model” is then subjected to similar alternatives to those listed above, i.e. siting options, fabric and system alternatives, window-to-wall ratios, etc. with the intent of demonstrating percentages of annual energy consumption reductions. The reductions are then used to meet delineated levels of energy performance improvement as designated by Green Building Rating Systems, e.g. United States Green Building Council (USGBC) advancing the possibility of qualifying for a more prestigious certification level.

Neither of the above two scenarios are a negative and both have favorably impacted the design and construction of buildings with improved energy performance as well as driving improvements in modeling software. Neither of those two modeling tactics is particularly concerned with actual energy use, rather the interest lies in relative energy use.

Modeling an existing building possessing metered energy data or energy records and then duplicating the building in all relevant aspects raises the bar considerably. Now the “Baseline Model’s” simulation output, is intended to represent the real building’s energy use, and a modeled intervention is meant to reveal not comparative changes, but rather reflect a real energy reduction or increase. If the intervention is implemented, new
post intervention energy data acquired and checked against the simulation outputs a matching of the data is unequivocally - a model’s ultimate credibility.

The terms used to establish an energy model’s credibility are defined by ASHRAE:

**Calibration models** compare “theory” to reality (actual utility use). Done well the end result is a good virtual representation of building performance. That virtual representation can be used to evaluate the impact of changes with high confidence in the results.

**Verification models** are used when a substantial energy conservation measure (ECM) has been implemented to compare actual post-ECM performance against the predicted performance.

**Comparison models** evaluate “eco-system” ECMs, which represent a system change that affects many aspects of operation. Heating, cooling, operating schedule, control schemes, and climate interact in ways that are not always intuitive.²⁶⁰

This project uses all three model types. The “FAC 2016 Baseline Model” (see 2.12.4, “FAC 2016 Baseline Model Calibration”). is used as a Calibration Model. The “FAC 1976 Baseline Model” (see 2.12.5, “FAC 1976 Baseline Model Verification”) is used in the context of both a Verification Model and a Comparison Model and is referred to as a Validation Model.

It will never be possible to be one hundred percent certain of all of the variables that are entered into an energy modeling program anymore then is it possible to be one hundred percent certain of all of the variables involved in the construction and operation of an existing occupied and operating building. Are lights or equipment left on when they should be off? Is there an incorrectly sized systems pump or fan? Are thermostats

**Notes**

²⁶⁰ (Dirkes II May 2016, 58-60)
maintained at design setpoints? Was a detail overlooked during construction creating elusive, difficult to detect thermal bridges or air leakages? Are mechanical systems receiving scheduled and correct maintenance? Are systems performing at designed efficiencies? Everything associated with human control is suspect and forever in flux, sometimes in synchrony with the model and at other moments in discord.

### 2.12.2 FAC Model

It is possible to optimize the accuracy of a model. There are three broad categories of inputs into a model. The first category contains the inputs that are based on observable, definable, and measurable entities. The Methodology chapter has delineated and detailed these entities and the processes that were involved in collecting the information pertinent to them and transferring this information into the model:

- **Accurate geometry was constructed recreating the real building with small GSF margins of error between the actual building and the DesignBuilder model, i.e. Revit Model, -1.17%; DesignBuilder Model, -3.07%, (see 2.2, “Modeling Geometry” and Appendix E, “Model Square Footage Reconciliation”).**
- **Accurate digital geo-positioning and orientation of the digital model was made possible through use of GoogleEarth.**
- **Accurate construction details were made possible through the availability of original “Construction Documents”, original “Specification Documents”, and site visits.**
- **Accurate material properties were made possible by the plentiful assortment of books, journal articles, and websites referencing assorted material property metrics.**
- **Zoning was accurately inserted with the aid of detailed occupancy and program delineations taken from the original “Construction Documents” and, original “Specification Documents”. Solar orientation of zones was implicit from the building’s siting and orientation.”
• Systems and design setpoints were accurately programmed based on the specifications of the original equipment taken from the original “Construction Documents” and, original “Specification Documents”. Further checking of accuracy was accomplished through interviews with UMass Facilities Engineers (see “Footnote 223”).

• The accuracy of the existance of the dominant lighting technology used in the 1976 FAC (Flourescent T-12s) is substantiated by the original “Construction Documents” and, original “Specification Documents”. It is also supported by the 2004 “UMass Energy Services Contract” with Johnson Controls that initiated a campus wide flourescent lighting upgrade from T-12 to T-8 technology.\(^{261}\)

• Accuracy of the weather file was improved with the adjustment of embedded TMY HDD, necessary to duplicate HDD at the FAC site on UMass-Amherst campus in order to compare space heating loads (see Appendix D, “HDD Reconciliation”).

The second category includes inputs where accuracy is not as definitive as in the first category (there are no concrete walls to inspect) and is reliant on the modeler’s research based decision making, i.e. air leakage, water usage, and plug loads. The Methodology chapter has dealt with each of these topics delineating the reasoning behind the informing of the metric that was input into the model (see 2.6, “Constructions” & 2.9, “Lighting & Plug Loads”). These inputs have been reduced to hard metrics, but they are not infallible, rather they can only be characterized as reasonably accurate after a simulation and comparison with real energy usage.

The third category, the one that is impossible to model with reasonable accuracy is human behavior. In a real building the unanticipated behaviors of occupants, maintenance personnel, and administrators profoundly affect the performance of a

Notes

\(^{261}\) (UMass Amherst 2004)
building. The energy model is ignorant of those possibilities and performs as if the world was a perfect and static place.

Does this remove the model from the possibility of being considered accurate? Does improved accuracy result in an accurate model or merely a more accurate model? Is a more accurate model still an inaccurate model? Can an accurate model become a precise and accurate model? Is there a threshold to reach?

Accuracy is a range that expresses a degree of uncertainty. In an energy model, the accuracy of the whole model is a summation of the accuracy of the individual inputs. The more of these inputs that are at an absolute standard, reflecting duplication of the real building’s characteristics, the more accurate the model. The hours of modeling geometry and programming with definitive metrics have improved the accuracy of the FAC model enormously, but absolute accuracy is compromised by the inputs belonging to categories two and three.

It is also important to recognize the varying degree of impact on total model accuracy that individual inputs have on this accuracy. A small error in the conductivity of an envelope assembly will have significant impact on the total energy consumption of a model, because space heating loads represent very substantial percentages of the total building loads (63.6% in the “FAC 1976 Baseline Model”). A large error in DHW usage will have negligible impact on the total model, because energy used to produce the DHW is a very small amount of total model energy (0.3% in the “FAC 1976 Baseline Model”).

The inputs from the first category, where we are most certain of accuracy, contain the component areas from the model geometry, material conductivities from the “Construction Template”, solar gain coefficients from the weather file, and system
capacities from the “HVAC Template”. They affect major energy consumption categories, e.g. space heating, space cooling, and system electric loads (pumps and fans). The first two, space heating & space cooling, represent 76.09% of total energy consumption of the “FAC 1976 Baseline Model”. Add in the third and the percentage soars to 93.20%. These three categories are influenced by other inputs, e.g. occupancy density and behaviors, but not significantly relative to the total loads.

If the intent of the model is to examine specific component usage impact, then the accuracy of those components’ usage inputs are critical, but if the modeling intent is whole building energy consumption then the importance of the accuracy of minimally impacting inputs on total model accuracy must be taken into consideration.

2.12.3 Calibration

By convention, an energy model is considered calibrated if the coefficient of variation of the root mean square error CV(RMSE) is less 15%.\(^{262}\) 15% is not an especially rigorous target, especially for an energy model where iterations of changes, Energy Conservation Measures (ECM), are imposed on a model. As each ECM is added to the model, there is a compounding effect and increased level of uncertainty (Fig.2.37). Lower CV(RMSE) must be the goal in order to have confidence in the simulations.

The ASHRAE protocol is intended for existing buildings for which energy consumption data is available. For the FAC, this was not the case as energy consumption

**Notes**

\(^{262}\) (ASHRAE 2002)
data was not available in 1976, so it was necessary to employ an alternate strategy to
determine if the 1976 model was performing similarly to the building in the 1976 world.

![Figure 2.37: Compounding Effects of High CV(RMSE). Courtesy of Benjamin Weil.](image)

**2.12.4 FAC 2016 Baseline Model Calibration**

The FAC’s Energy data, i.e. steam usage and electricity consumption is metered and the energy usage data is available from “UMass-Amherst Physical Plant”:

- Six years of data (July 2009 thru June 2015) was acquired and averaged.
- In 1998, 4742 sq.ft. (440.55 m²) of conditioned space was added to the FAC, which when added to the KRJDA GSF, 206,641 sq.ft. (19,197.58 m²), would total 211,383 sq.ft. (19,638.12m²). The additional conditioned space represents 2.24% of the existing FAC’s GSF. Energy consumption averages were reduced by this factor to more accurately reflect the consumption of the models geometry, which did not include the 1998 additions (see Appendix F, “Reconciliation of 1998 Additions”).

The “FAC 1976 Baseline Model” of the FAC received the following changes:

- All window and skylite glazings that had been improved from single pane to double pane were inputted.

**Notes**

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263 Note: “Baseline Model” as use in this document refers to an energy model of an existing building that closely duplicates the performance of the real building at a designated point in time. It can be a contemporary moment or a time in the past.

264 Note: New conditioned spaces include the enclosing of the main lobby between the Auditorium and the Theatre and enclosing the lobby outside of Music Auditorium.
- Solar Absorptance of buff-colored concrete was changed to reflect existing degraded condition.
- Construction of sloped concrete roofs that had originally been exposed buff-colored concrete and had received an additional layer of lead-coated copper cladding were altered to include the new material with associated physical properties.
- Fluorescent Lighting was changed from T-12 to T-8 technology.
- Fuel Source was changed from Coal to Natural Gas.
- All Activity Data (included Plug Loads) were changed to “DesignBuilder ASHRAE Library” default inputs for each of the individual FAC programs.
- All Schedules were changed to “DesignBuilder ASHRAE Library” default inputs for each of the individual FAC programs.

The “HDD Compensation Protocol” (see Appendix D, “HDD Reconciliation”) was applied to the simulation results. There were no other changes made to the model, which is now termed, “FAC 2016 Baseline Model”.

Energy data recorded by “UMass-Amherst Physical Plant” for the FAC for the six years, July 2009 thru June 2015 (Table 2.3) was used to calibrate the model. Protocols for converting pounds of steam to KBtu are discussed (see Appendix D, “HDD Reconciliation”). Six-year average consumption numbers were determined.

Table 2.3: FAC Energy Consumption Averages July 2009 thru June 2015.

<table>
<thead>
<tr>
<th></th>
<th>Six-Year Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Totals (KWh)</td>
<td>2,427,196.49</td>
</tr>
<tr>
<td>Electricity Totals (KBtu)</td>
<td>8,281,934.22</td>
</tr>
<tr>
<td>Steam Total (Pounds)</td>
<td>12,804,465.89</td>
</tr>
<tr>
<td>Steam Total (KBtu)</td>
<td>15,288,532.27</td>
</tr>
<tr>
<td>Steam Total (KWh)</td>
<td>4,480,626.71</td>
</tr>
<tr>
<td>Total (KBtu)</td>
<td>23,570,466.49</td>
</tr>
<tr>
<td>Total (KWh)</td>
<td>6,907,822.15</td>
</tr>
</tbody>
</table>
Adjustment were made to compensate for the additional 4,742 sq. ft. (440.55 m²) representing 2.24 percent of conditioned space that had been added since 1976 (Table 2.4).

Table 2.4: 2.24% Energy Usage Compensation for Additional Conditioned Space added since 1976.

<table>
<thead>
<tr>
<th></th>
<th>Six Year Average</th>
<th>Adjusted Usage (-2.24%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Totals (KBtu)</td>
<td>8,281,934.22</td>
<td>7,991,973.50</td>
</tr>
<tr>
<td>Electricity Totals (KWh)</td>
<td>2,427,196.49</td>
<td>2,342,216.33</td>
</tr>
<tr>
<td>Steam Total (KBtu)</td>
<td>15,288,532.27</td>
<td>14,945,561.36</td>
</tr>
<tr>
<td>Steam Total (KWh)</td>
<td>4,480,626.71</td>
<td>4,380,111.85</td>
</tr>
<tr>
<td>Total (KBtu)</td>
<td>23,570,466.49</td>
<td>22,937,534.86</td>
</tr>
<tr>
<td>Total (KWh)</td>
<td>6,907,822.15</td>
<td>6,722,328.19</td>
</tr>
</tbody>
</table>

The “FAC 2016 Baseline Model” constructed and programmed as described was simulated for one year with Chicopee Falls-Westover Air Force Base TMY file (Table 2.5).

Table 2.5: “FAC 2016 Baseline Model”: Simulation Results.

<table>
<thead>
<tr>
<th></th>
<th>Simulated Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Totals (KBtu)</td>
<td>8,987,037.36</td>
</tr>
<tr>
<td>Electricity Totals (KWh)</td>
<td>2,633,840.78</td>
</tr>
<tr>
<td>Steam Total (KBtu)</td>
<td>13,224,242.07</td>
</tr>
<tr>
<td>Steam Total (KWh)</td>
<td>3,875,642.95</td>
</tr>
<tr>
<td>Total (KBtu)</td>
<td>22,211,279.43</td>
</tr>
<tr>
<td>Total (KWh)</td>
<td>5,923,341.56</td>
</tr>
</tbody>
</table>

The “FAC 2016 Baseline Model” with adjusted Steam KBtu totals after “HDD Compensation Protocol” was applied (to Space Heating Steam only) (Table 2.6).
Table 2.6: “FAC 2016 Baseline Model”: Deviation from Metered Data with HDD Compensation Protocol.

<table>
<thead>
<tr>
<th>Simulated Results</th>
<th>Deviation from Metered Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Totals (KBtu)</td>
<td>8,987,037.36</td>
</tr>
<tr>
<td>Electricity Totals (KWh)</td>
<td>2,633,840.78</td>
</tr>
<tr>
<td>Steam Total (KBtu) Adjusted</td>
<td>14,297,766.59</td>
</tr>
<tr>
<td>Steam Total (KWh) Adjusted</td>
<td>4,190,232.43</td>
</tr>
<tr>
<td>Total (KBtu)</td>
<td>23,284,803.95</td>
</tr>
<tr>
<td>Total (KWh)</td>
<td>6,824,102.72</td>
</tr>
</tbody>
</table>

The difference of 995,063.86 KBtu (291,624.44 KWh), 11.07%, of electricity usage from simulated to metered was expected as the electrical simulation outputs are very dependent on the schedules that are programmed into the model. In the case of the “FAC 2016 Baseline” model, all of the schedules were from the DesignBuilder ASHRAE Library and cannot accurately reflect all of the idiosyncratic schedules that exist within the FAC’s multi-programmed spaces. Only detailed surveys can refine scheduled data. Over seventy schedules were created to program the 1976 model. Determining present day schedules through the use of dataloggers and surveys amounts to a significant time investment with the rewards of improving a model that was calibrated well within ASHRAE protocol deemed unproductive in view of the amount of time required.

The model’s simulated steam usage adjusted after “HDD Compensation Protocol” varies less than 5% (-4.53% deviation) from the metered data. This is consistent with the fact that the dominant use of steam in the model is for space heating, which is primarily a response to the physical characteristics of the model, i.e. geo-position, orientation, geometry, construction details, material properties, zoning, mechanical systems, and weather file. These are programmed inputs, which have the most impact on the accuracy
of the model’s steam consumption (see 2.12.2, “FAC Model”), but other factors can account for the discrepancy:

- Use of the default setback schedules can inaccurately predict when heating setbacks are activated or not activated affecting space heating fuel consumption
- The use of default occupancy schedules also can impact heating loads as when lights and equipment are turned on there is less mechanical space heating required. This would be consistent with the +11.07% electricity consumption deviation of the model from average metered consumption total.
- The solar absorptance value inputted into the FAC, representing the degraded condition of the concrete, might be too high (see 2.6, “Constructions”) which increases solar impact on the building and decreases mechanical heating and fuel consumption.

Just as in a real building it is a complicated and intricate dance that goes on between the various activities and schedules that exist in a model. Simulation predictions using defaults are rarely as accurate as when custom data inputs are employed.

However, programmed in this manner and without any further effort to improve the imperfect default inputs the CV(RMSE) for the “FAC 2016 Model” was small, +3.15% (Table 2.7). Statistically the FAC 2016 Model was well within the ASHRAE calibration protocol, and is considered calibrated.

<table>
<thead>
<tr>
<th>Monthly Data Compared</th>
<th>CV(RMSE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+3.15%</td>
</tr>
</tbody>
</table>

A defense of the quality of the result can be made referencing Fig.2.37. Uncertainty percentages increase with the introduction of multiple EEMs, a common
practice when exploring performance optimization. The cost of implementing each intervention “package”, combined with the performance results, are deciding factors for stakeholders. In this project the explorations (see Chapter 3, “Analyses”) all maintained single EEM introductions, e.g. concrete’s solar absorptance change, resulting in a small percentage of uncertainty (Fig.2.38, blue line).

![Percentage of Uncertainty for Single EEM](image)

**Figure 2.38:** “FAC 2016 Baseline Model” Percentage of Uncertainty for Single EEM (red star). Courtesy of Benjamin Weil.

### 2.12.5 FAC 1976 Baseline Model Validation

Without period energy data the “FAC 1976 Baseline Model” cannot be calibrated in the traditional sense; however, the calibration of the “FAC 2016 Baseline Model” provides a reasonable basis for validation of the “FAC 1976 Baseline Model” when the following logic is applied:

- In 1976 the dominant use of steam in the building was for space heating, just as it is in 2016.
- The inputs related to the physical characteristics of the model are unchanged, i.e. geoposition, orientation, geometry, construction details, material properties, zoning, mechanical systems, and weather file. Exceptions are: fuel source changed (Coal to Natural Gas), sloped
concrete roofs returned to buff-colored concrete without Lead-Coated-Copper cladding, glazing returned to all single pane, main lighting system reverts to T-12 technology, and solar absorptance returned to clean buff-colored concrete.

- The simulation of the 1976 model would be as accurate as it was for the 2016 model given the consistency of unchanged inputs and the researched and established accuracy of the changes above, even though the “FAC 1976 Baseline Model” existed forty years earlier.

Continuing with that logic and related to the second category of inputs, i.e. air leakage, water usage, and plug loads. They either remain consistent with the 2016 Model (air leakage), have been demonstrated to impart minimal impact on total energy consumption (water usage), or have been refined through period research (plug loads). These inputs would not only maintain consistency with the 2016 Model, but in the case of plug loads, improve its accuracy.

The remaining third category of inputs relating to human behavior is still and always will be problematic. The degree to which it is problematic cannot be quantified, but a reasonable case can be made that the refinements made to seventy schedules in the FAC based on period research improves the accuracy of the model.

As previously stated, using ASHRAE protocol to calibrate the model would not be appropriate as the energy data is for a different building in a different time. What is relevant, however, is reviewing the simulation outputs of the “FAC 1976 Baseline Model” and comparing the simulated data with the 2010-15 average energy consumption. The reported results demonstrate small deviations (Table 2.8).
Table 2.8: “FAC 1976 Baseline Model”: Simulation Results compared to 2010-2015 Metered Consumption (all compensation protocols applied).

<table>
<thead>
<tr>
<th></th>
<th>Simulated Results</th>
<th>1976 Deviation from Metered Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Totals (KBtu)</td>
<td>7,758,503.65</td>
<td>-3.01%</td>
</tr>
<tr>
<td>Electricity Totals (KWh)</td>
<td>2,273,793.06</td>
<td></td>
</tr>
<tr>
<td>Steam Total (KBtu)</td>
<td>14,856,790.23</td>
<td>-0.60%</td>
</tr>
<tr>
<td>Steam Total (KWh)</td>
<td>4,354,095.61</td>
<td></td>
</tr>
<tr>
<td>Total (KBtu)</td>
<td>22,615,293.88</td>
<td>-1.43%</td>
</tr>
<tr>
<td>Total (KWh)</td>
<td>6,627,888.67</td>
<td></td>
</tr>
</tbody>
</table>

Comparison of the 1976 Model with the 2016 Model (Table 2.9) reveals the following consistencies of expectations. The decrease in electricity consumption of 1,228,533.71 KBtu (360,047.70KWh), -13.67%, from the 2016 Model was expected for two reasons:

- When in use, the lighting’s electrical consumption increased because of the use of T-12 technology; however, the electrical simulation outputs are tempered by dependencies on the occupancy schedules, which are programmed into the model. These custom schedules have had attendant impact on lighting electrical loads.

- Equipment loads in spaces are similarly decreased by refinements in schedules.

- “Office Plug Loads” consumption levels were reduced (see 2.4, “Programming”) with additional reductions are imposed by the schedules.

As expected the steam consumption totals are similar with the 1976 Model demonstrating only slightly more steam consumption (3.76%). A response to:

- Sloped concrete roof solar absorptance returned to buff-colored concrete without Lead-Coated-Copper cladding.

- Glazing returned to all single pane.

- Solar absorptance adjusted for clean buff-colored concrete on all concrete surfaces.
Table 2.9: Simulation Data Comparison between 2016 and 1976 Model.

<table>
<thead>
<tr>
<th></th>
<th>2016 Simulated Results</th>
<th>1976 Simulated Results</th>
<th>Deviations between 2016 and 1976 Metered Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Totals (KBtu)</td>
<td>8,987,037.36</td>
<td>7,758,503.65</td>
<td>-13.67</td>
</tr>
<tr>
<td>Electricity Totals (KWh)</td>
<td>2,633,840.77</td>
<td>2,273,793.06</td>
<td></td>
</tr>
<tr>
<td>Steam Total (KBtu)</td>
<td>14,297,766.59</td>
<td>14,856,790.23</td>
<td>+3.76</td>
</tr>
<tr>
<td>Steam Total (KWh)</td>
<td>4,190,261.94</td>
<td>4,354,095.61</td>
<td></td>
</tr>
<tr>
<td>Total (KBtu)</td>
<td>23,284,803.95</td>
<td>22,615,293.88</td>
<td>-2.88</td>
</tr>
<tr>
<td>Total (KWh)</td>
<td>6,824,102.72</td>
<td>6,627,888.67</td>
<td></td>
</tr>
</tbody>
</table>

The change in Total Energy (~2.88%) is relatively small, a combination of variations from all of the data inputs impacting both the electrical and steam consumption. These are a complicated interaction of forces, loads, and behaviors that come into play in an energy model and without access to actual period energy data with segregated and metricized usages they are difficult, even impossible, to assign.

It is acknowledged that it is not possible to calibrate the 1976 Model with ASHRAE protocol. However, two points are made supporting validation of the model:

- The consistency of the FAC 1976 Model’s simulation outputs to the 2016 Model’s simulation outputs support a real credibility to the accuracy of the “FAC 1976 Baseline Model”.
- The FAC 1976 Model’s simulation outputs, when compared to 2010-2015 energy consumption averages, are extraordinarily close, lending further support to the credibility of the accuracy of the “FAC 1976 Baseline Model”.

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2.12.6 Calibration and Validation – Section Summary

The analysis introduced in the next chapter is based on the conviction that a validated and credible energy model of the FAC has been constructed. The argument is that when conscientious and extensive effort is expended researching and verifying all of the requisite data inputs, from geometry to schedules, necessary to inform an energy model of a large complex building, as was done in the “FAC 1976 Baseline Model”, an accurate and useful outcome will result in spite of many obstacles:

The model itself will not contain the same errors and deficiencies that an existing building contains, absent Dynamic Statistical Modeling (see 2.7, Activities”):

- Lights and/or equipment can be left on when occupants are not present.
- Windows can be opened when cooling or heating systems are on as occupants seek unpredicted or unreasonable individual comfort levels.
- Incorrectly sized or failing systems pumps or fans can continue to operate.
- Thermostats can be changed to override design setpoints.
- Details overlooked during construction can create elusive, difficult to detect, or impossible to repair thermal bridges or air leakages permanently impacting energy consumption.
- Mechanical systems not receiving scheduled (or receiving improper) maintenance.

There can be errors in the data collection by the modeler, despite intensive research efforts and despite repeated scrutiny of the model, that become intrinsic components of a model creating unknown error:

- Inputs based on inaccurate recollections of interviewees.
- Inputs based on inadequate data collection procedures.
- Undetected schedule programming errors.
- Rounding errors accumulate as large numbers are rounded to ease visualization and comprehension.
Within the frontend itself there can be inconsistencies and idiosyncrasies that pollute data:

- Imprecise conversions of imperial data to metric and vice versa as programs can be written with bias toward one system or the other resulting in rounding errors as the conversion is made within the program.

- Translation of geometric data from one program to another can result in discrepancies or false interpretations of areas and volumes (see Appendix E, “Model Square Footage Reconciliation”).

In the case of calibrating a model, as was done with the “FAC 2016 Baseline Model”, the model can be correct with the error lying within the metered or documented building energy consumption data to which the model’s simulation results are compared:

- Transcription from meters to spreadsheets and one spreadsheet to another.

- A faulty steam or electric meter, e.g. orifice plate flow meters that provide the metered steam usage data are prone to errors during periods of low flow.265

- Low level leakages can occur and be undetected for long periods of time compromising consumption totals.

Finally, to all of the above obstacles must be added the worrisome caveat that what can appear to be an excellent model, calibrated with low CV(RMSE), might actually have two errors that effectively cancel each other out. Accuracy is proofed out, but does not exist.

In the AEC world of evaluating an existing building possessing energy consumption data through calibration using ASHRAE protocol, the standard is set, i.e. less than 15% CV(RMSE). It is a statistically accepted convention, albeit with a huge

Notes

265 (Fiocchi, Hoque and Weil, Matching Building Energy Simulation Result against Measured Data with Weather File Compensation Factors 2014)
accuracy range. The statistical sampling set is quite large as can be judged by United States Green Building Council’s report, claiming over 74,500 commercial projects completed by year-end 2015.\textsuperscript{266} Many of these buildings would have used calibrated energy models to maintain energy consumption credits.

The “FAC 2016 Baseline Model” with +3.15\% CV(RMSE) deserves inclusion in this group, if further efforts were made in customization of the inputted ASHRAE default schedules the CV(RMSE) value should improve.

The “FAC 1976 Baseline Model” is a sample group of one, lacking a precedent. Efforts can be found where period buildings have been inserted into energy models for the purpose of studying solar loads,\textsuperscript{267} shading strategies,\textsuperscript{268} or comparative energy consumptions based on proposed interventions.\textsuperscript{269} However, all have been executed on simpler building forms and never with the intent recapitulating real energy usage and calibrating or validating a model.

This work maintains that for some buildings, especially the ones belonging to the Brutalist sector, where geometry is relatively static because of the intransigence of concrete construction, that a valid methodology has been proposed to create a model that cannot be calibrated with ASHRAE protocol, but in actuality can be superior to all but a minority of ASHRAE calibrated models. This model exists within a range of accuracy that is small for an energy model and is a validated product, if not a calibrated one. It is

Notes

\textsuperscript{266} (USGBC 2016)
\textsuperscript{267} (Fiocchi, Shahadat and Hoque 2011)
\textsuperscript{268} (Fiocchi and Hoque, Sustaining Modernity: An Analysis of The Gropius House 2011)
\textsuperscript{269} (Douglas and Leake 2011)
expected, based on the methodology described, that the “FAC 1976 Baseline Model’ will reasonably predicts the 1976 energy usage of the real University of Massachusetts-Amherst Fine Arts Center and will be most effective in illustrating and supporting the analyses performed on the building.
CHAPTER 3

ANALYSES

Evaluation: to determine the significance, worth, or condition of; usually by careful appraisal and study.\footnote{Merriam-Webster n.d.}

Modernist buildings as an architectural category, Brutalist buildings as a collective subset of Modernist buildings, and individual examples of Brutalism have each been dissected relevant to social and architectural: history, perception, reception, and acceptance (see “Chapter 1”). A neglected aspect of evaluation, in need of study, is performance. Performance as related to building energy consumption and occupant comfort.

The study should examine the buildings, both in their entireties and in spatially specific programmatic subdivisions, i.e. zones and rooms/spaces. The study should, also, examine the contributions of original design strategies, existing material properties, and assembly constructions as they relate to performance.

When an understanding of these elements has been included in the evaluation a complete and valid evaluation will be the outcome. The following analyses of the FAC is an effort to be an early contributor to this type of complete evaluation.

3.1 FAC EUI

Once a building’s EUI has been determined the question of which buildings should it be compared to arises. For this project, the decision was to compare the FAC’s

Notes

\footnote{Merriam-Webster n.d.}
EUI with the buildings surveyed in the most recent CBECS, Table C5: *Consumption and Gross Energy Intensity by Census Region for Sum of Major Fuels, 2012*, released in May of 2016 (Table 3.1).  

Evaluation of energy performance requires more than dissociated adjectives, e.g. good, bad, great, terrible. Comparisons imbued with the authority imparted by a metric are mandatory. The metric CBECS uses, kBtu/sq.ft. (KWh/m$^2$) allows buildings of similar age, size, construction type, programmatic use, climate locations to be evaluated with respect to the amount of total energy (fossil fuel and electricity) use per unit area over a one-year period.

Table 3.1: EUI Data from “CBECS 2012 Table C5”.

<table>
<thead>
<tr>
<th>For Buildings in the Northeast</th>
<th>EUI (kBtu/sq.ft. (KWh/m$^2$))</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Buildings</td>
<td>93.9 (296.08)</td>
</tr>
<tr>
<td>Building Floor Space 200,001 – 500,00 sq.ft.</td>
<td>109.7 (345.83)</td>
</tr>
<tr>
<td>Principal Building Activity: Education</td>
<td>82.1 (258.82)</td>
</tr>
<tr>
<td>Year constructed: 1970-1979</td>
<td>134.9 (425.27)</td>
</tr>
<tr>
<td>Climate Region: Mixed-Humid</td>
<td>104.7 (330.06)</td>
</tr>
<tr>
<td>Government Owned: State</td>
<td>153.4 (483.59)</td>
</tr>
<tr>
<td>Predominant Exterior Wall: Material Concrete</td>
<td>101.6 (320.29)</td>
</tr>
<tr>
<td>Predominant Roof Material: Built-up</td>
<td>113.4 (357.48)</td>
</tr>
<tr>
<td>Roof Characteristic: Flat</td>
<td>105.4 (332.27)</td>
</tr>
<tr>
<td>Energy Source: District Heat</td>
<td>143.5 (452.38)</td>
</tr>
</tbody>
</table>

Notes  

271 (U.S. Energy Information Administration n.d.)  
272 Note: Only categories relevant to the FAC were selected from the “CBECS 2012 Table C5”.
From this point forward, all simulation outputs and EUIs will be discussed with reference to this table, placing one Brutalist building, the FAC, into a context where it can be metrically compared to other buildings of related type or with similar characteristics.

The “FAC 1976 Baseline Model” simulates an EUI of 109.44 KBtu/sq.ft. (345.01 KWh/m²). A comparison with the “CBECS 2012 Table C5” reveals the FACs position amongst its contemporaries (Table 3.2).

Table 3.2: Comparison of “CBECS 2012 C5 Table” EUI Data with “FAC 1976 Baseline Model”.
Note: Red signifies poorer performance.

<table>
<thead>
<tr>
<th>For Buildings in the Northeast</th>
<th>EUI KBtu/sq.ft. (KWh/m²)</th>
<th>FAC’s % Deviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAC 2016 Baseline Model</td>
<td>109.44 (345.01)</td>
<td>0</td>
</tr>
<tr>
<td>All Buildings</td>
<td>93.9 (296.08)</td>
<td>+16.55</td>
</tr>
<tr>
<td>Building Floor Space:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200,001 – 500,00 sq.ft.</td>
<td>109.7 (345.83)</td>
<td>-0.24</td>
</tr>
<tr>
<td>Principal Building Activity:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>82.1 (258.82)</td>
<td>+33.30</td>
</tr>
<tr>
<td>Year constructed:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970-1979</td>
<td>134.9 (425.27)</td>
<td>-18.87</td>
</tr>
<tr>
<td>Northeast Climate Region:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed-Humid</td>
<td>104.7 (330.06)</td>
<td>+4.53</td>
</tr>
<tr>
<td>Government Owned:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>State</td>
<td>153.4 (483.59)</td>
<td>-28.66</td>
</tr>
<tr>
<td>Predominant Exterior Wall:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material Concrete</td>
<td>101.6 (320.29)</td>
<td>+7.72</td>
</tr>
<tr>
<td>Predominant Roof Material:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Built-up</td>
<td>113.4 (357.48)</td>
<td>-3.49</td>
</tr>
<tr>
<td>Roof Characteristic:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat</td>
<td>105.4 (332.27)</td>
<td>+3.83</td>
</tr>
<tr>
<td>Energy Source:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>District Heat</td>
<td>143.5 (452.38)</td>
<td>-23.74</td>
</tr>
</tbody>
</table>
The data demonstrates that in the Northeast U.S. the FAC performs more poorly than all buildings of all types and sizes (-16.55%) and substantially more poorly than buildings with the principal activity of education (-33.30%).

The FAC performs similarly to all buildings of similar size (+0.24%), with buildings using built-up roof material as the predominant material (+3.49%), with buildings having flat roofs (-3.83%), with buildings located in the same Northeast Climate Zone (-4.53%), or with buildings constructed with concrete walls (-7.72%).

The FAC performs better than all buildings constructed in the same decade (+18.87%) or utilizing district heating (+23.74%) and substantially better than other state owned and operated buildings (+28.66%).

Overall the FAC’s performance can be characterized neither as especially good or bad, but rather as ordinary. Perhaps a surprise to the pundits of Brutalist building’s performance. A closer look at each of the categories yields additional insights:

- “All Buildings” in the “CBECS 2012 C5 Table” includes 15,534,000,000 sq.ft. (1,443,155,820.00 m²) of GSF, constructed in the Northeast U.S. up until 2012. These buildings would include the poorest performers as well as the finest high performance state-of-the-art constructs.
  - As more high performance buildings have populated the Northeast the average EUI has diminished. The EUI for all buildings in the Northeast was 98.5 kBtu/sq.ft. (361.91 KWh/m²) in the preceding survey, i.e. “CBECS 2003 Table C5” 273.
  - In the context of the previous survey the EUI of the FAC is within 7.16%, rather than the 16.55% calculated from the average in the 2012 survey. Notable given the FAC’s

### Notes

273 (U.S. Energy Information Administration 2006)
monolithic concrete construction (see 3.2.1, Monolithic Wall vs. Layered Assembly Wall”).

- “Large Buildings” typically have high occupancy numbers, high envelope to volume ratios, and multiple systems. All of these contribute to higher EUI (EUI is directly proportional to size, see complete “CBECS 2012 Table C5”). The FAC’s lower EUI than the average building of its size can be attributed to:
  - Low window-to-wall ratio (5.82%):
    
    Windows should clearly be considered first: in terms of importance to energy consumption, the window-to-wall ratio (WWR) and window performance are likely the most significant decisions for a low-energy commercial or institutional building. Contrary to the belief of some, highly-glazed buildings (WWR>40%) in cold climates do not save more daylighting energy than they lose in heat. Large swaths of south-facing windows rarely collect more useful free heat during the day than they lose at night. These are myths of a by-gone era...

  - While data could not be found comparing the average underground GSF to aboveground GSF ratio in large buildings the “Level Plans of the FAC” (Figs.1.70 - 1.74) indicate a substantial amount of underground space. In these locations the reduced Delta-T between conditioned space and exterior (ground temperature vs. ambient air temperature), reduces both heating and cooling loads as well as limiting air leakage.

  - An abbreviated operations schedule, which responds to the academic year calendar rather than a commercial working year calendar reduces associated occupancy driven building loads, e.g. lighting and plug loads. Additionally, permitting mechanical systems to operate at setback or be turned off.

- “Education”, is the sole category where the FAC fairs substantially more poorly with an EUI 33.30% higher than the average. This can be attributable to a minority representation of

Notes

274 (Straube 2014, 3)
275 (Meixel Jr. 1981, 256)
its building type in academia (see 1.1.3, “Residential Sector” & 1.1.4, “Corporate and Institutional Sectors”).

- Additionally, the Education Sector has accumulated a high percentage of Green Buildings, when compared to other sectors, where cost can intrude on decision making and connecting the built environment to climate change is less frequently discussed. In comparison, higher education is in the forefront of addressing building’s implication in climate change.276

- Similarly to the “All Building” category, when the “CBECS 2003 Table C5” is referenced the EUI for Education buildings is 101.6 KBtu/sq.ft. (373.31 KWh/m²) resulting in a drop from 33.30% to only 7.17% poorer then the CBECS average.

- “Northeast Climate Zone”, “Constructed of Concrete Walls”, and “Built-up and Flat Roofs” are all categories in which the FAC demonstrates similar EUI to the CBECS data. This is attributable to the FAC being categorized with buildings that are most similar in construction type, i.e. flat roofed, monolithic concrete buildings in the same climate zone. This category would include the majority of the Brutalist buildings in the Northeast U.S.

- CBECS’ “Buildings Constructed in the same Period, 1970-1979” demonstrate a higher EUI than the FAC (+18.87%). Of the ten time periods in the “CBECS 2012 C5 Table” the 1970-1979 period has the highest EUI, the closest was the following decade’s EUI of 109.3 KBtu/sf (401.59 KWh/m²) and it is a positive that the FAC EUI is 18.87% lower than the average in this category.

- The higher performance of the FAC when compared to State owned and operated buildings (+28.66) is perhaps a tribute to the maintenance efforts of the UMass Physical Plant engineers. The importance of scheduled maintenance to optimize a system’s performance is significant.277

Notes

276 (Naik 2013)
277 (Piper 2009)
The following sections will investigate the factors that contribute to the FAC’s EUI of 109.44 KBtu/sq.ft. (323.69 KWh/m²).

3.2 The Obvious

3.2.1 Monolithic Wall vs. Layered Assembly Wall

Even the most ardent supporter of Brutalist architecture should be reluctant to make the claim that the conductive qualities of a monolithic concrete building, the FAC being an exemplar of the type, are better than poor. The limitations of monolithic reinforced concrete when used as a building’s exposed finishing and structural material, since it emerged as the Brutalist designers’ finish and structural material of choice in the 1950s, has been previously discussed in multiple sections (see 1.1.4, “Corporate and Institutional Sectors”; 1.2.1, “Definition”; 1.2.3.2, “Building Geometry”; 1.2.3.4, “Construction Module Scale”; 1.2.3.5, “Lack of Ornamentation”; 1.2.3.8, “Brutalism’s Concrete”; 1.2.5.2, “Tadao Ando’s Concrete”; 1.3.1.4, “Roche and Concrete”; 1.3.2.3, “FAC Concrete”; 1.3.2.4, “Design and Construction”; 2.2.2, “Digital Drawing”).

Although ignorant of some of concrete’s long-term eccentricities and shortcomings, the designers and engineers of the Brutalist period were not ignorant of concrete’s thermal inadequacy (see below and 3.2.2, “Possible Contemporary Interventions”); rather they elected to and could afford to ignore this quality as energy
consumption and related carbon impact\textsuperscript{278} (see 3.5.2, “Demolition and Embodied Energy”) was not a consideration at that time in history (see 1.2.6.2, “Architects Education” & 1.3.2.5, “FAC Systems”). They also possessed an awareness and a concern (without a comprehensive understanding) that within layered construction assemblies there were thermal gradients and condensation issues that could at times precipitate serious problems.

Colin Porteous writes in \textit{The New Eco-Architecture: Alternatives from the Modern Movement} how, in the 1930s, architects such as Albert Frey, Mies van der Rohe, A. Lawrence Kocher, William Lescaze, and John H. Howe, among others, were studying layered assemblies.

\textit{There is ample evidence, and some already suggested, that in many instances the precise make-up of the opaque components mediating between inside and outside was very carefully considered, not only in terms of structural fitness, durability and weatherproofing, but also in terms of thermal adequacy.}\textsuperscript{279}

Porteous continues with a discussion of condensation and the advantage of monolithic hygroscopic wall construction, a subset to which the monolithic concrete wall belongs:

\textit{However, mono-material constructions do have other thermal advantages compared with multi-material ones. If there is only one material, there is only one set of thermal properties - density, specific heat capacity, thermal conductivity and vapor permeability. Consequently, there is no risk of interstitial condensation, and if the material is hygroscopic ... there is also no likelihood of surface}

\textbf{Notes}

\textsuperscript{278} Note: Carbon is not the same as carbon dioxide, a greenhouse gas, but is often used, in this work, as a shortened form of the term of ‘carbon dioxide emissions’.

\textsuperscript{279} (Porteous 2002, 13)
condensation. The material simply self-adjusts with respect to moisture content and this sponge effect, as well as inhibiting surface condensation, will also tend to lower relative humidity (RH) within occupied rooms. Also, Simonson, has shown that solar radiation reduces the moisture content ... and hence increases their vapor permeability.280

Porteous concludes the chronology with:

In general, although by the 1960s the initial temporary post-war building period had moved on to an apparently more secure phase in terms of investment, it is paradoxical that building technology was so shy of sophisticated prefabrication. Rather it regressed to a more traditional plateau, from which there have been few advances in spite of the micro-chip, petro-chemicals, and research related to space exploration.

...has the construction of external floors, walls and roofs evolved through the decades in a climate of ignorance or one of knowledge gained through experience and research? The answer may well be a mixture of both, given the evidence. But the prevalence of poor construction supports the former contention and reinforces the case for shifting the emphasis of our published material. Constructional and spatial interpretation and analysis of buildings are required in equal measures.

Then in terms of this appraisal, is it possible to identify post-war trends or characteristics arising from the Modern Movement? It has been shown that the main advantage offered by a multi-layer construction is a fairly high thermal resistance for a fairly modest thickness. However, due to inherent vulnerability to interstitial condensation, specification of materials and ventilation of any air gaps become very important. In the pre-war period the types of insulant and other relatively porous materials trends to limit damage in this respect, by the dominance of post-war problems suggests that the principles were not generally well understood by architects.281

Notes

280 (Porteous 2002, 32)
281 (Porteous 2002, 33-34)
A methodology is not available that would ascribe a fear of interstitial condensation as the primary driver for the design decision to use monolithic concrete assemblies in either Brutalist architecture as a group or the FAC as a single entity. However, it does raise the question as to what the FAC’s performance and resulting EUI would be if the wall assembly had been a layered one.

To provide insight, all exterior walls in the DesignBuilder “FAC 1976 Baseline Model” were changed from monolithic 2% reinforced steel concrete construction to a typical 1970s “Brick Layered Wall Assembly” (Fig.3.1).

![Figure 3.1: “FAC 1976 Baseline Model”: Exterior Brick Layered Wall Assemblies.](image)

The wall detail was copied from typical uninsulated brick wall assemblies used in construction of other buildings on the UMass-Amherst campus during the 1960s and 1970s (Fig.3.2) and represents a modest R-value = 5.67 ft²°F·hr/Btu (1.00 m² °C/W).<sup>282</sup> Although a poor value by today’s standards, it is a substantial improvement over the FAC’s poor monolithic wall R-value = 1.703 ft²°F·hr/Btu (0.30 m² °C/W).

**Notes**

<sup>282</sup> Note: All R-values include interior and exterior air films.
The “FAC 1976 Model with Brick Wall Construction” simulated annual energy consumption with a resulting EUI of 76.20 KBtu/sq.ft. (240.22 KWh/m²). The “FAC 1976 Baseline Model” had performed most poorly, when compared with the EUI data from “CBECS 2012 Table C5”, in the category, “Principal Building Activity: Education”. The concrete walled FAC’s EUI had shown it performed 33.30% more poorly than other educational buildings in the Northeast U.S. The change in wall assembly has shifted the FAC’s EUI substantially, to 7.18% better than the “Principal Building Activity: Education” average EUI data from “CBECS 2012 Table C5”, i.e. 82.1 KBtu/sq.ft. (258.82 KWh/m²).

Additionally, the Glaser Diagram of the “Brick Layered Wall Assembly” (Fig 3.3) shows an absence of both interstitial condensation and a reduced propensity for mold growth on the exterior, an issue that will be discussed more thoroughly (see 3.4.4, “Solar Absorptance”).

Figure 3.2: “FAC 1976 Baseline Model”: Exterior Brick Wall Layered Input in DesignBuilder.
3.2.2 Possible Contemporary Interventions

Two related interventions were imposed on the “FAC 1976 Baseline Model”. The first intervention was to add to the interior sides of all exterior walls excepting those in the theatres and auditoriums where aesthetics and acoustics would have been compromised:

- 2” (5.08 cm) of board insulation: R-value = 9.29 ft²·°F·hr/Btu (1.64 m²·°C/W).
- 2.5” (6.35 cm) air space with metal framing, effective: R-value = .7905 ft²°F·hr/Btu (0.14 m²°C/W).
- 5/8” (1.59 cm) Drywall R-value = .5636 ft²°F·hr/Btu (0.10 m²°C/W).

Installing this additional layered assembly, total thickness 5 1/8” (13.01 cm), would require:

- Execution of 90° return details with air-sealing at door and window opening interfaces.
- Relocation of all signage, electrical devices (plugs and switches), radiators and convectors to similar to original location in elevation with corrected allowance for new wall thickness.
- Interfaces with ceilings and walls with required clean air-sealed joint.

All other envelope related inputs in the model, e.g. solar absorptance and air leakage rates remain unchanged.

The scope of this work falls well within the range of similar interventions performed on masonry structures throughout the Northeast U.S. and Canada’s southern border, where performance related to high heating costs associated with high HDD values is of special interest. Concern for these buildings, which are more typically brick or stone than concrete, is that a modified thermal gradient with improper or inadequate air-sealing can lead to interstitial condensation, wherein the exterior wall’s masonry can experience degradation (efflorescence, spalling, mold) and/or interior cavities can become wet, resulting in decreased thermal performance, structural compromise, or mold/mildew issues.

In some instances spray-applied foam insulation rather than insulating boards are used, because of unevenness of the interior surfaces of exterior walls and the foam’s

**Notes**

283 (Straube, Ueno and Schumacher 2012)
inherent air-sealing qualities, but a similar result is obtained, i.e. increased R-value with 
board installation carefully detailed with air-sealing measures.

In the case of the FAC, the 2” (5.08 cm) of insulation improves the walls 
performance enormously without compromising much of the interior square footage. The 
R-value of the wall (including air films) changes from the uninsulated buff-colored 
heavyweight concrete with 2% steel wall’s R-value = 1.7023 ft²-F⁰-hr/Btu (0.30 m² 
°C/W) to R-value = 12.35 ft²-F⁰-hr/Btu (2.17 m² °C/W) with the addition of the 
insulation and interior drywall covering.

The Glaser Diagram for this assembly (Fig.3.4) demonstrates a successful 
assembly.²⁸⁴ The simulation resulted in an EUI of 82.42 KBtu/sq.ft. (259.83 KWh/m²) 
placing the FAC’s performance approximately equal (within 0.4%) to the average of all 
of the educational buildings in the Northeast U.S as reported in the “CBECS 2012 Table 
C5”.

The second intervention was an extension of the previous intervention with the 
addition of performing the identical procedure to all exterior bounding roof/ceilings 
excepting the auditoriums and theatres where aesthetics and acoustics would have been, 
similarly to a wall intervention, aesthetically unacceptable.

This is a considerably more involved intervention. These surfaces not only are 
host to lighting systems, but exposed pipes, conduits, ducts and mechanical system

Notes

²⁸⁴ Note: The Glazer Diagram also predicts condensation at the interface of the concrete 
and insulation board. The total amount is small, 35.35 grams/m², with drying during summer 
months. This amount can be reduced to close to zero with proper air sealing of insulation boards 
or alternate use of spray foams to depth of 2” (5.08 cm).
components are either anchored to the surfaces or are obstructing or hindering access to the ceiling plane. If executed, the EUI drops to 58.41 KBtu/sq.ft. (184.14KWh/m²).

Figure 3.4 Glaser Diagram: Condensation Report:
Mold Growth unlikely at worse Month (red line).

Improving the thermal performance of the FACs envelope to what is not an overly rigorous standard, e.g. compare to 2015 International Energy Code: Climate Zone 5 requires\textsuperscript{285}:

- Mass Walls Above Grade R-value = 11.4ci ft\(^2\)-F\(^\circ\)-hr/Btu (2.01ci\textsuperscript{286} m\(^2\) °C/W).
- Mass Walls Below Grade R-value = 7.5ci ft\(^2\)-F\(^\circ\)-hr/Btu (1.32ci m\(^2\) °C/W).
- Roofs, R-value = 30ci ft\(^2\)-F\(^\circ\)-hr/Btu (5.28ci m\(^2\) °C/W).

versus the FAC’s roof/ceilings and walls (excepting Auditorium and Theatre surfaces): R-value = 12.35 ft\(^2\)-F\(^\circ\)-hr/Btu (2.17 m\(^2\) °C/W) demonstrates that the FAC, divested of its poor performing thermal envelope performs better than all category averages in the “CBECS 2012 Table C5” (Table 3.3).

Notes

\textsuperscript{286} ci = continuous insulation.
No argument can support the poor thermal performance of the FAC’s concrete envelope, but with a single intervention, executing a commonplace thermal upgrade, the FAC models indicate that the FAC’s EUI would improve to a level that approaches the 50% reduction goals of the 2030 Challenge (Table 3.4). This would not take place in 2030, but could take place presently, in 2016, and for that matter could have taken place at any time in the FAC’s occupied timeline.
Table 3.4: The 2030 Challenge Targets for U.S. National Medians for College/University Campus Level Buildings.287

<table>
<thead>
<tr>
<th>Reduction Percentage</th>
<th>Expected EUI KBtu/sq.ft. (KWh/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>52 (163.93)</td>
</tr>
<tr>
<td>60</td>
<td>41.6 (131.14)</td>
</tr>
<tr>
<td>70</td>
<td>31.2 (98.36)</td>
</tr>
<tr>
<td>80</td>
<td>20.8 (65.57)</td>
</tr>
<tr>
<td>90</td>
<td>10.4 (32.79)</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

The implication is that there are strategies, concealed within the FAC, consistent with good performance. It is their operation and existence, which contributes to the FAC’s respectable EUI, once the large negative of the thermal envelope’s conductivity is eliminated from the discussion (Table 3.5).

Table 3.5: FAC Simulations compared to CBECS 2012 Table C5: Northeast Education Sector.

<table>
<thead>
<tr>
<th></th>
<th>EUI KBtu/sq.ft. (KWh/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBECS 2012 Table C5: Northeast Education Sector</td>
<td>82.10 (258.82)</td>
</tr>
<tr>
<td>FAC 1976 Baseline Model</td>
<td>109.44 (323.69)</td>
</tr>
<tr>
<td>FAC 1976 Baseline Model with Wall Insulation</td>
<td>82.43 (259.61)</td>
</tr>
<tr>
<td>FAC 1976 Baseline Model with Roof/Ceiling and Wall Insulation</td>
<td>58.41 (183.98)</td>
</tr>
</tbody>
</table>

Notes

287 (Architecture 2030 2012)
3.3 Intentional Sustainable Strategies Employed

While fossil fuel consumption was not a consideration at the time of the FAC’s design, occupant comfort was an important consideration (see 1.3.1.1, “Roche’s Personal Experiences”). Roche’s underlying design parti of creating a “Sun Machine” (see 1.3.1.3, “Roche and Modeling”) meant that the surfaces of the FAC’s exterior would absorb and reflect both the positive and the negative qualities of sunlight.

With so much attention devoted to sunlight striking the building it could be inferred that Roche was both knowledgeable and thoughtful of the impacts of the various solar loads on the building’s interiors and responded appropriately.

3.3.1 Daylight Maximization

Human attraction to interior spaces illuminated with sunlight is almost universal.

Sunlight. Daylight is consistently identified as an important and preferred feature by most people in the built environment. The simple use of natural rather than artificial light can improve morale, comfort, and health and productivity. This preference reflects the fact that humans are a largely diurnal animal, heavily reliant on light for securing resources and avoiding hazard and danger. People depend on visual acuity to satisfy various physical, emotional, and intellectual needs.\(^{288}\)

The FAC’s low window-to-wall ratio (5.82%) is a response to the building’s programs, many of which required either elimination or restriction of exterior views (see 1.2.3.7, “Transparency” & 1.3.2.2, “Description”). This was not the case with the

Notes

\(^{288}\) (Kellert, Heerwagen and Mador 2008, Chapter 1, 5-6)
approximately sixty offices or small studios that populate the perimeters of the Speech, Music, and Art Departments, or the Art Studios that line the 646-foot-long (196.90 m.), length of the Bridge.

The Ecotect Model was used to examine these spaces. The orientations of the exterior wall or walls (a few are corner offices) of the Office/Small Studio spaces are to all ordinal directions. All windows except those on the north facing exterior walls required protection of varying degrees from glare (see 3.3.2, “Glare Defense”) and all provide ample daylight to the office space as will be demonstrated.

Two example offices are used to represent the Office/Small studio group. The first, “Music Office 139” located on the east side of the Music Department (Fig.3.5) is one of a group of six offices with identical solar exposure. Of all of the perimeter offices, grouped by ordinal exposure, this group is the one most susceptible to glare. The eastern façade of the Music Department receives minimal shading benefit from other parts of the FAC complex and none from any other nearby building.

![Figure 3.5: FAC Music Office 139 (red arrow).](image)

The second, “Speech Office 112” is located on the south side of the Speech Department (Fig.3.6) and is shielded from direct solar exposure from the east, south, and west except for a limited time of the day when solar position allows brief direct sunlight
to reach this south facing elevation from over the top of the neighboring, 20 ft. (6.1 m.)
high, “Studio Theatre” less than 15 ft. (4.57 m) to the south. Later in the day, a
neighboring building shields this exposure from direct western sunlight.

The Art Studios that line the length of the Bridge are almost identical in geometry
and all subject to the same exposure. Art Studio 338 was chosen to represent the group
(Fig.3.7).

When examining daylight with Ecotect, two categories were used to quantify
data:

- Daylight Factors (metric: Percent) is the ratio of the natural illuminance at a particular point
  on a horizontal plane within a space to the simultaneously occurring external illuminance of
the unobstructed overcast sky. Three elements contribute to the factor: sky component, externally reflected component, and internally reflected component.

- Daylight Levels (metric: foot-candles or lux) are measures of illuminance, i.e. the amount of light falling onto and spreading over a given surface area.

The output data is conveyed using Ecotect’s “Analysis Grid”, which displays both metrics and graphics in a visually intuitive manner. The calculation is accomplished with “Ray Tracing”. Using the program’s analysis grid, typically covering the footprint of the space to be examined and located horizontally at a desired height\(^{289}\), the software scatters spherical rays from each analysis grid node and tracks them as they pass through windows toward the unobstructed sky, strike external objects, or are reflected off internal surfaces.

Ecotect uses a Design Sky Illuminance methodology based on the building's latitude (557.4 fc for the FAC\(^{290}\)) including an adjustable variable for window cleanliness (average x 0.90). Given the Earth's orbit around the Sun, locations closer to the equator generally have brighter skies that those closer to the poles. To account for this, the total illuminance for any location is usually given as a single design value known as a Design Sky.

*The Design Sky is an illuminance level that is exceeded 85% of the time during the hours of 9am to 5pm throughout the year. Using this value, it is possible to convert a daylight factor into an illuminance level by simply multiplying the two. Thus, a point with a daylight factor of 10% at a location with a design sky value of 5000 lux (500 foot-candles) will likely have an illuminance level of at least 500 Lux (50 foot-candles) 85% of the time.*

Notes

\(^{289}\) Analysis Grid was placed at desktop height, 30” (76.2 cm) above floor

\(^{290}\) Autodesk Ecotect Library
The Daylight Simulation of “Music Office 139” showed, Daylight Factors fell between 3.62% - 44.93% (Fig.3.8). Only 1.25%\(^{292}\) of the space fell below the minimum level, 2%\(^{293}\), for offices and classrooms.

Daylight Levels were between the ranges of 20.18 fc - 250.39 fc (Fig.3.9), demonstrating levels significantly above the Illuminating Engineering Society’s 30 foot-candles requirement for offices, except in 2.5% of the space.

The Daylight Simulation of “Speech Office 112” showed Daylight Factors fell between 1.87% – 28.58% (Fig.3.10). Lower than in “Music Office 139”, which is expected, given its considerably more sheltered location. Nevertheless, levels only fell

Notes

\(^{291}\) Autodesk Ecotect Help Library
\(^{292}\) Deficiency percentages = Number of Grid Points below Requirement * Area of Grid Cell / Room Area.
\(^{293}\) (Lechner 2009, 391)
below the minimum threshold, where electric lighting is required, in 14.46% of the total area of the space. In those areas the average Daylight Factor was still 68.75% of the minimum level.

Daylight Levels were between the ranges of 10.40 fc – 159.17 fc (Fig.3.10) again demonstrating levels, except in 31.35% of the total room area where the average of 25.90 fc represents 86.33% of the required level.

The Daylight Simulation of “Art Studio 338” revealed Daylight Factors fell between 1.83% – 27% (Fig.3.12). The minimum requirement in Art Studio spaces is 4%-6%. Note that the lowest levels are found at the entrance to the studio space where reduced ceiling heights are located (see red outline in Fig.3.12). This area, approximately 200 sq.ft. (18.58 m²). is north of the upper level light monitors, which bear the bulk of the responsibility of bringing daylight into the space. In this area, Daylight Factors averaged 3.68%, which is only 8% below the minimum requirement for a studio and 84% higher than an office’s requirement.

Notes

294 (Lechner 2009, 391)
Excluding this sheltered space at the studio entrance, Daylight Factors fall between 6.17% – 14.87% with very small area exceptions (0.03% of total studio area) throughout the main area, primarily immediately adjacent to the south wall of the space. Intensity predictably wanes as distance from the north facing light monitors increases, but then increases again when directly under the skylights lining the south end of the studio (see red arrow Fig.3.12).

Daylight Levels were between the ranges of 13.79 fc – 124.09 fc (Fig.3.13) with a significant area (560 sq.ft., 54.63% of the main studio space) falling in the range of 30 – 60 fc. This indicates that while these areas of the studio are adequate for the majority of tasks required in a studio, there will be a need for artificial lighting when detailed design and drawing is performed on days with worst case daylighting, as the Illuminating Engineering Society’s “Art Studio” requirement is 100 fc.

Totaling the GSF for each of the categories, Office/Small Studios and Art Studios, yields more than 30,000 sq.ft. (2787.08 m²). This is approximately 15% of the FAC’s total area; however, it represents approximately 85% - 90% of the spaces with glazed surfaces. The remaining 10% -15% of areas with glazing are located at building entry.
areas, accompanying entry stairways, and the long corridor outside of the Art Studios on
the Bridge.

The advantages and benefits to the available level of daylighting in the
Office/Small Studios and Art Studios is twofold. First, it lends support to Roche’s
recognition of the importance of daylighting and his focus on occupant comfort (see
1.3.1.1,” Roche’s Personal Experiences”). Secondly, it exposes a real contemporary
opportunity to reduce lighting loads in these spaces with appropriate strategies, e.g.
occupancy sensors, daylight sensors, task lighting, etc. The opportunity to reduce the
electrical consumptions in these spaces is optimum and would be accompanied by
reduced carbon impacts as well as a reduction in the FAC’s EUI.

3.3.2 Glare Defense

A frequent and unwanted partner to introducing daylight into buildings is glare
Unfortunately, as anyone who has occupied a building with glare issues knows, strategies
to eliminate or minimize glare are sometimes neglected. The relatively recent
introduction of computer screens, which not only changed occupants’ visual targets from
printed paper with low levels of reflectance to backlit monitors with relatively high
reflectivity, also moved the work surface from horizontal desktop to vertical monitor-all
compounding the issue of glare.

Glare within the built environment falls into two categories:

Disability glare results when a light source reflects from or otherwise
covers the visual task, like a veil, obscuring the visual target, reducing
its contrast and making the viewer less able to see and discriminate
what is being viewed. Such glare "disables" the process of reading.
Discomfort glare arises when light from the side of the task is much brighter than the light coming from the task. The eyes attempt to focus on the light from the task, but so much extra light is entering the eye from the side that the visual processes are confused.\(^{295}\)

Ecotect does not have a tool to specifically measure glare. There are other analysis programs that attempt this simulation, e.g. Radiance, Daysim, but hard metric quantification is illusive. While illuminance can be quantitatively evaluated, as was done in the previous subsection, glare relates to visual comfort. This is a subjective sensation, as humans have varying degrees of visual capabilities to compensate for the phenomenon, so it is impossible to attach a hard metric to it.

As glare is associated with the increase of contrast within a delineated task area, e.g. a computer screen, a painter’s canvas, or a writing surface, it is directly associated with strong, bright, direct light entering from a window. It is the reason (along with the preferred color temperature parameters for tasks associated with art and the reduction of strong shadows) that the Art Studio’s north facing light monitors are placed high and out of the sight line of the typical activities in the spaces below (Figs.3.7, 3.12, 3.13).

There are no glare issues to examine in the Art Studios as all glazing is north facing. Nor are there glare issues to address in Speech Office 112 and its façade neighbors. Roche has used the sawtooth configuration of the Speech Department’s south façade coupled with the immediate adjacency of other building geometries to the east to completely defend the windows on this façade from all direct sunlight (Fig.3.6).

Notes

\(^{295}\) (Florida Solar Energy Center n.d.)
All of the sixty perimeter Office/Small Studio spaces have their windows located within identical sawtooth façades. They are differentiated from each other only by their hosting façade’s ordinal direction and by varying degrees by adjacent building geometries’ shading. The protection of the glazing within the sawtooth from direct solar radiation is a performance driven task that Roche has married to the aesthetic task of creating beautiful shadow patterns on the building’s concrete surfaces.

To demonstrate the glare protection offered by this design strategy Music Studio 189 (Fig.13.14) and Music Office 139 (Fig.3.5) were used. Similarly, to the other perimeter Office/Small Studios these space have excellent natural light levels (see 3.3.1, Daylight Maximization”). In the case of Music Studio 189, the adjacent building geometry does not offer this west facing façade any protection from afternoon light, leaving glare protection solely to the responsibility of the sawtooth geometry. In the case of Music Office 139, there is a degree of direct radiation shielding from adjacent building geometry, but not as complete as it is for Speech Office 112.

Figure 3.14: FAC Music Studio 189 (red arrow).

To determine the efficacy of the sawtooth geometry, an Ecotect shading simulation was performed first with the sawtooth geometry in place, affording protection
to the window in Music Studio 189 (Fig.3.15: Left). This was followed by a simulation to an identically sized and constructed window, only with the new window located on a flat façade in the identical plane to what would have existed, if the façade had been flat rather than in a sawtooth configuration (Fig.3.15: Right).

Using Ecotect analysis tools to determine the degree of shading the window and subsequently the interior space received from the two alternate geometries resulted in the following graphics (Figs. 3.16 & 3.17). The graphics illustrate the percentage of shading that is experience by the window over a 24-hour period (y-axis) during each month (x-axis). Total shading is represented by dark grey cells, no shading is represented by white cells, and degrees of grey represent the percentage of shading that the window experiences during the one-hour period the cell represents with numerical percentages indicated in the centers of the cells.
The sawtooth strategies almost completely limits direct sunlight and attendant glare issues (Table 3.6; Column 2).

Table 3.6: FAC Music Studio 189: Shading Comparison with Sawtooth Geometry.

<table>
<thead>
<tr>
<th>Month</th>
<th>% Shading Sawtooth Configuration</th>
<th>% Shading Flat Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>February</td>
<td>100%</td>
<td>0%</td>
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<td>March</td>
<td>100%</td>
<td>0%</td>
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<tr>
<td>October</td>
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<td>0%</td>
</tr>
<tr>
<td>November</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>December</td>
<td>100%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Other ordinally positioned sawtooth geometries’ impacts are not as powerful as that of the west facing facades. In these other ordinal instances, it is not as critical, as glare and solar gain are minimized by other strategies, e.g. adjacent building geometry or short duration of direct solar exposure. Still it is of interest to view the sophistication of the strategy, so identical analyses, with an identical geometry modifications and accompanying simulations, were performed to Music Office 139 (Fig.3.5).

The simulation demonstrated a subtler, but still effective design effort (Figs.3.18 & 3.19). The difference shows that the Sawtooth geometry reduces the total monthly hours when the window is not completely shaded from 63 hours to 59 hours and increases the total hours the window is partially shaded from 7 hours to 15 hours.
A finer parsing of the data reveals that there are months when the window within the Sawtooth geometry does experience less in total shading, but the average yearly difference is small, 2.33%, given that the orientation was changed from eastern to the typically far more exposed southern ordinal (Table 3.7).

<table>
<thead>
<tr>
<th>Month</th>
<th>% Shading Sawtooth Configuration</th>
<th>% Shading Flat Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>51%</td>
<td>51%</td>
</tr>
<tr>
<td>February</td>
<td>48%</td>
<td>48%</td>
</tr>
<tr>
<td>March</td>
<td>40%</td>
<td>48%</td>
</tr>
<tr>
<td>April</td>
<td>43%</td>
<td>47%</td>
</tr>
<tr>
<td>May</td>
<td>50%</td>
<td>46%</td>
</tr>
<tr>
<td>June</td>
<td>49%</td>
<td>44%</td>
</tr>
<tr>
<td>July</td>
<td>49%</td>
<td>48%</td>
</tr>
<tr>
<td>August</td>
<td>45%</td>
<td>47%</td>
</tr>
<tr>
<td>September</td>
<td>36%</td>
<td>44%</td>
</tr>
<tr>
<td>October</td>
<td>43%</td>
<td>50%</td>
</tr>
<tr>
<td>November</td>
<td>45%</td>
<td>51%</td>
</tr>
<tr>
<td>December</td>
<td>56%</td>
<td>59%</td>
</tr>
<tr>
<td>Average</td>
<td>46.25%</td>
<td>48.58%</td>
</tr>
</tbody>
</table>

It is also important to note that it is in the “appending triangles” created by the sawtooth geometry, where the windows of the Offices/Small Studios are located. The unique location of the window, in that triangular niche, provides multiple opportunities for occupants to orient desks or working surfaces in locations where any glare from the
window does not impact visual contrast and create discomfort. Finally, an important element of the design parti - creating geometry that produces ever-changing shadows on facades - is preserved with little, if any impact, on occupant comfort.

3.4 Unintentional Sustainable Strategies Employed

3.4.1 Siting and Orientation

When the FAC, in its present form and orientation, is viewed and considered within the context of the dictates and goals of Sasaki Associates’ 1961 Campus Master Plan and colored by Richard Galehouse’s observation and comments regarding the brilliance of Kevin Roche’s design, it might seem that there were no other siting or orientations options for the FAC that might have been considered.

Sasaki had opened the site to the south:

_The fine entrance mall would have been lost, and the site for Kevin Roche's Fine Arts Center would have been lost, said Sasaki, " had we been only program planners instead of design planners."

_He is referring to the fact that the Administration Building ... was moved westward while still in the working-drawing stage ... disassociated from the completed School of Business Administration ... The program planning which predated the work of Sasaki had already grouped the three by category.

_The Fine Arts Center was established at the heart of the campus on the southern edge of the pond. It is to become the campus activity center and gateway. The major campus road to the south will become a tree-lined boulevard from which the necessary loop road, now designed as a great mall will lead to the chief portico of the Fine Arts Building. The projected Administration Building lay right in its path and had to go._

Notes

296 (Architectural Record 1966, Study 358)
Roche responded to the challenge with the building’s geometry:

Theaters, auditoriums, studio space and other elements of a typical university arts program might—in the hands of another architect have produced five buildings. But these elements have been resolved by Kevin Roche into one brilliantly organized structure which Pietro Belluschi believes will be the most distinguished fine arts complex to be built on any campus in the United States. Richard Galehouse, a Sasaki associate who has played a large part in developing the University of Massachusetts master plan is equally enthusiastic about the scheme. Said he: "In most cases it is now a mistake to design a campus building with a front and a back. Such structures are becoming large enough to be multi-faced. One of the wonderful things about Roche's building is that you can enter it from many places." And another wonderful thing about it is the manner in which Roche has composed his multi-faced elements. Spanning the most-prized site at the academic center of the campus, overlooking the pond and adjoining what will become the main entrance mall to the campus, the splendid location afforded by the master plan reflects the growing importance of the fine arts to the life of the University, to the nearby colleges, Amherst, Mt. Holyoke and Smith, and to the public.297

However, there were no restrictions or limitations placed on Roche. The form of the building and its geometries might have responded to the University’s programmatic dictates in a different fashion than what was ultimately drawn. It was Roche’s own self-imposed design parti, to create a building that would respond to the shadow patterns the sun created on sculptural facades, that resulted in the building he termed, “A Sun Machine” (see 1.3.1.3, Roche and Modeling”).

The FAC’s monumental concrete geometry is an immutable reality. Although a hypothetical alteration to its geometry was simulated (see 3.4.2, “Solar Defense via Self-Shading”) the simulations in this subsection are an effort to examine the FAC’s orientation on the site and whether this orientation had any energy performance benefits.

Notes

297 (Architectural Record 1966, Study 358)
The FAC’s orientation is a fine example of the architectural design fundamental targeting optimization of passive solar strategies in order to reduce a building’s mechanical system’s fossil fuel consumption, i.e. orient a building with long axis parallel to the equator with glazing and geometry optimally responsive to the solar loads.

The FAC deviates from that directive by seven degrees, an accommodation to the formal access road to the University (see 1.3.2.2, “Description”). A degree of tolerance (+/- 15 degrees) is recognized by the AEC industry, i.e. the intruding real world realities that the siting of buildings requires a degree of latitude, in order to reasonably accommodate additional site and economic constraints.\textsuperscript{298} An added bonus is for the purposes of photovoltaic or solar thermal panels greater deviation (+/- 20 degrees) is still acceptable.\textsuperscript{299} The FAC’s 646-foot-long (196.90 m.) Bridge with sloped roof (45°) is near ideal for optimal solar panel performance in both orientation and angle (see “Appendix G, “FAC Bridge Photovoltaic Array”).\textsuperscript{300}

In addition to the “FAC 1976 Baseline Model” simulation, three other simulations were performed

- Orientation turned 180 degrees, i.e. south facade of Bridge is now facing north.
- Orientation with south facade of Bridge facing due east.
- Orientation with south facade of Bridge facing due west.

As anticipated, the simulation showed there were no changes to Interior Lighting, Interior Equipment, or DHW loads. The changes were all related to cooling and heating loads, which in turn affected cooling electricity and heating steam. These in turn affected

Notes

\textsuperscript{298} (United States Green Building Council n.d.)
\textsuperscript{299} (Lechner 2009, 184-185)
\textsuperscript{300} (Lechner 2009, 192)
pump and fan loads, and in turn, total steam, total electricity, and total energy consumptions (Table 3.8).

### Table 3.8: Orientation Consumption Impacts.

<table>
<thead>
<tr>
<th>Consumption</th>
<th>FAC 1976 Baseline Model KBtu (KWh)</th>
<th>East Orientation KBtu (KWh)</th>
<th>West Orientation KBtu (KWh)</th>
<th>180 Degree Rotation Orientation KBtu (KWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>7,726,877.62 (2,264,524.39)</td>
<td>7,729,725.56 (2,265,359.04)</td>
<td>7,798,567.41 (2,285,534.59)</td>
<td>7,795,340.48 (2,284,588.88)</td>
</tr>
<tr>
<td>Steam</td>
<td>13,650,189.42 (4,000,475.80)</td>
<td>13,486,710.61 (3,952,564.89)</td>
<td>13,459,051.93 (3,944,458.93)</td>
<td>13,177,654.23 (3,861,989.40)</td>
</tr>
<tr>
<td>Cooling</td>
<td>2,672,123.82 (783,122.22)</td>
<td>2,661,868.53 (780,116.69)</td>
<td>2,710,598.18 (794,397.90)</td>
<td>2,723,403.12 (798,150.70)</td>
</tr>
<tr>
<td>Pumps</td>
<td>1,539,484.38 (451,178.36)</td>
<td>1,535,510.09 (450,013.60)</td>
<td>1,555,992.41 (456,016.38)</td>
<td>1,557,071.31 (456,332.57)</td>
</tr>
<tr>
<td>Fans</td>
<td>2,120,801.24 (621,545.51)</td>
<td>2,138,128.30 (626,623.58)</td>
<td>2,137,088.20 (626,318.75)</td>
<td>2,119,886.82 (621,277.52)</td>
</tr>
<tr>
<td>Site Energy</td>
<td>21,442,805.67 (6,284,266.29)</td>
<td>21,282,174.80 (6,237,190.02)</td>
<td>21,323,357.97 (6,249,259.62)</td>
<td>21,038,733.34 (6,165,844.37)</td>
</tr>
</tbody>
</table>

The percentage of changes were not significant (Table 3.9). Each one can be traced to increased or decreased gains attributable to pluses and minuses of the geometry’s presentation to solar position, e.g. heating loads decrease when the FAC is oriented to any other ordinal direction, because Direct Radiation solar loads, especially those through the long wall of light monitors lining the Bridge are increased as they are rotated away from their original protected (from Direct Radiation) northern exposure.

The FAC’s relative resistance to improved performance with optimal site orientation can be attributed to three of its unique design qualities, i.e. low window-to-wall ratio, substantial below grade GSF, and uniformity of monolithic concrete wall assemblies. All are qualities with low performance responses to orientation dependent on windows (operable for passive ventilation and fixed or operable for passive heating).

Both of these strategies are sensitive to site conditions, e.g. wind and shading, which vary considerably with ordinal direction. As a building is rotated on its site and
different facades with different window totals and placements assume new ordinal directions these strategies can respond powerfully. Absent operable windows, the FAC is unable to take advantage of passive ventilation. Absent a significant amount of glazing, the result is similar for passive heating strategies.

Table 3.9: Percent Changes from “FAC 1976 Baseline Model” in actual orientation as function of the building’s rotation on the site.

<table>
<thead>
<tr>
<th></th>
<th>East Orientation</th>
<th>West Orientation</th>
<th>180 Degree Rotation Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>0.04%</td>
<td>-0.56%</td>
<td>-1.90%</td>
</tr>
<tr>
<td>Steam</td>
<td>-1.20%</td>
<td>-1.40%</td>
<td>-3.50%</td>
</tr>
<tr>
<td>Cooling</td>
<td>-0.38%</td>
<td>1.44%</td>
<td>+1.93%</td>
</tr>
<tr>
<td>Pumps</td>
<td>-0.26%</td>
<td>1.07%</td>
<td>+1.15%</td>
</tr>
<tr>
<td>Fans</td>
<td>0.82%</td>
<td>0.77%</td>
<td>-0.04%</td>
</tr>
<tr>
<td>Site Energy</td>
<td>-0.75%</td>
<td>-0.56%</td>
<td>-1.90%</td>
</tr>
</tbody>
</table>

3.4.2 Solar Defense via Self-Shading

The first time someone exits Massachusetts Avenue onto Haigis Mall, the formal entrance to the University of Massachusetts-Amherst, their vision and sight line is controlled by architecture. The four and one-half acre grassy expanse is flanked by the Whitmore Administration Building and Herter Hall to the west and Isenberg School of Management to the east. Nine-hundred feet to the north lies the Fine Arts Center, its 646-foot (196.9 m.) Bridge, the aerial threshold to the campus beyond, and the termination of the approach.
The concrete mass of the Bridge’s body begins forty feet (12.9 m.) above the Mall’s grade, continues on upward for another thirty-three feet (10.06 m.) to its apex, and is supported by the twelve, thirty-foot-wide (9.14 m.) dihedral pilotis, separated by more than eighty feet (24.38 m.).

Does this Bridge and its supporting pilotis serve only as a sculptural architectural element programmatically housing a series of Art Studios or might there be an additional function performed by this massive construct?

Shading strategies are integral to any passive design effort. The strategies include:

- Extended overhangs at eaves or parapets offering protection to the façade below when the sun’s altitude is high.
- Horizontal projections above south facing windows offering dedicated protection to the window below when the sun’s altitude is high.
- Vertical fins at the sides of east or west facing windows restrict low solar altitude eastern or western sun’s access time to the adjacent glazing.
- The use of existing topography or nearby buildings to lend shade to a site and building.

All are strategies meant to reduce a building’s cooling loads by limiting solar exposure with shade or conversely by restricting shade and allowing solar exposure to reduce heating loads. These strategies frequently involve a degree of compromise to balance the pluses and minuses of the opposites in mixed-use climates, e.g. Northeast U.S.

To determine if the enormous shadow cast by the Bridge supplied the Bridge with an additional function, offering the FAC another benefit, besides the aesthetic and programmatic ones was a simple task for an energy model, i.e. eliminate the Bridge in the “FAC 1976 Baseline Model” in both the Ecotect Model (Fig.3.20 & 3.21) and the DesignBuilder Model (Fig.3.22 & 3.23), simulate, and compare.
Focus was placed on the Theatre (blue arrow in Fig. 3.23) and the Auditorium (red arrow in Fig. 3.23), which are the two largest spaces most acutely impacted by the Bridge’s shadow range. The outputs, which would most clearly demonstrate the impact of the Bridge’s shadow range, were best illustrated using DesignBuilder’s Cooling Design Simulation, which would examine each space on July 15, the cooling design day, when maximum cooling loads would be experienced (Table 3.10).

There was a discernable impact, but not a substantial one. The impact of removing the Bridge and subjecting the two spaces to greater direct solar radiation is more pronounced in the Theatre, because the added solar gain experienced by both spaces occurs through the south facing walls of each space. The Theatre’s south facing walls represent a greater percentage of the total roof and wall area than what exists in the larger
Auditorium and results in the greater solar heat gains and attendant greater space cooling requirements when expressed as a percentage of the entire space’s cooling loads.

Table 3.10: Theatre and Auditorium Changes in Cooling Design Loads with and without Bridge.

<table>
<thead>
<tr>
<th>1976 Baseline Model</th>
<th>With Bridge KBtuh (KW)</th>
<th>Without Bridge KBtuh (KW)</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theatre</td>
<td>166.37 (48.76)</td>
<td>174.89 (51.26)</td>
<td>+5.12</td>
</tr>
<tr>
<td>Auditorium</td>
<td>338.15 (99.10)</td>
<td>343.79 (100.75)</td>
<td>+1.67</td>
</tr>
</tbody>
</table>

The DesignBuilder outputs were then reinforced with Ecotect’s insolation studies (Figs. 3.24, 3.25), which are programmed to examine the total Direct Radiation insolation gains on the south walls of the two spaces from 6:00 to 18:00 on all days in June, July, and August, the three months in the Northeast U.S. producing the highest cooling loads.

The protection offered is significant as can be seen in the Ecotect studies (Figs 3.24 & 3.25). Areas of the Analysis Grid colored blue are at 0.0 Btu/sq.ft. (0.0 KWh/m²), areas colored red are in the range of 384,000 Btu/sq.ft. (1211.36 KWh/m²); areas colored
yellow are in the range of 640,000 Btu/sq.ft. (2018.94 KWh/m²). The additional area, 6400 sq.ft.(594.58 m²), impacted by Direct Solar Radiation, is approximately 85% of the Auditorium wall. Averaged Direct Gain (ADG)\textsuperscript{301} was 314.14 KBtu/sq.ft. (990.97 KWh/m²) with the Bridge in place and 455.86 KBtu/sq.ft. (1438.06 KWh/m²) with the Bridge removed – an increase of 31.1%.

The differences between the two simulations might at first imply a substantial cooling load reduction with the Bridge in place, but there is not. The reason is related and similar to the minimal impact of the FAC’s orientation changes, i.e. the absence of glazing. The increase in solar loads that glazing (if present) would have permitted would have dramatically increased cooling requirements if the Bridge were eliminated.\textsuperscript{302}

### 3.4.3 Window Direct Solar Gain Defense

Related to the previous discussion concerning the efficacy of the sawtooth geometry on many of the FACs facades to minimize glare (see 3.32, “Glare Defense”) is a related benefit of this strategy, i.e. minimizing direct solar gain.

This section might have been included in the previous section, “Intentional Sustainable Strategies Employed”, as Roche was well aware of solar heat loads on a space through glazed surfaces, but considering the period and the reliance on mechanical systems for this type of control the subject is placed in this section, “Unintentional Sustainable Strategies Employed”.

**Notes**

\textsuperscript{301} ADG is the average of all of the cells on an Analysis Grid.

\textsuperscript{302} Note: In Fig.3.24 the Bridge was in place during the simulation and only turned off after simulation to view Analysis Grid
All glazing on the Bridge is north facing and excluded from direct solar gain loads as well as glare issues based on their ordinal direction. Glazing on the Bridge, i.e. light monitors, skylights, and slit-windows (located intermittently on the north wall of the corridor outside of the Art Studios along the length of the Bridge) all contribute to daylight harvesting. Only the thirty slit-windows, 1’ x 4’ (30.4 cm x 121.9 cm), have the added function of providing limited views from the interior of the Bridge. These windows also provide an intermittent material relief along the 646-foot-long (196.90 m.) uninterrupted wall of concrete that serves as base and anchor to the matching 646-foot-length (196.90 m.) of glazed light monitors above it, creating an impressive elevation when the FAC is approached from the north.

Except for the glazing (doors, sidelights and transoms) at exterior entries and their adjoining stairwells, the remainder of the FAC’s glazing is contained in the perimeter Office/Small Studio spaces. The degree of direct solar gain they receive is proportional to the percentage of the day that they are shaded, i.e. no direct sunlight equals no direct solar gain. All windows admit a degree of indirect and diffuse solar gain, but this is a small component when compared to direct gain.

As energy consumption was not of concern at the time of the FAC’s design and construction, value was not placed on reduction of mechanical space heating loads by direct solar gain through glazing. Nor was the inverse a concern, i.e. increased cooling loads due to direct solar gains through glazing.

Related occupant discomfort to direct solar gain was minimized and addressed in these perimeter spaces by equipping each of the spaces with an individual fan-coil unit located beneath each window (minimizing condensation on the single glazed assembly)
controlled by a dedicated thermostat. Occupants had effective thermal control of their personal spaces, through mechanical intervention.

Today the University’s Central Plant is a cogeneration facility. Natural Gas powered turbines produce electricity for the campus with steam as a secondary byproduct of the process. As of 2016, the plant produces more steam than the campus requires, so steam supply and steam’s relationship to space heating loads are neither a concern or a priority. As the campus expands and more and more new buildings come online this could change, but at present the University has all of the steam necessary to address the campus’ heating and laboratory requirements.

This is not the case for electricity during the New England summer months when cooling loads spike and electrical demand is at its peak. During these times, the Central Plant is not able to produce enough electricity to meet the campus wide demand and is forced to purchase electricity from the grid. The cost of electricity produced by the Central Plant is $0.45/KWh. Purchased from the grid, the cost is $0.14/KWh. The increase in cost generates a priority, which as more buildings come on line with campus expansion is always increasing.

DesignBuilder is capable of calculating decreases in heating loads, increases in cooling loads, and attendant decreases and increases of equipment sizes, which would be necessary if the FAC’s building geometry was changed and the sawtooth facades eliminated.

Notes

303 UMass Physical Plant Energy Spreadsheet Data.
Accomplishing these substantial geometry changes would have required creating another FAC model and investing many modeling and proofing hours. It was not done. Alternatively, Ecotect was used to examine the changes in direct solar load that spaces receive with the sawtooth geometry in place and with the geometry reconfigured into a more conventional flat wall geometry, which in Ecotect is a far less time consuming task than in DesignBuilder.

Two Office/Small Studio spaces, Music Office 139 and Music Studio 189 were altered identically to what was done in the glare studies (see 3.32, “Glare Defense”). The selection criteria were the same. These were spaces where adjacent building geometry offered little or no protection from Direct Radiation, leaving the responsibility solely to the sawtooth geometry.

The interest in these simulations is not Daylight Levels or Factors, but rather Insolation Levels and particularly Direct Radiation. Diffuse Radiation is less of a contributor to space thermal loads and is not defended by geometry. Since summer cooling loads are of the biggest concern at the University the simulation was restricted to Direct Radiation gains for the Summer months, i.e. June, July, and August from 6:00 to 17:00 each day.

In order to evaluate the effect of the geometry four simulations were executed for each of the two spaces:

- Sawtooth geometry intact with Analysis Grid at plane of the window.
- Sawtooth geometry intact with Analysis Grid 6” above floor.

Notes

304 (Autodesk Sustainability Workshop n.d.)
• Sawtooth geometry replaced with an identically sized and constructed window; only with the new window located on a flat façade in the identical plane to what would have existed if the façade had been flat rather than in a sawtooth configuration (see Fig.3.15) with Analysis Grid at plane of the window (see Fig.3.15)

• Sawtooth geometry replaced with identically sized and constructed window only with the new window located on a flat façade in the identical plane to what would have existed if the façade had been flat rather than in a sawtooth configuration (see Fig.3.15) with Analysis Grid 6” above floor.

The simulations measured, first, the average hourly Direct Radiation on the window surface in all cells on the Analysis Grid, and secondly, the average hourly Direct Radiation in the space itself in all cells on the Analysis Grid. To arrive at the hourly metric, Ecotect calculates the sum of all Direct Radiation, Btu/sq.ft. (KWh/m²) in the Analysis Grid cells and then divides this total by the number of hours in the time period, Summer (June, July, August), to give the overall average. This indicates the geometry’s protective qualities or lack of protective qualities; first, to the window surface and secondly, to the space itself.

Results for the Music Studio 189 were as anticipated. The window’s ordinal direction is northern when the Sawtooth geometry is in place and western when it was replaced with the Flat Wall configuration employed. With Sawtooth geometry in place, the Direct Gain on the window was only 0.0-.41 Btu/sq.ft. (0.0-0.129 KWh/m²) with the 98.84% of the window area receiving the lower value. The interior space’s values were from 0.0-12.85 Btu/sq.ft. (0-0.04 KWh/m²), again with the majority, 98.4%, of the room’s area, experiencing no Direct Radiation. (Fig.3.26).

When the Sawtooth geometry was in place the ADG on the window was 20.70 Btu/sq.ft. (0.06 KWh/m²), When the Sawtooth geometry was replaced with the Flat Wall
geometry the ADG on the window increased to 294.76 Btu/sq.ft. (0.93 KWh/m²), i.e. 14.2 times more Direct Radiation.

Figure 3.26: Music Studio 189, Direct Solar Gain: Sawtooth Geometry.

The space’s interior values were similarly impacted. ADG for the space was 21.80 Btu/ft.sq. (0.068 KWh/m²), versus .7 Btu/ft.sq. (0.002 KWh/m²), when the Sawtooth geometry was in place. The highest intensities 238.96 Btu/ft.sq. (0.75 KWh/m²), were immediately in front of the window (Fig.3.27) as opposed to the maximum of 17.81 Btu/ft.sq. (0.056 KWh/m²), near the window in the sawtooth geometry (Fig.3.26).

Figure 3.27: Music Studio 189, Direct Solar Gain: Flat Façade.
In Music Office 139 the results of the simulations were less dramatic as the change in orientation was from south to east rather than north to west, but the impact of the Sawtooth geometry was interesting. With Sawtooth geometry in place, ADG value on the window was 425.51 Btu/sq.ft. (0.09 KWh/m²). The interior space’s ADG value was 27.17 Btu/sq.ft. (0.09 KWh/m²) with the loads concentrated in the triangular area where the window is located (Fig.3.28).

![Figure 3.28: Music Office 139, Direct Solar Gain: Sawtooth Geometry.](image)

When the Sawtooth geometry was eliminated, the ADG value of the window was 313.31 Btu/sq.ft. (0.99 KWh/m²), with one hundred percent of the eastern sunlight’s Direct Radiation on the glass. No southern sunlight radiated directly through the glass. The interior space’s ADG value was 29.42 Btu/sq.ft. (0.93 KWh/m²), with the highest intensities again at the front of the window (Fig.3.28).

What Roche’s geometry has done on this eastern facade exposure is not as extreme as it was on the western façade, but his goals were achieved. Overall Direct Radiation value averages on the window was greater, 425.51 Btu/sq.ft. (0.09 KWh/m²) vs. 313.31 Btu/sq.ft. (0.99 KWh/m²), with the Sawtooth geometry, but interior space
loads were similar, 27.17 Btu/sq.ft. (0.09 KWh/m²) vs. 29.42 Btu/sq.ft. (0.93 KWh/m²) and not increased even though the window was oriented toward the south.

![Figure 3.29: Music Office 139, Direct Solar Gain: Flat Façade.](image)

A balance had been struck for the spaces with this ordinal exposure. More Direct Solar Gain was allowed to strike the window itself, but the geometry of the room prevented deeper penetration of light into the more utilized area of the room (see 3.3.2, Glare Defense) and allowed only a slight increase in Direct Solar Grain to the space than an eastern window orientation.

### 3.4.4 Solar Absorptance

> A warm buff-color cement for all concrete which has an exposed face in the finished work; Penn-Dixie Nazareth, Pa or Howe’s Cave, N.Y. plants or Coplay Saylor’s Light or another of the same color.\(^{305}\)

Roche’s desire for a specific color of cement to be used in the concrete mix was driven by aesthetics. The creamy color of the specified concrete mix would provide a soft

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\(^{305}\) From FAC Specifications Document.
warm-toned canvas on which the sculptured geometry of the FAC could paint its continually morphing shadows as the day progressed.

As the years passed the soft warm canvas changed to a grim mottled grey streaked with blackish mold and mildew (Fig.1.43) the contrast within the shadow play diminished and an aura of neglect dominated the once gleaming icon (Fig.P.18). The question arises as to whether this change, besides compromising aesthetics, had any impact on the building’s performance. Did the change in albedo increase cooling loads in summer? Decrease heating loads in winter? Were there other subtler, but related impacts?

To evaluate potential performance impacts relating to the Solar Absorptance of the “FAC 1976 Baseline Model” concrete requires a return to DesignBuilder. Solar Absorptance was changed to impart the qualities of the dirty discolored concrete surfaces that the building presently possesses (see 2.6, “Constructions”). Two simulations, one with clean buff-colored concrete and one with degraded buff-colored concrete, were compared. A sample of the clean buff-colored concrete input window is shown (Fig.3.30).

![Figure 3.30: Solar Absorptance: Clean Buff-Colored Concrete.](image)

The simulations determining Heating and Cooling Design Loads were executed. As expected the Heating Design Loads were unchanged as Solar Absorptance of surfaces is not included in the steady state calculation used for Heating System Design. The calculations for Cooling Design Loads are dynamic and are executed over a period of
twenty-four hours on the designated design day, which for the FAC is July 15. Special attention was focused on the Auditorium and Theatre. Both spaces have large volumes, substantial exterior wall areas, significant solar exposure, and high occupancies. These areas would show discernable variation, if variation was present.

Cooling Design Loads were increased significantly in all categories (Table 3.11). As the concrete’s exterior surfaces absorbed solar radiation and became warmer, the solar-air temperatures at these surfaces also increased, increasing the Delta-T, measured against the FAC’s interior cooling setpoint/setback temperatures, 78°F (28.6°C) / 82°F (28.8°C), and exterior dry-bulb temperature.

Table 3.11: Clean to Dirty Buff-Colored Concrete Cooling Design Load Changes.

<table>
<thead>
<tr>
<th></th>
<th>FAC Total</th>
<th>FAC Sensible</th>
<th>FAC Latent</th>
<th>Auditorium Total</th>
<th>Auditorium Sensible</th>
<th>Auditorium Latent</th>
<th>Theatre Total</th>
<th>Theatre Sensible</th>
<th>Theatre Latent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Clean Buff-Colored KBtuh (KW)</td>
<td>Dirty Buff-Colored KBtuh (KW)</td>
<td>% Change</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAC</td>
<td>Total</td>
<td>2682.9 (786.28)</td>
<td>3411.1 (999.69)</td>
<td>27.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sensible</td>
<td>1837.8 (538.6)</td>
<td>2490.7 (729.95)</td>
<td>35.53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Latent</td>
<td>845.1 (247.67)</td>
<td>920.4 (269.64)</td>
<td>8.91</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auditorium</td>
<td>Total</td>
<td>812.9 (238.24)</td>
<td>891.6 (261.30)</td>
<td>9.68</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sensible</td>
<td>533 (156.21)</td>
<td>594.8 (174.32)</td>
<td>11.59</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Latent</td>
<td>279.9 (82.04)</td>
<td>296.7 (86.95)</td>
<td>6.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theatre</td>
<td>Total</td>
<td>396.8 (116.29)</td>
<td>456.6 (133.82)</td>
<td>15.07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sensible</td>
<td>259.8 (76.14)</td>
<td>307.3 (90.06)</td>
<td>18.28</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Latent</td>
<td>137 (40.14)</td>
<td>149.3 (43.76)</td>
<td>8.98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The elevated Delta-T value increased the interior conductive and infiltration heat loads, along with humidity gains from infiltration, demonstrated by increased latent gains. It now might be concluded that, if the Cooling Design Load simulation demonstrates an increase with the dirty concrete, then cleaning and returning the FAC’s surface to an original condition would have a two-fold effect. One, total cooling electrical consumption would be reduced and two, a smaller system could be installed (lower equipment cost), whenever a system replacement was scheduled. Both are positives, especially the former, as summer cooling loads are a priority of the UMass-Amherst Physical Plant (see 3.4.3, “Window Direct Solar Gain Defense”). However, this assumption would be incorrect.

To aid in placing the Cooling Design Load results within DesignBuilder’s context it is first necessary to evaluate the differences in Energy Consumption between the two models and their WBES (Table 3.12).

Table 3.12: Clean to Dirty Buff-Colored Concrete WBES Comparison.

<table>
<thead>
<tr>
<th></th>
<th>Clean Buff-Colored KBtu (KW)</th>
<th>Dirty Buff-Colored KBtu (KW)</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>21,485,862.50 (6,296,884.99)</td>
<td>20,291,587.14 (5,946,877.42)</td>
<td>-5.56</td>
</tr>
<tr>
<td>Heating</td>
<td>13,661,620.21 (4,003,825.83)</td>
<td>12,692,658.69 (3,719,851.23)</td>
<td>-7.09</td>
</tr>
<tr>
<td>Electricity</td>
<td>7,759,503.65 (2,274,086.14)</td>
<td>7,533,189.82 (2,207,760.10)</td>
<td>-2.92</td>
</tr>
<tr>
<td>Cooling</td>
<td>2,687,924.2 (787,752.85)</td>
<td>2,534,917.70 (629,688.50)</td>
<td>-5.69</td>
</tr>
</tbody>
</table>

The reduction in Heating Loads resulting from the albedo change of the concrete was expected, because of a decreased winter Delta-T between the interior
setpoint/setback temperature, 70°F (21.1°C)/55°F (12.8°C) and exterior dry-bulb temperature. There would be a decreased reliance on mechanical heating for the opposite reason that there was an increased reliance on the mechanical cooling system during the summer. Both the concrete’s absorbed solar radiation temperature increased and the sol-air temperature increased. These two, in consort, decreased the Delta-T between the FAC’s heating demand setpoint/setback temperatures on the interior and the outside temperature, reducing both conductive and exfiltration losses.

The reduction of mechanical heating needs would also be accompanied by reductions in fan and pump electrical demands. The reduction in exfiltration losses also increases humidity levels resulting from increased accumulation of water vapor from occupant physiology (respiration and perspiration) elevating humidity levels.

At the present time, reductions in heating loads and associated electrical reductions are not a priority for the Physical Plant as during the heating season the UMass-Amherst Cogen Plant produces enough steam and electricity to meet campus needs (see 3.4.3, “Window Direct Solar Gain Defense”) and the reduction (although improving the FAC’s EUI) is counterproductive to any lobbying effort to have the FAC’s concrete cleaned - for reasons other than aesthetics. The simulations demonstrate that a clean FAC consumes more total annual energy in a year than the dirty FAC.

What was surprising was the reduction in Cooling Electricity (-5.69%). The change would be even greater than what is shown (Table 3.12) when the cooling related segment of Pump and Fan Electric Loads are factored in, adding additional value to the total change in electricity related to cooling. This was opposite from what was predicted
when the Cooling Design Day, July 15, was used for sizing equipment and opposite of what was hoped for relative to the lobbying effort supporting cleaning the FAC.

Determining precisely where the reduction in Cooling Electrical Loads comes from in a multi-zone (128) model using the available computing power available to this project is not possible. The 153,010.48 KBtu (44,842.94 KWh) reduction in Cooling Electricity represents only 1.97% (not including related Pump and Fan Electric Load reduction totals) of Total Electricity Loads. This small percentage is divided into the smaller increments originating in the various zones. Within each space the Cooling Electrical Load is further divided into Sensible and Latent Loads. These values are dependent on occupancy, activity, program, surface area of exterior envelope, and volume of each space.

While the change in the entire FAC’s KWh Cooling Electricity aggregate is digestible in both annual and monthly whole building metric outputs, the single zone metric outputs are rounded off to at best three places. Reductions or increases to load metrics that are already small are not possible to parse with the computing power available on this project. Simulation times for Annual and Monthly results take approximately ten hours. Weekly or hourly data simulations, which would parse the data into metric outputs that might more clearly point to zones and/or times where the load reductions are more discernable and understandable are possible, but the increase in simulation time would be enormous and was not attempted.

Where the load reductions occur can be hypothesized. Increases or decreases in Latent Loads and accompanying shifts in Sensible Heat Ration (SHR) can impact the Cooling Coil Load totals significantly (Table 3.13) as more electricity is required to
reduce Latent Loads than Sensible Loads, so attention should be paid to those zones that are most susceptible to Latent Load changes, i.e. high occupancy areas.

Table 3.13: Clean to Dirty Buff-Colored: Total, Sensible, Latent Cooling Coil Load Comparison.

<table>
<thead>
<tr>
<th></th>
<th>Clean Buff-Colored KBtuh (KW)</th>
<th>Dirty Buff-Colored KBtuh (KW)</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>6,484,472.00 (1,900.41)</td>
<td>6,149,377.24 (1,802.20)</td>
<td>-7.09</td>
</tr>
<tr>
<td>Sensible</td>
<td>4,432,086.58 (1,298.91)</td>
<td>4,286,743.29 (1,256.32)</td>
<td>-2.92</td>
</tr>
<tr>
<td>Latent</td>
<td>2,052,385.43 (601.49)</td>
<td>1,862,633.95 (545.88)</td>
<td>-5.69</td>
</tr>
<tr>
<td>SH Ratio</td>
<td>68.35</td>
<td>69.7</td>
<td>+1.98</td>
</tr>
</tbody>
</table>

Determining precisely where the load reductions occur is worthy of future exploration as the reduction of Cooling Electrical Loads when solar absorptance increases seems counterintuitive and a thorough investigation of the phenomena might have impact on contemporary building designs or retrofits. Where directionally in the building does it occur? What impact does exterior material selection have? Does the impact change with occupancy level, activity, program?

The investigation could be carried out with a simpler model as well as with more computing power. The key would be to reduce the simulation to a reasonable time period.

A final caveat to this subsection is to note that while the Cooling Design Loads (Table 3.11) showed increases in loads from Clean Model to Dirty Model, the Cooling Coil Loads in the WBES (Table 3.13) showed a reduction. The reason for the difference is that the Cooling Design Loads calculations are based solely on the impact of the Design Day
(July 15) while the Cooling Coil Loads are based on CDDs and the HVAC inputs of the modeler.

In the FAC model the HVAC option of auto-sizing was elected and is the reason that the Dirty Buff-Colored Concrete Model has a smaller system than the Clean Buff-Colored Concretes (589 tons vs. 621 tons$^{306}$). Each of these systems would consume electricity at different rates based on system specifications and different hysteresis. The reduced consumption in the Dirty Buff-Colored Concrete Model could be a result of a more efficient system rather than an impact of Solar Absorptance changes.

Further investigation of the Solar Absorptance impacts should be undertaken. The maintenance of most Brutalist buildings has been neglected (see 1.2.3.6, “Maintenance”) and a detailed understanding of the phenomenon’s impact on energy consumption could aid in reducing energy cost, climate impact, and aesthetic degradation.

### 3.4.5 Thermal Mass

In the Northeast U.S. thermal mass impacts are typically discussed within the context of the relationship of glazed surface to floors or walls constructed of high density, high heat capacity materials (concrete, brick, stone). The transmittance of solar radiation through the glass to the high mass surface initiates a lag time (Thermal Lag) between the initial absorption of the radiation and its release, which does not occur until the material

---

**Notes**

$^{306}$ Note; The 621 Ton Chiller, predicted by the “FAC 1976 Baseline Model”, is comparable (-7.8%) to the original 674 Ton (Twin 327 Ton) Chiller specified for the FAC lending increased credibility to the “FAC 1976 Baseline Model” validation.
has absorbed as much heat as the material’s properties permit, i.e. saturation. This is a passive energy reduction strategy useful in both heating and cooling seasons.

During heating seasons, heat is typically released late in the day or evening after having been accumulated throughout the day. At that time, the released heat reduces demands on the fossil fuel driven mechanical system. During cooling seasons, the time period when the mass is absorbing heat (daytime) reduces loads on the electrically driven mechanical system. Later in the day or evening, when saturation is reached, the heat is released, when cooling loads are typically less intense with nighttime cooling temperatures and occupancy and/or activities diminish.

As has been discussed (see 3.4.1, “Siting and Orientation”, “Solar Defense via Self Shading”), the low window-to-wall ration in the FAC precludes significant impact from passive strategies associated with glazing.

A variation of this strategy that excludes glazing is more typically employed in climates with large diurnal temperature swings (desert climates), i.e. high daytime temperatures followed by low nighttime temperatures. In this situation, heavy concrete or masonry wall construction with the associated Thermal Lag is a powerful and useful strategy. During the daytime, when exterior surfaces are exposed to solar radiation, the interior spaces are defended by the masses’ absorbed radiation. Until thermal saturation is reached, interior spaces are excluded from the intense solar radiation gains on the building’s exterior. During lower nighttime temperatures, the stored radiation is released into the interior space (where it is of value as conductive losses to the exterior are occurring). Or if the Delta-T between interior space and exterior is sufficiently reversed from the daytime extremes, the heat will be released to the exterior, never having
impacted the interior – preparing the building and its interior space for the identical cycle the following day.

The thermal mass of the FAC is enormous. Twenty-five thousand yards (19,113.87 m³) of concrete weighs approximately 87,500,000 pounds (39,689,332 kg) or 43,750 tons (39,689 metric tons). To gain perspective on these numbers, a 4” (10.16 cm) concrete floor slab in a 2000 sq.ft. (185.81 m²) American single floor dwelling contains 24.69 yards (20.25 m³) of concrete, 76.6 tons (69.49 metric tons).³⁰⁷ This is 0.17% of the concrete mass of the FAC.

Does this mass of concrete have an impact on the FACs performance in the Northeast US? A second model was created, identical to the “FAC 1976 Baseline Model”, with a single variable changed, i.e. the density of the concrete. This was changed from the density of heavyweight concrete, 149.83 lbs./ft³ (2,400.05 kg/m³) to the density of lightweight concrete, 74.19 lbs./ft³ (1,188.41 kg/m³). Neither conductivity nor specific heat were changed.³⁰⁸ Heating and cooling sizing simulations and WBES simulations were performed and the results compared.

Again as expected, there was no change in Heating Design as Thermal Mass is not included in the calculation. Cooling Design showed important changes (Table 3.14).

Cooling Design Capacity is increased when the density of the concrete is decreased, most notably in sensible cooling (12.31%). The capacity of the denser

Notes

³⁰⁷ (Concrete Network n.d.)
³⁰⁸ Note: Lightweight concrete would have a higher R-value than heavyweight concrete, because of additionally entrapped air. By maintaining a consistent R-value this variable was removed from the simulations in order to focus the result exclusively on density and mass.
concrete, which exists in the FAC, to influence the interior temperatures of the FAC, through the principles of Thermal Lag, reduced the simulated design capacity of the FAC’s cooling system by almost 10%.

This result indicates an effective strategy to reduce mechanical cooling system size is in place, even though unintentional, and it should be emphasized that in a desert type climate, where the strategy is most effective, greater differences would be expected - many Brutalist buildings exist in these climates.

Table 3.14: Cooling Design Comparison of 1976 Baseline Model with Adjusted Density Model.

<table>
<thead>
<tr>
<th></th>
<th>1976 Baseline Model KBtuh (KW)</th>
<th>Adjusted Density Model KBtuh (KW)</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>2,682.9 (1,900.41)</td>
<td>2,937.3 (1,802.20)</td>
<td>+9.48</td>
</tr>
<tr>
<td>Sensible</td>
<td>1,837.8 (1,298.91)</td>
<td>2,064.0 (1,256.32)</td>
<td>+12.31</td>
</tr>
<tr>
<td>Latent</td>
<td>845.1 (601.49)</td>
<td>873.3 (545.88)</td>
<td>-3.34</td>
</tr>
<tr>
<td>SH Ratio</td>
<td>68.5</td>
<td>70.27</td>
<td>+2.58</td>
</tr>
</tbody>
</table>

The WBESs of the two buildings, when compared, showed very similar total annual energy consumption to the “FAC 1976 Baseline Model”: 21,485,862.5 KBtu (6,296,884.99 KWh) versus the “Adjusted Density Model”: 21,531,244.93 KBtu (6,310,185.27KWh). The variations were in the subcategories (Table 3.15).

The obstacles described in the Solar Absorpancy subsection also emerged in this subsection. The WBES simulation when viewed in its most macro, the entire building, is
too coarse of a scale to determine if the density of the FAC’s heavyweight concrete is a positive for the reasons listed in the last subsection.

Indications can be inferred, as they were in the previous subsection, from the monthly changes in Cooling Loads that were experienced in a single representative space in the FAC. The Theatre (Fig.3.23, blue arrow) was selected as it has substantial above grade concrete walls.

Monthly cooling load averages varied between the models with the annual average of 3.52% (Table 3.16) demonstrating consistency with the Cooling Design simulation, i.e. the denser concrete reduces cooling loads.

<table>
<thead>
<tr>
<th></th>
<th>1976 Baseline Model</th>
<th>Adjusted Density Model</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KBtu (KWh)</td>
<td>KBtu (KWh)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>21,485,862.50 (6,296,884.99)</td>
<td>21,531,244.93 (6,310,185.27)</td>
<td>+0.21</td>
</tr>
<tr>
<td>Heating</td>
<td>13,661,620.21 (4,003,825.83)</td>
<td>13,784,779.9 (4,039,920.37)</td>
<td>+0.90</td>
</tr>
<tr>
<td>Total Electricity</td>
<td>7,759,503.65 (2,274,086.14)</td>
<td>7,680,726.39 (2,250,998.8)</td>
<td>-1.05</td>
</tr>
<tr>
<td>Cooling Electricity</td>
<td>2,687,924.18 (787,752.85)</td>
<td>2,623,461.61 (768,860.73)</td>
<td>-2.40</td>
</tr>
</tbody>
</table>

The greatest changes occur during heating seasons. What impacts the load changes, besides the density variable, cannot be determined at this this level of simulation. All related load variables, i.e. space occupancy, space activity, and space program, must be viewed at daily and hourly levels beyond the computing power of this project (see 3.4.4, Solar Absorptance).
Additional investigations seeking a detailed understanding of Thermal Mass absent of glazing (in a northern climate) should be undertaken, as many Brutalist buildings have, similar to the FAC, low window-to-wall ratios. Of even greater importance would be a study of Brutalist building in northern climates with higher glazing percentages. The attendant simulations would verify or refute what should be a Brutalist building’s superior performance in the niche of high density materials and the related passive benefits of Thermal Lag.

Table 3.16: Theatre Monthly Sensible Cooling Load Comparison of 1976 Baseline Model with Adjusted Density Model.

<table>
<thead>
<tr>
<th>Month</th>
<th>1976 Baseline Model KBtu (KWh)</th>
<th>Adjusted Density Model KBtu (KWh)</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>-900 (-264)</td>
<td>-1,086 (-318)</td>
<td>20.68</td>
</tr>
<tr>
<td>Feb</td>
<td>-265 (-78)</td>
<td>-327 (-96)</td>
<td>23.40</td>
</tr>
<tr>
<td>Mar</td>
<td>-813 (-238)</td>
<td>-1,242 (-364)</td>
<td>52.77</td>
</tr>
<tr>
<td>April</td>
<td>-3,754 (-1,100)</td>
<td>-5,782 (-1,695)</td>
<td>54.02</td>
</tr>
<tr>
<td>May</td>
<td>-14,244 (-4,175)</td>
<td>-16,877 (-4,946)</td>
<td>18.48</td>
</tr>
<tr>
<td>June</td>
<td>-39,677 (-11,628)</td>
<td>-40,058 (-1,1740)</td>
<td>0.960</td>
</tr>
<tr>
<td>July</td>
<td>-66,250 (-19,416)</td>
<td>-64,874 (-19,013)</td>
<td>-2.08</td>
</tr>
<tr>
<td>Aug</td>
<td>-50,428 (-14,779)</td>
<td>-50,097 (-14,682)</td>
<td>-0.66</td>
</tr>
<tr>
<td>Sept</td>
<td>-23,598 (-6,196)</td>
<td>-24,779 (-7,262)</td>
<td>5.00</td>
</tr>
<tr>
<td>Oct</td>
<td>-8,426 (-2,469)</td>
<td>-10,309 (-3,021)</td>
<td>22.35</td>
</tr>
<tr>
<td>Nov</td>
<td>-968 (-284)</td>
<td>-1,248 (-366)</td>
<td>28.93</td>
</tr>
<tr>
<td>Dec</td>
<td>-623 (-183)</td>
<td>-648 (-190)</td>
<td>4.013</td>
</tr>
<tr>
<td>Total</td>
<td>-209,946 (-61,529)</td>
<td>-217,327 (-63,692)</td>
<td>3.52</td>
</tr>
</tbody>
</table>
3.5 Future Investigations

In addition to further investigation into the impacts of Solar Absorpancy and Thermal Mass through the creation of simpler, yet still representative models with reasonable simulation times, to capture daily and hourly data for individual spaces and individual components (roofs, walls, windows) within the spaces, two other categories deserve consideration.

3.5.1 Wind

Wind studies and how they might relate to Brutalist buildings is of interest as air flows can be harnessed to impact both passive cooling strategies and passive ventilation strategies. Analysis in a suitable energy simulation program, e.g. Autodesk Flow Design, might offer insight as to whether a designer of a Brutalist building incorporated a wind related strategy into the design.

Modernist designers have often used wind related strategies in their residential designs. The Milam House, 1961, was the first of Paul Rudolph's Florida residences to include central air.309 Prior to designing the Milam House, Rudolph designed approximately fifty houses, either alone or in collaboration with Ralph Twitchell, all in Florida,310 all relying on passive strategies to provide occupant comfort. At the extreme:

...maximum ventilating area may be achieved, as in Paul Rudolph’s Cocoon House in Sarasota, Florida, by treating almost the entire house

Notes

309 (Howey 1997)
310 (Rohan, Challenging the Curtain Wall: Paul Rudolph's Blue Cross and Blue Shield Building 2007 , 250-52)
as a single room and opening its opposite walls completely with operable louvers. (Fry and Drew, 1956, p.75)

Effective ventilation may be achieved when the wind does not come from a direction perpendicular to the window (Givoni, 1976, P.289; Chandra et al., 1986, p.66.)

This project has maintained, from the beginning, that the Modernist masters did not jettison the passive environmental strategies relating to occupant comfort that they had personally experienced, formally been educated in, and successfully employed in earlier projects (see 1.2.6.3, “Architects - Subsection Summary”).

In the instance of the FAC, Roche has stated that air flows from southwesterly breezes, lowering air temperatures through evaporative cooling as breezes passed over the waters of the reflecting pools, cooling pedestrians as they traveled the length of the bridge, was not part of his thinking when designing (see 1.3.1.2, “Roche’s Architectural Education”). The reflecting pools were included for reasons of a final delineation and focusing of the long approach to the threshold of the campus and the view beyond created by the Bridge and the open terrace between the Theatre and Auditorium. However, wind related strategies might be present in other Brutalist building designs. More research is needed to determine the effectiveness of these strategies, especially in buildings with operable windows and/or locations in warm-humid climates.

Autodesk Ecotect offers a rudimentary Wind Analysis tool, a digital Wind Rose. Referencing the FAC, on the positive side, the tool points out the effectiveness of using the reflecting pools for pedestrian cooling under the Bridge (Figs.3.31 & 3.32). On the Notes

(Dekay and Brown 2014, 236)
negative side, the issue of northern winds funneling and intensifying within the terraced opening between the Auditorium and Theatre is illustrated (Figs. 3.33 & 3.34).

The first two of the Ecotect images show a concentrated period of prevailing wind direction and speed (Fig. 3.31, Red Arrow) and warm wind temperatures 77-95 °F (25-35 °C) (Fig. 3.32, Blue Arrow) passing over the waters of the reflecting ponds (evaporative cooling by the breeze) in the afternoon hours (12:00 – 18:00) of the summer months (June, July, August). The time of the day and year when cooling breezes would be most appreciated by the passerbys under the Bridge.

The final two Ecotect images show a concentrated period of prevailing wind direction and speed (Fig. 3.33 Red Arrow) and cold wind temperatures 32-41 °F (0-5 °C) (Fig. 3.34 Red Arrow) coming from the north in the late afternoon to late evening hours (14:00 – 22:00) of the winter months (December, January, February). The time of the day and year when cold wind funneled into the open area between the entrances to the Theatre and Auditorium would be least appreciated by attendees.

Notes

312 Note: Having lived in the Amherst area for many years, the Ecotect coldest wind temperature scale for winter appears quite conservative.
Of course, neither of these wind related events are in play at the present time. The opening between the Theatre and the Auditorium has been occluded with a colored and textured glass construct that protects the Theatre and Auditorium patrons from the unpleasant winds, while simultaneously eliminating Roche’s intended gateway to the campus. The reflecting pools are gone. One mutated into a sunken garden, collecting as much debris as the reflecting pond did, only more effectively hiding it. The other morphed into a parking lot where breezes pass over heated masonry rather than cool water.

3.5.2 Demolition and Embodied Energy

A discussion of Brutalist buildings would not be complete without referencing demolition of the buildings and embodied energy. Embodied Energy considers the energy consumed and carbon dioxide (CO₂) emitted during the construction (including energy required to extract, manufacture, transport, and assemble the construction materials), refurbishment, and sometimes demolition of a building. Operational Energy considers the energy used by a building for heating, ventilating, lighting, etc. in order to maintain occupant comfort and the CO₂ emitted during the use of the building. They are the two defining metrics.
useful in arriving at the decision of what to do with a building, i.e. refurbish or demolish and build a new one.

Substantial weight has been traditionally attached to Operational Energy as a building’s life expectancy can be fifty to one-hundred years or longer and the sums of energy and carbon impacts accumulate over the years, dwarfing Embodied Energy.

The pressures created by the related concerns of fossil fuel availability, energy costs, and the climate related impacts associated with fossil fuel consumption have spurred the development of systems and interventions that when imposed on a building, coupled with a transition to renewable energy supplies, is altering that paradigm.

Energy needed for operations can be decreased considerably by making improvements to the insulation of the building envelope, technical solutions, etc. These measures can then change the relationship between operational energy and embodied energy.  

Embodied Energy is measured as a quantity of non-renewable energy per unit of building material, component or system, expressed as unit of energy per unit of weight or volume and there exists a strong correlation between embodied energy and environmental impacts.

This shift is of special interest to concrete buildings for two reasons. First, the amount of embodied energy within concrete. As a building material concrete is not high on the list of materials with large quantities of embodied energy (Table 3.17), even though cement, a material of high Embodied Energy, is one of its ingredients. While not

Notes

313 (Thormark 2006, 1019)
314 (Canadian Architects n.d.)
315 Note; Embodied energy values are based on several international sources; local values may vary.
high in Embodied Energy per unit, the importance increases when total units are considered. The FAC’s twenty-five thousand yards (19,113.87 m$^3$) of concrete contains 102,868,107.7 pounds (346,758,230.8 kg) and is responsible for 60,785.7 GJ.

Table 3.17: Embodied Energy Values of Common Building Materials (Demolition is not included).

<table>
<thead>
<tr>
<th>Material</th>
<th>MJ/KG</th>
<th>MJ/m$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>227</td>
<td>515,700</td>
</tr>
<tr>
<td>Brick</td>
<td>2.5</td>
<td>5,170</td>
</tr>
<tr>
<td>Cement</td>
<td>7.8</td>
<td>15,210</td>
</tr>
<tr>
<td>Concrete</td>
<td>1.3</td>
<td>3,180</td>
</tr>
<tr>
<td>Glass</td>
<td>15.9</td>
<td>37,550</td>
</tr>
<tr>
<td>Gypsum Wallboard</td>
<td>6.1</td>
<td>5,890</td>
</tr>
<tr>
<td>Lumber</td>
<td>2.5</td>
<td>1,380</td>
</tr>
<tr>
<td>Steel</td>
<td>32</td>
<td>251,200</td>
</tr>
</tbody>
</table>

In an effort to gain perspective on a number this large the embodied energy in the concrete alone is equal to the total amount of energy the FAC consumes in 2.55 years as simulated in the “FAC 1976 Baseline Model”. If the total energy consumption simulation from the FAC model where 2” (5.08 cm) insulation was installed (see 3.2.2, “Possible Contemporary Interventions”) the number increases to 3.38 years.

This is from the concrete alone. An Embodied Energy standard is that the envelope accounts for approximately 25% of a building’s total embodied energy. ³¹⁶ Adding roofing materials, structural steel, reinforcing steel, aluminum windows, and steel doors to the FAC’s Embodied Energy envelope total and extrapolating the results with

Notes

³¹⁶ (Cole and Kernan, Life-Cycle Energy Use in Office Buildings, Building and Environment 1996)
concrete representing approximately twenty percent of total Embodied Energy, finds the FAC’s embodied energy at ten to thirteen and one-half years’ worth of Operational Energy, depending on which model is used in the comparison.

The second point of interest concerning Brutalist buildings and the Embodied Energy of concrete is the additional Embodied Energy attached to a demolition effort. Methods of demolition vary:

- Mechanical, i.e. executed by excavators, cranes, loaders, and bulldozers.
- Induced Collapse, i.e. the systematic and sequential removal of key elements of the structure by applying a force that results in the controlled collapse of that structure.
- Building Implosion, i.e. using high-powered explosives to collapse a building.

All are energy intensive and all are followed by intensive clean-up and final disposal of the demolition debris.

The evolving relationship between Embodied Energy and Operational Energy, when evaluating a Brutalist building, must always be considered because of the sheer quantity of concrete involved. Additionally, any potential for renewable energy precipitated by the building itself must be factored in to the equation (see, “Appendix G, “FAC Bridge Photovoltaic Array”). The presence of a Brutalist building in a stakeholder’s real estate portfolio demands special consideration.

For a Brutalist building, the expression, “Set in Concrete”, firmly established and very difficult to change317, has much more significance than immutability.

Notes

317 (Heacock 2003)
CHAPTER 4

CONCLUSIONS

The assorted avenues of inquiry required for a thorough investigation of the University of Massachusetts-Amherst’s Fine Arts Center have led to a deeper understanding and appreciation of a singular period in architectural history, Brutalism. In the first chapter, “Architecture”, the exploration began from the broader perspective of the social and technical revolutions spawning the development of architectural Modernism and, in turn, Modernism’s evolution and enthusiastic embrace of Brutalism. This was followed by a narrowing of perspective, wherein the building type was dissected and examined in detail through a diverse array of research topics, e.g. architectural criticism, philosophies of aesthetics, building sector construction type preferences, period construction material choices, pressures and influences related to architectural design decisions, and evolving occupant comfort expectations. The concluding perspective is a final tightening of focus onto the actual building, the Fine Arts Center, and Kevin Roche, the architect from whose mind the construct emerged.

Chapter One’s final section, “University of Massachusetts-Amherst Fine Arts Center” and its two subsections, “The Architect – Kevin Roche” and “The Building” define the physical anchor of the central theme of this project. The theme: utilize a single Brutalist building, designed and constructed before the tidal wave of computer assisted architectural drafting aids and evolving energy modeling tools, and insert that building into the new digital technologies. Once the physical construct had been reproduced as a virtual doppelganger and analyzed, the outcome was an understanding of a building, of this size and type, from a perspective not previously available.
The second chapter, “Methodology”, provides the description of the complicated and time consuming processes (at this moment in the evolution of digital technology) necessary to develop and program an energy model of a building as large and complex as the FAC. The processes and reasoning behind the programming of the various inputs, complicated by the fact that the targeted building is from an earlier period absent building meters or energy records, are reviewed and explained. The intentions of six sections of this chapter (see 2.1, “Original Documents”; 2.2, “Modeling Geometry”; 2.3, “Energy Models”; 2.4, “Programming”; 2.10, “Weather Files”; 2.11, “Energy Use Intensity and Square Footage”) are to assist others who might attempt a similar task. To that end, existing obstacles to the process, discovered and resolved or “worked around”, in order to accomplish the final goal of a robust and validated model, are included.

The execution of an energy model, as described, permits not only an intrinsic and detailed understanding of a building, as it was originally designed, but also offers a tool to be used by existing or future stakeholders to evaluate the efficacy of building program changes or construction related (fabric and systems) interventions.

The second chapter also includes discussion of the issues surrounding energy model calibration and validation, a thorny topic in the world of energy modeling. Calibration and validation conventions are discussed, within the conventional framework of RMSE protocols. It is followed by a subsection, 2.12.5, “FAC 1976 Model Validation”, that presents a reasonable methodology to supply the required veracity to an energy model of a period building.

In the final chapter, “Analyses”, the results of the simulations of the FAC, as performed by the two energy analysis programs, DesignBuilder and Autodesk’s Ecotect
Analysis, are documented. Analyses fall into five categories, each useful in placing the
FAC in perspective:

- Confirmation that a performance strategy is ineffective or absent, e.g. envelope performance
  inadequacy and deficiency.
- Confirmation that intentional positive performance strategies are in place and effective, e.g.
  Daylight Harvesting, Glare Control, Shading.
- Confirmation that unintentional positive performance strategies are in place and effective, e.g.
  Window Solar Gain Control.
- Confirmation that unintentional positive performance strategies are in place and not effective,
  e.g. Siting and Orientation.
- Possible confirmation that unintentional positive performance strategies are in place and
  might be proven effective with further study of the FAC and/or other Brutalist buildings
  having higher window-to-wall ratios and/or locations in hot climates, e.g. Solar Defense via
  Self-Shading, Solar Absorptance, Thermal Mass, Wind

The first analytical task confirms that an envelope performance deficiency exists.
This might be viewed as support of the harsh energy performance criticism that the FAC
and other Brutalist buildings endure. However, simulations with models, altered by
commonplace, if not inexpensive, interventions addressing the poor thermal envelope
performance, demonstrate that a reasonable remedy is possible (see 3.2.2, “Possible
Contemporary Interventions”). These simulations also point out that an improved thermal
envelope performance intervention, if implemented, results in a building with a more
“acceptable” EUI (see 3.1, “FAC EUI”).

The second analytical category focuses on Daylight Harvesting and Glare
Control. The confirmed results supply the opportunity to shift these specific performance
discussions from anecdotal statements, “the building has good daylighting and glare
control qualities in the perimeter offices/small studios”, to a discussion with defining metrics quantifying these qualities. With metrics in place, stakeholders are able to investigate strategies of electric lighting controls incorporating daylight sensor technology, balancing the intervention’s cost against electricity consumption and the attendant EUI reduction.

The third analytical category confirms that unintentional positive performance strategies are in place and effective, e.g. Window Solar Gain Control. This result addresses the premise that the FACs poor thermal envelope performance so dominates all discussions of its performance that in place and effective strategies are ignored. This strategy’s effectiveness at reducing energy consumption, while not a concern in 1976, has evolved into a performance category of value, i.e. reduction of summer cooling loads.

The fourth analytical task, Siting and Orientation, represents an examination of a strategy that had little consequence for the FAC, because of a low window-to-wall ratio. However, the results suggest that other Brutalist buildings with higher window-to-wall ratios, in a similar climate, might prove to have been carefully sited by their designers. Energy model investigations of other buildings should include ordinal rotation iterations to determine and understand the effectiveness of the building’s positioning.

The final analytical category, unintentional positive in-place performance strategies might prove to be effective with further study for both the FAC and/or for other Brutalist buildings with different window-to-wall ratios and/or locations in hot climates. This is the most exciting of all the results. It is of secondary importance that the simulations suggest that these strategies might be present in the FAC. It is of primary importance to realize that these strategies might be in place and effective in the
significant inventory of Brutalist buildings designed with varying window-to-wall ratios and/or constructed in hot climate regions around the world.

Additional studies of the FAC within DesignBuilder and Ecotect with models created with selectively designed partial geometries, within different energy modeling programs performing specialized simulations, or expanding the simulations of the existing models with more computing power are the next steps to be undertaken.

The weakness of this project is, of course, a statistical weakness. It is a study of one building with energy modeling programs that are considered statistically marginal, but these are the tools that are presently available and all bodies of research begin with a single, solitary exercise.

Still, a detailed understanding of the FAC offers multiple contributions. There are numerous paths down which the information supplied by this project can and will travel.

Architecture Scholars of Modernism or Brutalism are provided with an example of a single Brutalist exemplar, the FAC, examined in painstaking detail from a multiplicity of perspectives, architectural, social, and energy performance.

Architecture Critics defending the preservation of an endangered building can refute the opponent’s claim of negative aesthetics and poor performance in an adjacent paragraph to the one in praise of geometry with information provided by this project.

Architects or Designers can emulate or modify and incorporate the FAC’s effective design strategies, documented within this project, into their own work’s performance and aesthetic goals; complimenting Roche and the FAC with precedent acknowledgement.
Organizations supporting Modernist Architecture, e.g. Docomomo, can populate their newsletters and electronic communications with newly acquired information about the FAC, supplied by this project. The information will reach a clientele already receptive to the building type, but lacking information on maintenance and performance issues that relate to the aesthetics they admire.

Preservationists can glean information about the FAC and Brutalism that contributes to preservation theory and practices across the world with respect to changes that would be acceptable within the sometimes-conflicting philosophy and goals of preservationists, energy conservationists, and property owners.

Architecture Schools’ pedagogy has increasingly been populated over the past two decades with coursework directed at sustainable strategies. The interest and student demand is synchronized with the awareness and concern of building energy consumption as it relates to fossil fuel availability, energy costs, and climate change. The performance analyses provided by the FAC can comfortably partner with the lessons taught relating to earlier traditional building’s passive strategies addressing ventilation, heating, or shading expanding the student’s design repertoire.

“Physical Plant” and “Campus Planning and Facilities Management”, here at the University of Massachusetts-Amherst, will have access to this document, several of their members have contributed. Chapter 1, “Architecture” will provide some with information about the FAC and Brutalism that will prompt a reassessment of a dominant campus building and its Brutalist companions. This analyses of the FAC will expose the campus planners and energy conservation proponents in these departments to the
possibility of a reassessment of the perception of the FAC’s existing performance and a reassessment of opportunities for future energy performance improvements.

**Municipal, State, National, or other Institutional Managers** with Brutalist buildings similar to the FAC, in every climate, can make use of the appropriate observations from this investigation to explore energy performance improving interventions for their buildings identical to the opportunities experienced by UMass-Amherst managers.

**Energy Modelers** will benefit in a broader context than all of the above as their interest as a group is in building performance in all architectural styles. The information within this project related to energy modeling was acquired through multiple sources and now this project is one more source on the library shelf. However, this project focuses on the task of a large complex period building without digital documentation and is without precedent. Repeating this task for other similar buildings will be a requirement sometime in the future as the digital world continues to advance. Pertinent information in this project will lessen the task for some modeler some place in the world.

The final contribution is a hope, that this examination inspires an appreciation of University of Massachusetts-Amherst’s Fine Arts Center and its brethren, on campus and around the world. It is a hope that this appreciation leads to: improved maintenance procedures restoring these building’s original public visages, heightened awareness and optimization of the existing sustainable strategies within these buildings, and an initiation of aesthetically thoughtful interventions improving their performances. These architectural sculptures are significant members of the Architectural Community.
Respectfully treated they will be able to execute their program, ordained or new, while treading lightly on or even contributing to our environment.

*If you cannot measure it, you cannot improve it. – Lord Kelvin*
APPENDIX A

HINTS, TECHNIQUES, AND OBSTACLES ENCOUNTERED

The scope of this work does not include the step by step instructions necessary to produce a robust 3D energy model. However, in an effort to add to the body of information that presently exists relating to the process of creating a large complex building in Revit with the intent of successfully exporting the 3D geometry into an energy modeling program via gbXML format, a series of hints, techniques, and obstacles encountered that were discovered in the process of producing the FAC model and not found elsewhere in modeling literature follows.

Floors, walls, roofs should be drawn as simply as possible. Use Revit’s “Basic” Families, which supply a core surrounded by two core boundaries. Thickness selection can be unlimited. Material choices for the elements can help the modeler visually identify types of walls, roofs, or floors while working within the Revit Graphical User Interface (GUI) and will not be imported into the energy model. All programing of geometric element’s properties, e.g. material, color, layers, reflectance, thermal characteristics, etc. will be entered within the energy model.

As the Revit model is constructed, be absolutely certain to attach all walls to the floor they originate at and to the roof they are supporting. This helps to insure intact Room/Space volumes.

Even though the exterior and interior sides of the “Basic” wall families appear identical they do have interior and exterior sides and the correct orientation should be

Notes

318 Note: This information is specific to Revit, DesignBuilder, and Ecotect. It may or may not be appropriate for every energy modeling frontend.
maintained as complex non-orthogonal joins and intersections of wall members are simplified and more correctly interpreted through the export/import process.

It is imperative, in the case of large models, to clearly number and name each of the Room/Spaces in such a way that the frontend displays in its “Room/Space List Window” a sequence that is completely logical and decipherable. The links between the numbers and names in this list and the geometry in the “Edit Screen” are the tools used to locate and isolate a particular Room/Space within the geometry, which might lie deep within the interior of a large model.

Although interior doors are not necessary for the energy model and do not impact the simulation, it can be quite helpful in large models with complex interior arrangements of Room/Spaces to include the doors for purposes of visual navigation and orientation when the geometry of the model is viewed in the GUI of an energy modeling program where geometry is often presented in wireframe view (Fig. A.1).

As the building is constructed, it is helpful to export a gbXML file and import that file into the energy modeling program in order to insure that
all is correct. This will allow, if necessary, a productive and timely correction, as the incorrect geometry will only have recently been created. An early undetected geometry error that disallows exporting of a gbXML file can be difficult to locate and correct if it is deep within a total geometry and error compounding might have occurred that disqualifies many hours of work, if an import is delayed until all geometry is thought to be correct and complete.

In Revit the command (File/Export/gbXML) will open the “Export gbXML-Settings” window, the left side of which allows a visual 3D inspection of the model. This is helpful in identifying any errors in the Revit construction of the Room/Spaces needed to establish the energy model’s geometry. The “Export gbXML-Settings” window’s visual display has tools that can isolate building levels, building Room/Spaces, and building elements in a fully interactive 3D environment. Activating the “Analytical Surfaces” radio button on the “Details Tab” will distinguish elements by color, which can be visually helpful. Frequent viewing with this technique prevents the intricate geometry, which will ultimately be present when a large building model is completed (Fig.A.2) from overwhelming a modeler’s inspection capacity, as only the most recent additions need be inspected for error.

On the right side of the “Export gbXML-Settings” window is a “General Tab” requiring inputs depending on the intended use of the model that is created in Revit, which can include some analysis within the Revit software itself or export to “Green Building Studio”, Autodesk’s cloud-based energy analysis program. For purposes intended in this work Revit’s function was solely to create the geometry that will be
accurately imported into an energy modeling frontend. The inputs to be used are shown below (Fig.A.3).

![Figure A.2: “Export gbXML-Settings” Window. All Room/Spaces visible.](image)

The right side of the “Export gbXML-Settings” window also has an “Analytical Surfaces” tab (mentioned above), which will allow detailed viewing of each constructed Room/Space helping to further proof out the model (Fig.A.4).

Finally, the “Details Tab” also has an “Error Message” button. It is not safe to assume that if this button is not active (lit) that the model is without errors. In some cases, especially with “Room/Space Volume” heights that are not consistent with the
“Room/Space Ceiling/Roof” heights the button will not be active (lit), but there actually is/are error/errors in the model. Always scroll through “Building/Level/Space/Component Tree” to check if there are “Error Message Tags”. It is only there that the warning sign will always appear. Click on the “Error Message Tag” in “Building/Level/Space/Component Tree” (if found) and the main “Error Message Tag” at the right of the window will become active. When that icon is then clicked an Error Message (Fig.A.5) will appear. The modeler can then re-enter Revit and make the necessary modifications. There is no edit function in the gbXML window. If the assumption is made that the gbXML model is correct and the “Next” button at the bottom of the “Export gbXML-Settings” window is clicked, without the “Building/Level/Space/Component Tree” reviewed thoroughly, Revit will produce a gbXML file, which will be missing the Room/Space containing the error, which in turn will be missing from the energy model’s geometry.
It is critical to be aware that the accurate transfer of geometry from Revit via gbXML export into an energy model frontend is accomplished solely by the complete and accurate digital construction of the geometry of the volume of the Room/Space as delineated by Revit’s “Room and Area” tools and the “Area and Volume Computations”. Any error occurring during this process will either prevent a Room/Space from being created or result in a Room/Space being created with inaccurate geometry. There are some instances where the geometry can be corrected with the drawing and editing tools available in the energy model program, but often a modification is either difficult or not possible. It is almost exclusively best to resolve the issue within Revit, produce a revised gbXML file, and import the corrected file into the energy modeling frontend.

Additionally, there were some anomalies discovered in the creation of the gbXML file for the FAC that appeared seemingly without logic. In Revit there are two methods to transfer the gbXML data into DesignBuilder. The first method is using Revit’s gbXML export function (File/Export/gbXML) to produce the gbXML file after all editing and
proofing of the file has been executed. DesignBuilder software is then opened separately and the file imported into it (File/New Project/Import BIM/gbXML Model). The second method is using Revit 2015’s DesignBuilder Add-In (see Appendix C, “Revit’s DesignBuilder Add-In”), which uses the identical gbXML file data. An advantage of the Add-In (in addition to an excellent visual of the geometry that will be imported into DesignBuilder) is that there are also two spreadsheets produced, i.e. “Summary Report” and “Surface Report”; the first is of special value when determining the DesignBuilder model’s GSF (see Appendix E, “Model Square Footage Reconciliation”).

When creating the FAC model it was noticed when testing imports that one of the Rooms/Spaces that should be imported into DesignBuilder was missing. The Room/Space in question appeared in Revit’s gbXML export graphic and was imported correctly into DesignBuilder using the first methodology, but not when using the DesignBuilder Add-In. The remedy was to delete the defining Room/Space elements in Revit and then recreate the identical elements, produce another gbXML file within Revit, and try the DesignBuilder Add-In again. It now exported the correct geometry!

The above anomaly is mentioned to underscore the point that the process of moving a large complicated building possessing complex geometry is tremendously intricate and involves transfer of data that at this point in time is, if not in its infancy, is at least in its childhood. It is improving every year, but constant vigilance by the modeler is demanded to ensure that what was drawn in one program emerges intact and correct in the second.
APPENDIX B

AUTODESK ECOTECT ANALYSIS

Autodesk purchased Ecotect Analysis from its developer, Square One Research, in 2008. At that time, there was a general anticipation among the community of Ecotect users that the resources of Autodesk would expand and refine the program’s already robust analysis capabilities in the areas of solar impacts, shading studies, and daylighting. Unfortunately, that was not to be the case. Ecotect was minimally supported by Autodesk and the interface did not receive many advancements or improvements over the ensuing seven years. Alternatively, aspects of the Ecotect program were subsumed into Autodesk’s Revit and finally, in March of 2015, Ecotect purchases were discontinued completely.

Effective March 20, 2015, new licenses to Autodesk® Ecotect® Analysis software will no longer be available for purchase. Autodesk will integrate functionality similar to Ecotect Analysis into the Revit® product family. This change will allow Autodesk to shift resources, maximizing development efforts on BIM and cloud-based solutions for building performance analysis and visualization.

Customers with active Subscription contracts for Ecotect Analysis software will continue to receive access to their benefits, including support and the use of eligible previous versions of the software until their contracts expire. Customers who purchased Ecotect Analysis software with Maintenance Subscription, will continue to use their perpetual license even after expiry. 319

The efforts related to this work involving analysis with Ecotect, specific to analyzing existing buildings, had begun in 2008 and specific to this project in 2010. At the late date (referencing this project) of 2015, changing to another modeling program to

Notes

319 (Autodesk n.d.)
reproduce the findings in Ecotect was not an option. Ecotect results in this project can be reproduced and verified, but only if access to a previously purchased “Ecotect Perpetual License” is able to be located and accessed.
APPENDIX C

REVIT’S DESIGNBUILDER ADD-IN

When using software in a lengthy project such as this one, it is a usual occurrence that there will be new versions of the software that periodically becomes available. It is unusual that a software will be abandoned, as was the case with Ecotect (see Appendix B, “Autodesk Ecotect Analysis”), but periodic updates every year or two are typically inevitable.

Autodesk’s Revit has for the last several years had an annual update, but unlike many software programs, Autodesk allows the installation of multiple versions of the program to be installed on the same computer. The only restriction of consequence to a user is that once a file, created in an earlier version, is opened and saved in a newer version, it cannot be opened again in that earlier version. Consequently, care must be taken to use a copy of the original file in the newer version, if the user intends to continue using a file in the earlier version.

The question as to why the earlier version of the software might be preferred is that although it was the intent of the developer to improve the program with the newer version, there are instances when certain tools are changed and those improvements for a particular user’s intent are not improvements at all. This was the case with the “DesignBuilder Add-In”. There was a substantial change between Revit 2015 and Revit 2016.320

Notes

320 Note: At the time of this writing Revit 2017 has not been examined.
The “DesignBuilder Add-In” interface is not solely the responsibility of Autodesk Revit as it is linked on the hardware it is installed on to the updated version of the DesignBuilder software at the time of Revit’s release. This means that the “DesignBuilder Add-In” will only work if the correct version of DesignBuilder is also installed on the same hardware. There is a communicating dialogue between the two programs on the hardware and they must be chronologically respectful versions.

All of the work in this project transferring the geometry from Revit to DesignBuilder was done using Revit 2015 and with DesignBuilder version 4.2.0.054, released on October 3, 2014. The next two releases were version 4.5.0.148, released on October 8, 2015 and version 4.2.0.057, released on February 9, 2016. These versions were never used in this project, as the geometry import was successful with all issues resolved, as has been discussed (see 2.2, “Modeling Geometry” and 2.3.1, “DesignBuilder”).

In the interest of determining the continued relevancy of the methodology used to execute the transfer of geometry as described in this work, the Revit 2015 “FAC Model” was updated to Revit 2016 and the most current release of DesignBuilder, version 4.7.0.27, released April 7, 2016, was installed. DesignBuilder allows only a single version of its software to be installed on hardware, so the earlier version was uninstalled. The earlier versions are available for download and can be reinstalled, if desired, by reversing the process.

The investigation found that the “DesignBuilder Add-In” for Revit had changed. The Add-In was no longer located under the “Add-Ins Tab”, but now could be found under the “Analyze Tab” where it is now a two-step process. First, the “Settings Menu”,
which controls what data in the gbXML file is to be exported, is activated and second, the “DesignBuilder Button”, which initiates the export, is triggered.

Missing from the new Add-In dialogue process were the two detailed spreadsheets referencing geometry specifics and most importantly the 3D Window, which had allowed detailed 3D inspection opportunities (see 2.2, “Modeling Geometry” & 2.3.1, “DesignBuilder”). The Revit 2016 export into DesignBuilder evidenced both positives and negatives.

- Shading plane imports had been reduced enormously, i.e. from over 3400 (Fig.2.8) to 860 (A.6). Some of the 860 planes were incorrect, but a new error message alerts the modeler to the fact that they might exist and directs the modeler’s attention to roofs (Fig.A.7).
• Shading planes are now included with the imported geometry. The twelve pilotis that the earlier Add-In had excluded, i.e. it had restricted element imports that were only related to the conditioned zones. These objects are now defined as “Shading Planes”, which will defend the main building from solar gain, but they are not “Component Blocks” and cannot be inputted with materiality, which eliminates the impact of reflectance and albedo impacts for these surfaces from the model.

• The model was also missing several “Building Blocks” entirely, e.g. the Theatre and several others Room/Spaces have been imported as “Outline Blocks” rather than “Building Blocks” (see blue and red arrows respectively in Fig.A-6). An “Outline Block” is just a 3-D shape without associated building elements such as walls, floors, roofs, etc. DesignBuilder has a tool, which converts “Outline Blocks” to “Building Blocks”, but it is not always successful. In the case of the FAC model, the conversions were not successful. Drawing some of these missing “Building Blocks” might be possible within the program if the geometry is relatively simple, but in this case, it was the more complex geometries that were either missing or imported as “Outline Blocks” and drawing them within DesignBuilder would be problematic.

The “DesignBuilder Add-In” for Revit 2016, coupled with the current release of DesignBuilder, does result in some notable improvements, i.e. eliminating BIM transfer artifacts and the resulting incorrect shading surfaces along with the alerting message that more deleting might be required (Fig.A.7). However, the missing “Building Blocks” and imported “Outline Blocks” are significant negatives (referencing this project).

Note that an identical result was also found when using the alternative methodology (“Revit to gbXML to DesignBuilder” without using the Add-In).

Whether importing the identical gbXML file, created in Revit 2015, that executed exact geometry imports albeit with the attending excess of superfluous shading surfaces or importing a new gbXML file, created by Revit 2016, from the updated Revit 2015 FAC file the errors were consistent with using the “DesignBuilder Add-In”.

360
Yet a preview of the gbXML model in the DesignBuilder Import BIM Model screen, which allows axonometric (not interactive), plan, and elevation views shows all the Blocks as being present (Fig.A.8). This is in agreement with the gbXML export preview that was in the Revit interface. The imported results, nevertheless, demonstrate the identical block errors.

In conclusion, if the missing “Building Block” and “Outline Block” issue can be resolved by the modeler then the Revit 2016 “DesignBuilder Add-In” is superior. If that cannot be resolved, then the Revit 2015 DesignBuilder Add-In being used to closely examine the gbXML model along with the use of the Add-In’s two spreadsheets followed by a DesignBuilder version 4.2.0.054 gbXML import is the superior technique – at least for the FAC model in this project.
APPENDIX D

HDD RECONCILIATION

A HDD data for the Chicopee Falls-Westover Air Force Base TMY file was obtained from Autodesk Ecotect’s Weather Manager. The program opens the “wea file” that was originally converted from the “bin file” downloaded from “DOE2 Weather Data & Processing Utility Programs”, which is the source of the TMY files.\(^{321}\)

HDD are itemized in the “Weather Manager” monthly as Heating Degree Hours (Fig.2.32) and reported in Celsius. Data is first converted to HDD (Table A.1).

Table A.1: Heating Degree Hours to Heating Degree Days.

<table>
<thead>
<tr>
<th>Month</th>
<th>Heating Degree Hours</th>
<th>Heating Degree Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>13,287</td>
<td>553.63</td>
</tr>
<tr>
<td>Feb</td>
<td>12,762</td>
<td>531.75</td>
</tr>
<tr>
<td>Mar</td>
<td>11,870</td>
<td>494.58</td>
</tr>
<tr>
<td>April</td>
<td>8,006</td>
<td>333.50</td>
</tr>
<tr>
<td>May</td>
<td>4,244</td>
<td>176.83</td>
</tr>
<tr>
<td>June</td>
<td>1,044</td>
<td>43.50</td>
</tr>
<tr>
<td>July</td>
<td>499</td>
<td>20.79</td>
</tr>
<tr>
<td>Aug</td>
<td>791</td>
<td>32.96</td>
</tr>
<tr>
<td>Sept</td>
<td>2,849</td>
<td>118.71</td>
</tr>
<tr>
<td>Oct</td>
<td>5,522</td>
<td>230.08</td>
</tr>
<tr>
<td>Nov</td>
<td>9,179</td>
<td>382.46</td>
</tr>
<tr>
<td>Dec</td>
<td>12,180</td>
<td>507.50</td>
</tr>
<tr>
<td>Total</td>
<td>82,233</td>
<td>3,426.375</td>
</tr>
</tbody>
</table>

Notes

\(^{321}\) http://doe2.com/index_wth.html
Celsius HDD are then converted to Fahrenheit HDD:

\[ ^\circ F \text{ HDD} = 1.81 \times ^\circ C \text{ HDD} \]
\[ ^\circ F \text{ HDD} = 1.81 \times 3426.375 \text{ } ^\circ C \text{ HDD} = 6201 \text{ } ^\circ F \text{ HDD} \]

HDD data for the South Deerfield, Massachusetts Weather Station KMASOUTH15 was obtained from DegreeDays.net (Table A.2). Data was requested at monthly intervals and extended from July of 2009 until June of 2015. The UMass-Amherst annual energy data is reported on a calendar year of July 1 thru June 30, which allowed clear correlation of data sets.

Table A.2: KMASOUTH15 HDD.

<table>
<thead>
<tr>
<th>Year</th>
<th>HDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-09 thru 6-10</td>
<td>6621</td>
</tr>
<tr>
<td>7-10 thru 6-11</td>
<td>6865</td>
</tr>
<tr>
<td>7-11 thru 6-12</td>
<td>5719</td>
</tr>
<tr>
<td>7-12 thru 6-13</td>
<td>6548</td>
</tr>
<tr>
<td>7-13 thru 6-14</td>
<td>7275</td>
</tr>
<tr>
<td>7-14 thru 6-15</td>
<td>7252</td>
</tr>
<tr>
<td>Six Year Average</td>
<td>6713.33</td>
</tr>
</tbody>
</table>

The HDD the FAC actually experiences was 6713 HDD (six-year average) as opposed to the 6201 that the model experiences in simulation. The 512 HDD represents a difference of 8.26%, which is significant with respect to space heating. Space Heating is the single largest load that the FAC experiences, not an atypical scenario for buildings in the Northeast, United States.

Notes

322 http://www.degreedays.net/
Heating energy usage in the FAC is included in the steam usage reports that UMass-Amherst produces each July at the completion of their energy usage year. Steam usage includes DHW and Laboratory Usage. The FAC does not have any Laboratory steam usage, but it does use DHW. Although the UMass-Amherst Physical Plant does not meter separately for DHW the DesignBuilder model does segregate that usage.

Low-pressure steam is delivered from the UMass-Amherst Central Heating Plant (CHP) at 1 bar or 15 psig (103,421.4 Pa). Steam at that pressure is at a temperature of 250 °F (121.1 °C). In a 15 psig (103,421.4 Pa) steam supply there is 217 Btu/lb (507.1 kj/kg) of sensible heat and 945 Btu/lb (2,198.1 kj/kg) of latent heat for a total of 1,164 Btu/lb (2,705.2 kj/kg).\(^{323}\) This is consistent with CHP information, which uses the multiplier of 1,194 to convert pounds of steam to Btu.\(^{324}\) To be consistent with CHP calculations and because they measure steam pressure, 1,194 Btu/lb is the multiplier used in all steam to Btu conversions.

The compensation protocol implemented was to convert the six-year average of the FAC’s annually reported steam usage into energy (KBtu) and then deduct from that total the amount of energy used to produce DHW as simulated in the DesignBuilder “FAC Model”. With UMass-Amherst steam energy usage for the FAC now representing only the space-heating segment and excluding the DHW segment the actual HDD total and the modeled HDD total could be reconciled.

The discrepancy factor of 8.26% was used to adjust the model’s space heating energy to more realistically represent the HDD that the model would have been exposed

**Notes**

\(^{323}\) (Brubaker 1985)
\(^{324}\) (Burbank 2015)
to if the Chicopee Falls-Westover Air Force Base TMY file’s HDD had matched the six-year average that the FAC actually experienced, which precipitated the actual energy data.
APPENDIX E

MODEL SQUARE FOOTAGE RECONCILIATIONS

The GSF of the FAC was established at 206,641 sq.ft. (19,197.58 m²) based on the verification of the ten “Plan Drawing Sheets” from the Original 1969 Construction Set found in Box 67 at the “Kevin Roche John Dinkeloo and Associates Records at the Yale University Library’s Manuscripts and Archives”, which contained annotated GSF measurements.

E.1 Revit Model Geometry Validation

Diligent digital drawing practices were used creating the model’s geometry within Revit in an effort to assure that the digital model would duplicate, with a low level of error, the areas and volumes of the actual building. “Schedules” in Revit are able to tabulate areas, but they do not tabulate with GSF protocol.

Revit’s default area tools are targeted at the Real Estate sector with two different total area tabulations possible. The first option is to arrive at the total area of the building as measured “At Wall Finishes”. This tabulation excludes all wall thickness, both interior and exterior. The total results of this calculation was 170,466 sq.ft. (15,836.81 m²), i.e. 36,175 sq.ft. (3,360.77 m²) less that the KRJDA GSF. The second tabulation, is taken from “At Wall Centers”, which includes all interior walls between Rooms/Spaces, but only to the wall center of the exterior walls, i.e. the halfway point. The results of this calculation was 179,598 sq.ft. (16,685.20 m²), i.e. 27,043 sq.ft. (2512.38 m²) less that the KRJDA GSF.

366
The purpose of the default Room/Space tabulations that Revit provides is to aid in determining rentable areas for stakeholders, but are not relevant for GSF calculations. Revit does have tools within the program to tabulate GSF according to BOCA protocol, but it is a complicated task with a complex model.\textsuperscript{325}

An alternate method was used with the FAC Revit model to determine the amount of GSF that was located in the remaining half of the Room/Space exterior walls. By eliminating all walls that were not exterior perimeter walls of Room/Spaces and creating a “Wall Schedule” (Fig.A.9) for only exterior perimeter walls it was determined that the wall footprints occupied 11,757 sq.ft. (1,092.26 m\textsuperscript{2}). Half of that area 5,878.5 sq.ft. (546.13 m\textsuperscript{2}) was added to the Revit Room/Area calculation resulting in a corrected total of 185,473 sq.ft. (17,231.00 m\textsuperscript{2}).

![Figure A.9: FAC Perimeter Envelope Wall Areas.](image)

The missing GSF, 21,168 sq.ft. (1966.57 m\textsuperscript{2}), amounts to 10.24\% of the KRJDA GSF total. It can be accounted for by surfaces that would have been included in a BOCA or CBECS calculation of GSF, but were not drawn in the Revit model as these surfaces

\textbf{Notes}

\textsuperscript{325} (Vandezande, Krygiel and Read 2013, 745-746)
would have added to the complexity of the gbXML export and/or complicated the Room/Space volume constructions (see 2.2.3, “Room/Space Volumes”).

These spaces included:

- Mechanical floors or walkways, e.g. catwalks in Auditorium, Theatre, and Studio Theatre.
- Balconies and Mezzanines, e.g. Seating and Circulation areas above the Main Floor in Auditorium and Theatre.
- Footprints of stairways, elevator shafts, and vertical duct shafts are to be counted as gross area on each floor through which they pass.

Additional inspection of the KRJDA documents accounts for the missing areas:

- Drawing Sheet, A-2 shows that in the Studio Theatre there are 1,715 sq.ft. (159.42 m²) of Catwalks.
- Drawing Sheet, A-4 shows that in the Theatre there are 4,700 sq.ft. (436.64 m²) of Ticket Booth, Lobbies, Offices, Staircases, Ramps, and Chases above the Main Floor.
- Drawing Sheet, A-7 shows that in the Auditorium there are 6,860 sq.ft. (734.12 m²) of balconies.
- All Room/Spaces areas in the Revit Model only measure the area of the level they were created on. This is problematic for stairwells and elevators as it is necessary to add the GSF of each of the additional level above that level. There were nine Room/Spaces with this deficiency resulting in an additional GSF total of 5,472 sq.ft. (508.36 m²).

Total for the above additions is 18,747 sq.ft. (1,741.65 m²), which reduces the difference with the KRJDA GSF total to 2,421 sq.ft. (224.92 m²). The missing total is now 1.17% of the total KRJDA GSF.

No further effort was expended to justify the Revit model. Although great effort was involved to create the geometry of the model as accurately as possible, small errors most certainly exist. The time necessary to reconcile these cannot be justified and as the model’s geometry is so complex the 1.17% deviation was accepted.
E.2 DesignBuilder Model Geometry Validation

DesignBuilder’s reported total building area is 166,928.55 sq.ft. (15,508.17 m²).

This is verified in three places:

- Under “Floor Areas and Volumes” on the “Activity Tab” in the GUI.
- The full Simulation Report that can be accessed in the software and exported as an HTML file after a simulation is complete.
- In a spreadsheet, "DesignBuilder Summary Report" that is available for viewing at the time of importing into DesignBuilder using the Revit 2015 DesignBuilder Add-In when the DesignBuilder version 4.2.0.054 is also installed.

Similarly, to the justification of the Revit model, the DesignBuilder model must also be justified. Many of the justifications that were employed in the Revit model are also appropriate here:

- Surfaces that would have been included in a BOCA or CBECS calculation of GSF, but were not drawn in the Revit model. The surfaces are not included in the DesignBuilder model as they were not encoded in the gbXML file.
- Room/Spaces areas in the Revit Model that only measured the area of the level they were created on. The area and volume data that was encoded in the Room/Space volumes in Revit were transferred identically to the DesignBuilder model total just as if they were encoded in the gbXML file.

The aggregate of these two square footage totals is 18,747 sq.ft. (1,741.65 m²). Adding this figure to the 166,928.55 sq.ft. (15,508.17 m²) results in a total of 185,675.55 sq.ft. (17,249.82 m²).

The missing 20,965.45 sq.ft. (1,947.75 m²) is accounted for by the method that DesignBuilder uses to assign wall location lines and conditioned space volumes when
importing data via gbXML (see 2.3.1, “DesignBuilder”). All wall thickness, both exterior envelope walls and partitions are excluded from the area calculations.

Returning to the Revit model and using the “Area and Volume Computations” with “At Wall Finish” selected, the area total in Revit is 170,466 sq.ft. (15,836.01 m²), when the “At Wall Center” is selected there is an accounting of 179,598 sq.ft. (16,685.20 m²). This difference of 9,132 sq.ft. (848.39 m²), plus the additional half-exterior wall area, 5472 sq.ft. (508.36 m²), totals 14,604 sq.ft. (1,356.76 m²).

Addition of these figures brings the adjusted total for the DesignBuilder model to 200,279 sq.ft. (18,606.53 m²). This represents a difference of 6,362 sq.ft. (591.09 m²), a 3.07% deviation from the KRJDA GSF total.

The difference in errors between Revit and DesignBuilder models, 1.17% vs. 3.07% is not easily explained. It might lie within the geometry translations and rounding errors that exist between the Revit model and the DesignBuilder model as transferred by the gbXML file. Nevertheless, the deviation is relatively small given the complexity of the data transfers and the reconciliation of the DesignBuilder model with the KRJDA GSF was accepted.
APPENDIX F

RECONCILIATION OF 1998 ADDITION

The effort to create a new model with the additional 1998 geometry was not undertaken; rather a compensation factor (2.24%) for reducing the 2010-15 average energy consumption data was used. The percentage is consistent with the percentage of 1998 addition GSF within the 2016 FAC GSF (KRJDA GSF plus 1998 Addition GSF).

If the goal of this project had been to model the FAC, as it now existed, the additional geometry would have been created and all default data would have been replaced by information gathered from contemporary occupant surveys and datalogger recordings. This was not the goal of the project.

The decision was based on expediency. A new model with correct inputs would have resulted in a considerable effort with little return in information:

- Occupant surveys and datalogger recordings involves substantial effort and time commitment.
- The impact of specific program and schedules in this small area on the total energy consumption of the FAC, although a contributor (see 2.12.2, “FAC Model), would not have been overly informative or substantial given the dominant impact of the other inputs, i.e. geometry, materiality, and mechanical systems.
APPENDIX G

FAC BRIDGE PHOTOVOLTAIC ARRAY

At the time of this writing, June of 2016, the University of Massachusetts-Amherst has entered into an agreement to install a photovoltaic array on the south facing roof of the FAC Bridge.

UMass Amherst selected Brightergy LLC, Kansas City, MO, in a competitive procurement process to implement, through a Power Purchase Agreement (PPA), the installation and operation of these solar photovoltaic (PV) arrays for the campus.

The PV panels will be installed on the roofs of six existing buildings and on new, steel canopy structures to be built on two, existing asphalt parking lots at the UMass Amherst campus Fine Arts Center (123 kW).326

Referencing the information provided by UMass-Amherst Design and Construction Management Site the annual electricity production of the FAC’s PV Array is expected to average 641,048.03 KBtu (187,872.64 KWh).

The FAC’s annual existing electricity usage, as determined by the “FAC 1976 Baseline Model”, is 7,758,503.65 KBtu (2,273,793.06 KWh). This figure is within 3.01% of the adjusted six-year average of electricity usage reported by the UMass Physical Plant (Table 2.8). Subtracting the FACs electricity production from consumption results in adjusted Total Electricity, Total Energy, and EUI (Table A.3).

Notes

326 (UMass Amherst n.d.)
Table A.3: EUI Improvement by PV Production.

<table>
<thead>
<tr>
<th></th>
<th>Adjusted Results</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Totals (KBtu)</td>
<td>7,117,455.63</td>
<td>-8.26%</td>
</tr>
<tr>
<td>Electricity Totals (KWh)</td>
<td>2,085,920.43</td>
<td></td>
</tr>
<tr>
<td>Total (KBtu)</td>
<td>22,615,293.88</td>
<td>-2.93</td>
</tr>
<tr>
<td>Total (KWh)</td>
<td>6,627,888.67</td>
<td></td>
</tr>
<tr>
<td>EUI (KBtu/sq.ft.)</td>
<td>106.34</td>
<td>-2.83%</td>
</tr>
<tr>
<td>EUI (KWh/m²)</td>
<td>335.46</td>
<td></td>
</tr>
</tbody>
</table>

While the annual PV Array production results in only a modest decrease in EUI, it is important to note that, in New England, the peak electricity production of a PV Array is during the summer months when longer daylight hours, reduced cloud cover, and optimized solar angles to panels are present. This is the period when the University experiences maximum electricity demands forcing reliance on the grid and higher KWh costs, so the electrical contribution is a valued one.
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