Reworking: Transforming a Textile Mill

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REWORKING: TRANSFORMING A TEXTILE MILL

A Thesis Presented

by

JENNIFER M. HAYES

Submitted to the Department of Art, Architecture and Art History of the University of Massachusetts in partial fulfillment of the requirements for the degree of

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Department of Art, Architecture and Art History
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This project examines the adaptive reuse of a disused nineteenth century textile mill building in Gilbertville, Massachusetts. While the original form and structure of the building type was conducive to maximum production of goods, contemporary uses require different forms. Although other mills in New England have been reused for housing, museums, or professional offices, my goal was to propose a program that related to the building’s original function as a place where people worked. Because the unemployment rate is rising in Massachusetts in 2010, I propose that the mill be reused as a training center where people learn green building techniques that they can use in their jobs.

The form of this project is guided by environmental responses to the annual and daily solar paths. Primary among these responses is the conversion of the broad, south-facing masonry wall to a trombe wall system. Similarly, a south-facing light scoop is used on the north side to provide light and heat; shading devices are used throughout the building to prevent overheating.
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CHAPTER 1

INTENT/THESIS

Context

At the close of the first decade of the twenty-first century, the economic situation in the United States had taken a turn for the worse. In the fall of 2009, the unemployment rate in Massachusetts was 8.8% and increasing. Construction jobs have declined 16% (over 20,000 jobs) from a year ago. In comparison, trade, transportation, and utilities jobs have declined only 4.3% (while a smaller percentage, this figure represents over 24,000 jobs). At the same time, there is a recognition that homes in the northeastern region of the country use a lot of energy during the heating season. As part of the American Recovery and Reinvestment Act (ARRA) that has been supported by the current presidential administration, funds have been made available to “revive the renewable energy industry” and to “modernize 75 percent of federal building space and more than one million homes.” In Massachusetts, about $4.3 million has been allocated to workforce training and education programs in the central portion of the state.

However, some jobs have left the state permanently. In the late nineteenth and early twentieth centuries, mill buildings were created alongside rivers in the state. These structures were used for producing textiles and paper. Unfortunately, when less expensive labor was found outside of the state, these buildings lost the activities that had kept them running. As adaptive reuse has become more fashionable, older mill buildings have frequently been turned into apartments or smaller offices. Because these vernacular buildings are, in many cases, still in good condition, I would like to explore
the use of these structures for employment that is relevant to the current time, rather
than using them as large expanses of space to be carved up for uses that do not directly
address the former use of the structure.

The nineteenth century mill building type is organized for maximum efficiency
from the workers. (Fig. 1) The long rectangular shape allows supervisors to watch over
the work from an elevated platform. With this layout, supervisors can look down the
long corridors created by the factory equipment, and workers will feel as though they
are always being watched. In this way, the mill building evokes the philosopher Michel
Foucault’s discussion of the Panopticon type of surveillance that occurs not only in
prisons, but also in schools, factories, and other workplaces. Workers are aware that
there is supervision; although they know that they are being watched, they cannot
determine when they are being watched and when the supervisors are watching the
work of others. Because of this surveillance, in theory the workers are less likely to do
anything other than work. The supervisor’s office, in addition to being elevated above
the floor plane, is positioned so that the workers’ trips from the factory entrance to their
work stations is watched. The radial lines created by the equipment allow for the work
to be evaluated and compared with other workers.

In the last quarter of the nineteenth century, a new field of scientific
management gained currency. In this discipline, scholars such as Frederick Taylor
looked at ways of making the flow of work in production environments more
streamlined and efficient. These scholars were motivated by ways of making businesses
more profitable instead of making the work environments more pleasant to the workers.
Although they were not generally designed by architects, ideal designs for the mill building type were published and did incorporate the ideas that were discussed in scientific management.

Figure 1: Ideal first floor plan for a cotton mill.6

Because this project is looking at reusing the mill building more than one hundred years after it was originally built, it is useful to look at the context of manufacturing work in the last few decades of the twentieth century to provide more context about the environment that workers had become accustomed to. Frequently, when changes to workplace conditions have been enforced by management, the new conditions are less beneficial to the workers and are explained as being associated with the need to cut costs. In the 1970s, worker discontent led to a 1972 report that
recommended the strategies of job redesign and worker participation. On the surface, it may seem that the move toward despecialization is a departure from the Taylorist division of labor. These techniques were intended to improve productivity so that companies would increase their profits while at the same time workers became more involved in the work process. Some critics deride these techniques as mere manipulation of the workers, as many workers took on more job responsibility because some of their coworkers had their jobs eliminated.7

In the 1980s, recessions spread fear among workers who did not want to lose their jobs. As a result, labor unions conceded some of the gains that they had won in more prosperous times, such as “participatory mechanisms” and “labor-management cooperation.” In some ways, this meant that the workers were somewhat freed from the “design principles of scientific management,” as they could have a greater variety in their work tasks and more empowerment.8 Formal worker participation and employee involvement programs were sold to the workers as ways of realizing these characteristics in their work, but the programs were generally forced upon them.

In the 1990s, the new factor of globalization became a new justification for cutting company costs. Outsourcing of jobs and enforced part-time work became more common. The use of computers to monitor productivity was more widely seen, and benchmarking quantitative measurements became commonplace. Unfortunately, these quantitative measurements did not include an examination of workplace conditions, worker health and safety, or overtime demands.9 A new method of management became more common in Japanese automotive factories during this time. Known as “lean
production,” this type of management relied on providing workers with “extensive training, challenging work, and harmonious labor/management relations.”10 This type of management seemed to encourage the types of activities that had previously been given only scant attention in the past decades: work in teams, job rotation, “hiring criteria that emphasize willingness to learn and ability to get along with others, long hours of training,” and no division of spaces within or outside of the production facility according to whether an employee was a manager or a rank and file worker.11

These techniques spread to automotive factories in the United States, but unfortunately, workers here found that rather than the promising benefits that were described, the workers were overworked and overstressed and were forced to work more quickly and with heavier equipment. Perhaps the effects of the technique were not adequately studied in the original Japanese setting; a primary motivator of the system involves increasing production by doing more work with fewer employees. In the United States, as in Japan, workers had no time to discuss the ways to improve their jobs; rather, managers made the decisions, thus eliminating the primary benefit of the system.12

**Guild system**

In the early twenty-first century, workers are again fearful of losing their jobs; with the unemployment rate moving steadily toward 10%, many people have already lost their jobs. Although manufacturing work has largely left the region, there is still a division between jobs seen as “skilled” and jobs seen as “unskilled.” Rather than looking to the recent history of work as embodied by the nineteenth century mill
building, it may be useful to look even further back in time for new ways of working and organizing space that may be more relevant today. A way of working that relied heavily on training workers was the guild system. The guild system was widespread in Europe for a few centuries preceding the industrial period.

The guild system is based on an intensive training period in which workers start as apprentices before acquiring enough skills and knowledge to be known as journeymen; finally, once they have completed a master project, they are known as masters of their trade. There are a couple of elements of this system that are relevant to this project. First, the system acknowledges that training is a long process. This process includes teaching and learning not only factual details but also a more immersive type of learning that includes demonstration and practice. This second type of knowledge is more easily taught on a one-on-one basis and cannot be taught simply by imparting factual details. It seems that this level of collaboration is what more recent management strategies have strived for, but the actual dedication to training emphasized by the guilds is unmatched by more recent techniques.\textsuperscript{13} (Fig. 2)
Figure 2: Two types of knowledge that were taught through the guild system.

One commonly cited problem with the guild system is that the structure is seen as too conservative and not amenable to working with new technologies. On the contrary, some scholars see that guild masters, journeymen, and apprentices were in a good position to learn about new developments in their field. Journeymen travelled and met other masters who did similar work; new techniques could be brought back to the guild master during intensive training sessions. Sharing this new information did have to remain somewhat secretive, however. Frequent inspections that were intended to assure consumers of the quality of the guild’s work meant that discussion of the work process was kept quiet. As long as the final product remained of good quality, the inspectors would be unaware of any changes to the process.14

Although the craft guilds existed purely for the purpose of producing goods that could be sold, my intention for this mill building is to use some of the guild’s ways of
working. I see the reworked mill building manufacturing not products but instead knowledge about particular building techniques.


8 Ibid., p. 182.

9 Ibid., p. 184.

10 Ibid., p. 187.

11 Ibid.

12 Ibid.

14 Ibid., p. 6.
CHAPTER 2
SITE SELECTION

Geography

Hardwick is a town that is located in the center of Massachusetts. Geographically, it is bordered on the northwest by the large Quabbin Reservoir, which was completed in 1939. The presence of this body of water creates difficulty for people traveling to Western Massachusetts, as travelers are compelled to drive around the reservoir to arrive at destinations that are currently on the far shores of the artificial basin. The southeastern border of the town is formed by the Ware River. The town is bordered to the northwest by the town of Petersham, to the northeast by Barre, to the southeast by New Braintree, and to the southwest by Ware. Worcester is the largest nearby city and is located around 26 miles from the center of town. There is no public transportation in the town. There are sidewalks along some parts of the primary roads.

Primary automotive transportation routes in town include Route 32, which runs from Connecticut to New Hampshire; and Route 32A, a short road that runs only between Hardwick itself and Petersham, which is but one town away. The Massachusetts Central Railroad (MCR) operates freight tracks that run through Hardwick alongside the Ware River. A century ago, these tracks were used for passenger travel.
Figure 3: Location of Hardwick within the Commonwealth of Massachusetts.²

Figure 4: Location of primary roads and railways in Hardwick.³
**Demographics**

Demographically, the town of Hardwick is the home of just over 2600 residents, as of the 2000 US Census. This number is down from the high point of over 3000 residents in 1885. According to the 2000 US Census, the median age of the town’s residents is 37.5, which is somewhat higher than the United States average of 35.3. About 68% of the town’s housing units are owner-occupied. About 84% of the over-25 population has graduated from high school, although only around 21% of that group has a bachelor’s degree. Of the town’s residents who are at least sixteen years old, 65% were in the labor force in 2000.

Figure 5: Location of villages within the town of Hardwick.
Gilbertville

Within the rural town of Hardwick are four smaller villages, each with a slightly different character. In the early nineteenth century, the village of Hardwick was overall an agricultural one, with farmers raising corn and grains, as well as livestock and animal products such as dairy products, wool, and leather hides. The people of Furnace Village ran an iron furnace and forge; they produced goods such as teakettles and skillets.7

The geographic location of Gilbertville was ideally suited for the rise of industrial textile production during the middle part of the nineteenth century. By harnessing the hydropower of the adjacent Ware River, mills created the power necessary to run their textile machines. In the 1860s, George Gilbert, who had been successful in establishing flannel mills in neighboring Ware, expanded his business northward and constructed the first of five mill structures in 1862. Throughout the 1860s, four mills were built alongside the Ware River in Gilbertville. Near the end of the nineteenth century, these mills suffered the same slowdown in production that other New England mills experienced. Gilbertville’s mills remained in operation until the early 1930s, when textile production left the town.8

There are several mill buildings in the state that are no longer used for their original purpose, so I tried to select a building for this project that had a special significance to its site. From the beginning, the act of construction was important to this area. In addition to building a few more mill structures along the Ware River, Gilbert was also responsible for the construction of several multi-family residences in the immediate vicinity of the mills so that workers could walk from their homes to their
jobs. He also ensured the construction of a Trinitarian church in 1874 and a library in 1912. These buildings, constructed within walking distance to the workers’ homes and to their jobs, are perhaps evidence that Gilbert paternalistically determined how his employees would spend their time away from their jobs. In any case, the provision of these nearby structures does indicate an interest in education outside of the formal building type of a school.

Figure 6: Aerial view of the site, with library, church, and residences labelled.⁹
Figure 7: Typical multi-family residences in Gilbertville.\textsuperscript{10}

Figure 8: Gilbertville Library.
Figure 9: Gilbertville Trinitarian Church.
Because this project will look at a specific mill building as a prototype for changes that can be made to the New England textile mill building type as a whole, it will be useful to examine the specific attributes of this particular building. Some characteristics of this particular building can be seen in other examples of this building type: primary among these are proximity to a body of water; the existence of a regular structure within the building; and strong cognizance of solar orientation, either through location along an east-west axis or along a north-south axis with the inclusion of a sawtooth roof to allow daylight to enter the building.
The Gilbertville structure was opened in 1862, the first of four such buildings to be built in this section of Hardwick. The primary structure on the site is four stories tall on the southern, river-facing side, and two stories tall on a portion of the northern side. To estimate the height of the building, I have counted 221 bricks on the southern side of the building. Multiplying that number by 2.75” (2.25” for the height of the brick, and .5” for the thickness of the mortar) gives a dimension of 607.75 inches, or around 50 feet, 7.75 inches on the southern side. The primary structure on the site measures 323 feet on the long east-west axis and 86.5 feet on the shorter north-south axis. The shorter portion of the structure is two stories high and measures approximately 84 feet by 197 feet. Overall, the structure contains approximately 129,000 square feet, with 111,800 square feet in the larger structure and 17,300 square feet in the smaller structure.

The mill likely uses the heavy timber construction type: exposed brick exterior walls enclosing large interior spaces marked by a gridded structural system. Based on historical photographs of the mill’s interior, it appears that there are two lines of columns that traverse the interior of the interior space, dividing the space into thirds. In general, the mill building appears to be in good shape on the exterior, with very little external damage.
Today, many of the multi-family residences, the library, and the church that were built contemporaneously with the mill do still exist. In addition, a pizza shop, a convenience store with an attached gas station, a post office, and other small shops exist nearby. The mill building is located adjacent to the Ware River, which runs south of the structure. To the east, a bridge crosses the river on Route 32, which sees most of the town’s traffic. Route 32 forms the eastern border of the mill’s site. Railroad tracks run on the far shore of the Ware River from the mill building.

The mill building occupies a long rectangular shape along the geographic east-west axis, providing a large south-facing surface. The building itself is composed of two roughly rectangular blocks. Thirty-four windows of similar size are on the external walls of each floor of the building, on both the north and south faces.
Figure 12: Views of the Ware River from the mill site; bridge and multi-family homes can be seen.

From the mill building, there are views of the Ware River and the bridge that crosses over it and of a wooded area, as well as some of the nearby multi-family residences across the river. The short end of the mill building faces onto Route 32.

The sun reaches its highest point in the sky during the summer, while it is lowest in the winter.

Figure 13: Position of the sun in Worcester, Massachusetts on June 21 and on December 21.


7 Massachusetts Historical Commission.

8 Ibid.

9 Google Earth, 2009.

10 All photographs are the author’s own unless otherwise noted.

CHAPTER 3
PROGRAM

Mill reuse projects are certainly not unusual in New England, where these former factory buildings are frequently repurposed as housing, divided into professional offices, or even reimagined as large museum spaces. However, all of the aforementioned uses seem to disregard the initial purpose of the structure, as a place for people to work and as a place for production. Since many Massachusetts residents are currently out of work, this project will make use of an existing structure and repurpose it according to work that is more in demand than textile manufacturing. This project will show the transition between a hierarchical structure devoted to creating products that could be sold at the highest possible profit to a structure that is more conducive to the act of creating and sharing knowledge about green building.

People who have recently lost their jobs are frequently encouraged to search for additional training to ensure that they have skills necessary for current employment demands. Similarly, recent high school graduates who are new to working may need training in addition to what they have learned in school.

I am proposing the program of a green building center because this center will allow tradespeople to meet in a single location and share the information that they have learned while working in the field. In addition, there will be spaces for builders to learn more about the green aspects of building. Homeowners will be able to learn about what changes need to be made to their existing homes, and they will learn the skills that they need to make modifications or to find out about tradespeople they can hire to do this
work. Finally, researchers who talk with the builders and with the homeowners can learn about green building techniques that can be used to inform people outside of the local area and can form policies based on what has worked in the field.

**Conservation Services Group, Westborough, Massachusetts**

A local example of a similar program can be seen at Conservation Services Group, a national company that has headquarters in Westborough, Massachusetts. Their goal is to make buildings energy efficient. Here, three types of training activities happen within the organization. Builders learn practical skills such as duct sealing, HVAC sizing, equipment replacement, and installation best practices. They are also given instruction in conducting audit services for buildings.

Homeowners can obtain design support for the construction and renovation of their existing homes, including energy modeling. They can also find information and training about smaller home improvement tasks that they can accomplish by themselves, such as improving the insulation in their homes and sealing air leaks.

In-depth building science training is also provided by the center, covering such topics as mold and moisture control; the use of renewable energy, especially solar energy; combustion safety; building design; and HVAC installation.

In addition, this organization has a policy group that offers consulting about policies at the local and state levels. The company works with consumers by running a store to sell compact fluorescent lights and helping them to find out about rebates related to energy efficiency.¹
To an outsider, it appears that there are several different types of interactions happening. Customers of the retail space may become students if they are homeowners who are interested in improving their homes. Students, both builders and homeowners, may become staff once they have learned about green building. The instructors and researchers at the center work with students who come to the center, as well as with local builders and homeowners in off-site locations.

The different types of activities happening within this organization suggest that several types of spaces are needed. Demonstration spaces to test building materials and techniques are necessary. These spaces should be large enough to contain any large equipment or materials, and should have easy access to a loading dock. Large meeting spaces can be used to give lectures to large groups of people, while smaller meeting spaces can be used for individual consultation about design projects.

A small, easily accessible retail space can be used to sell green consumer products to the public. Researchers can work in offices that are within close proximity to the demonstration areas, so that they will be immersed in the current activities of the teaching staff.

**NEXUS Green Building Resource Center, Boston, Massachusetts**

Another local instruction center focuses more on disseminating green building information than on gathering practical data in the field. The NEXUS Green Building Resource Center is located in downtown Boston. Their audience includes builders, design and engineering professionals, but their center is also open to the general public.
Many of the services that this center provides are informational: studying for LEED exams and understanding building commissioning are included in their course offerings for January 2010. As a result, many of the spaces within their building are intended to spread information. A small lounge area allows visitors to find out about programs that are offered. Program sponsors can display their materials in a larger expo area.

Figure 14: Materials samples library.

A samples library includes swatches of green building materials, while a resource library allows visitors to read about green building techniques. Design software is available on computers within a public area. An open office area is designated for the staff of the center.2
Figure 15: Resource library contains books and journals about green building.

Because there are so many elements of this program and only a small space to work with, some of the allocated areas seem undersized. For example, although the reading materials are displayed on low shelves in a well-lit area, there is no corresponding area to sit and read those journals. The materials library provides samples of many finishes, but there is no room for larger samples such as full-scale wall sections that would allow visitors to see how materials might work together.
An examination of the floor plans shows that many of the programmatic functions are used to provide information in a visual way. While there are plenty of areas that are used to display information about green building, there simply is not room for demonstration areas where people can watch and participate in the construction of well insulated wall sections or the proper sealing of air ducts.

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3 Ibid.
CHAPTER 4

PRECEDENTS

The particular mill building that I am examining in this project has not been used for textile productions in several decades. As a result, people traveling along Route 32 have become accustomed to the mill building as an empty structure. Although this project will involve changes to the building’s interior, it will also be important to make changes to the exterior so that people become aware that there is a new source of activity within the town. It will be essential to blend the old, existing mill structure with a physical embodiment of the new energy within the building.

In general, I am looking for ways that existing buildings with programs similar to the one in this project have been changed, especially to show an exterior reflection of how the old and new pieces work together. Specifically, the programs in the precedent projects that I have looked at are educational facilities or research facilities. In the following descriptions of precedents, I have looked not only at textile mills but also at other projects that reuse existing structures for new purposes.
Woods Hole Research Center, Falmouth, Massachusetts

Image on file in department

Figure 17: Woods Hole Research Center, Falmouth, Massachusetts.¹

The people who work in this research facility at the Woods Hole Research Center in Falmouth, Massachusetts have a mission of promoting environmental science, interdisciplinary analysis, and public education as it relates to the interactions between humans and environmental ecology. This 19,200 square foot addition, known as the Gilman Ordway Building, was built in 2003 and was designed by William McDonough + Partners. The original building was a nineteenth century ship captain’s house. In thinking about the addition, the researchers wanted to preserve the original house’s character while expanding the functionality of their building for laboratory work.

Visually, continuity between the original building and the addition is achieved through the use of similarly colored materials -- specifically, wood cladding. The addition is not a prominent feature when viewed from the front of the house (Fig. 18,
19). In order to emphasize the researchers’ commitment to the natural environment, daylighting is maximized and visual connections to the outdoor wooded area are highlighted. Low-emissivity, double-glazed windows are used throughout the addition; triple glazing is used in large transparent areas.

Figure 18: Diagram showing prominence of original structure (in blue) and recession of new addition (in pink).

Figure 19: Plan view of separation between new and old structures.
Technology played an important role in designing this addition. Parametric energy modeling was used in the design process to examine infiltration, insulation, fenestration specification and placement, and heating system selection. Since the addition’s opening, energy performance is monitored continuously and data is logged every five minutes.²

**Holset Engineering Training Centre, Huddersfield, England**

![Image on file in department](image)

Figure 20: Holset Engineering Training Centre, Huddersfield, England.³

Projects that have reused mill buildings are frequently formally conservative. In these projects, the exterior façades seem very similar to their previous appearance although the interior functions have changed. Although the 1999 renovation of the Holset Engineering Training Centre in Huddersfield, England is not completely identical to its past life as a textile mill, the modifications are fairly subtle. Originally built in the nineteenth century, the design provided for five stories, of which only three were actually constructed.

The building was expanded to provide more space for the Holset Engineering company’s training center. The architect, James Cubitt and Partners, used lighter
materials to visually separate the new structure from the old. The fourth floor to the structure is primarily composed of glazing; the architects were certain that the old foundation could support this new addition.

This project retains its factory heritage in that the engineering company is involved in the design and manufacture of turbochargers. In an attempt to vary the original building exterior, a steel walkway runs along the exterior perimeter of the new construction. In addition to providing maintenance access, the architect claims that the staff can use this space to look at the outdoor views. It seems that this walkway also acts as a sunshade for the lower level.4

**CaixaForum, Madrid, Spain**

Figure 21: CaixaForum, Madrid, Spain.5
While other adaptive reuse projects are perhaps too respectful of the original structure, Herzog and de Meuron’s 2008 renovation of a nineteenth century power station treats the existing building as an important element that can be modified and adapted to suit the new design just as much as the newly introduced materials are. Apertures in the original been structure have been closed up, while new openings have been cut into the old walls without regard to the placement of the original fenestration.

As part of the building’s rebirth as a cultural center and museum, internal floor plates have been cut up so that spaces for displaying contemporary art installations are created. Perhaps most surprisingly, the power station has been elevated off the ground so that an underground auditorium could be created. This heavy mass of bricks now appears to float over the plaza. Atop the brick structure, several stories of space, wrapped in perforated rusted steel, add a different texture while still using a similar color palette. Immediately adjacent to the CaixaForum, the greenness of a living wall provides still more texture and serves to emphasize the colors in the new cultural center.
Figure 22: Diagram that illustrates integration of new and old materials.


4 Ibid.

5 Image from Creative Commons, Óscar Carnicero Sánchez.

CHAPTER 5

REGULATORY

Any adaptive reuse projects must be aware of the zoning and building code regulations that governed the site’s and building’s former usage, as well as those regulations that will govern the site and building once the project has been completed. In addition, because an existing structure will be modified as part of the project, the building code that relates to historic buildings should be consulted. Also, because this mill predates contemporary rules regarding accessibility, those regulations should be followed so that the public can use this building.

**Zoning**

This mill is located on a site that is zoned for industrial use within the town of Hardwick. Within the industrial zone, there is a height restriction of 35 feet and a minimum lot size of 40,000 square feet. Industrial zoning requires a minimum yard depth of 60 feet in the front, 50 feet in the rear, and 50 feet on the side.¹

**Building code**

Based on the program described in the previous chapter, there will be three use and occupancy classifications according to Chapter 3 of the current Massachusetts Building Code. In cases where there are multiple uses within one building and these uses are not separated, the building code specifies that “the most restrictive type of construction, so determined, shall apply to the entire building.”²

The lecture halls included in this building are classified as A-3, Assembly uses. Training spaces and offices fall under Business Group B occupancy. Although the
training center seems to be educational in nature, because it is intended for post-high school education, the actual classification is category B. The small retail store is categorized as Mercantile Group M.

According to Chapter 5 of the Massachusetts Building Code, the allowable heights and areas for the aforementioned classifications are listed below (Table 1). Since the mill building uses heavy timber construction, the heights and areas are associated with Type IV construction. This table assumes that a sprinkler system is not used.

<table>
<thead>
<tr>
<th></th>
<th>Allowable bldg. height</th>
<th>Allowable number floors</th>
<th>Allowable floor area</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-3</td>
<td>65 feet</td>
<td>3 floors</td>
<td>15,000 SF</td>
</tr>
<tr>
<td>B</td>
<td>65 feet</td>
<td>5 floors</td>
<td>36,000 SF</td>
</tr>
<tr>
<td>M</td>
<td>65 feet</td>
<td>4 floors</td>
<td>20,500 SF</td>
</tr>
</tbody>
</table>

Table 1: Allowable height and building areas for A-3, B, and M occupancies, using Type IV construction (heavy timber).

When sprinkler systems are used within a building, the minimum allowable heights and areas listed in Table 1 can be increased; allowable heights are increased by one story.

**Heavy timber construction**

To better understand the heavy timber construction type, it is useful to look at Chapter 6 of the Massachusetts Building Code. According to this section of the code, heavy timber structures are identified by noncombustible exterior walls. Interior wood columns must have a dimension of at least eight inches nominal when supporting floor loads. Floor framing members must be at least ten inches nominal in depth and at least
six inches nominal in width. Wooden flooring planks must be at least three inches
nominal in depth, splined or tongue-and-groove. Partitions must be at least four inches
thick.⁴

Although this mill building is an existing structure, it is not listed in the National
Register of Historic Places and as a result does not need to conform to the code that
pertains to making modifications to existing structures. Chapter 34 of the Massachusetts
Building Code requires that when such structures are used as museums, their primary
purpose must be that of a museum and must be open to the public at least twelve days of
each year.⁵

**Accessibility**

Because this structure is a public building, paying attention to accessibility
concerns is particularly important. As such, the Massachusetts Architectural Access
Board requires that all entrances to the building be accessible. On the building’s
exterior, paths leading to the entrances must be paved or otherwise have level, slip
resistant surfaces. Vestibules must have a minimum of 48 inches between hinged doors;
the width of the swinging door should be added to that dimension.⁶

In assembly spaces, consideration must be given to the number and location of
accessible spaces. Chapter 14 of the Architectural Access Board’s code specifies the
following numbers of spaces:

<table>
<thead>
<tr>
<th>Total Seating</th>
<th>Wheelchair Spaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 25</td>
<td>1</td>
</tr>
<tr>
<td>26 to 50</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>--------</td>
</tr>
<tr>
<td>51 to 300</td>
<td>4</td>
</tr>
<tr>
<td>301 to 500</td>
<td>6</td>
</tr>
<tr>
<td>over 500</td>
<td>6, one additional space for each total seating capacity increase of 100</td>
</tr>
</tbody>
</table>

Table 2: Number of wheelchair spaces to be provided in assembly areas.

1 Town of Hardwick Zoning Bylaws. Section 4, Land Intensity Regulations.


3 Ibid.

4 Ibid.

5 Ibid.

CHAPTER 5

SYSTEMS

Many New England mills have similarities in their solar orientation and in their location to nearby running water. As a result, it is useful to examine the amount of energy that could potentially be harnessed from these natural resources. In addition, the structure of the mills is based on repetitive elements. Because a change to the structure will likely include cutting through the existing floors and walls, it will be useful to determine how much of the structural elements can be removed.

Solar energy

The Climate Consultant tool (available from http://www2.aud.ucla.edu/energy-design-tools/) provides information about the available amount of insolation in Worcester, Massachusetts, which is the closest locale for which such information is available. The tool uses data sets containing hourly measurements compiled by the USDOE EnergyPlus Climate Data. This interface looks at both horizontal radiation and normal (i.e., vertical) insolation, so if the area measurement on the south-facing side of the mill structure is approximately 16,344 square feet (50.6 feet tall by 323 feet long) and the surface of the roof measures approximately 27,940 square feet (86.5 feet by 323 feet), then the following table shows the amount of available solar energy that can be captured by this building over the course of a year.
<table>
<thead>
<tr>
<th>Month</th>
<th>Global Horizontal Radiation (Avg. hourly) BTUH/sq. ft.</th>
<th>Direct Normal Radiation (Avg. hourly) BTUH/sq. ft.</th>
<th>Horizontal Avg. BTU/month</th>
<th>Direct Normal Avg. BTU/month</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>77</td>
<td>90</td>
<td>1,600,626,720</td>
<td>1,094,394,240</td>
</tr>
<tr>
<td>February</td>
<td>102</td>
<td>102</td>
<td>1,915,119,360</td>
<td>1,120,283,136</td>
</tr>
<tr>
<td>March</td>
<td>116</td>
<td>117</td>
<td>2,411,333,760</td>
<td>1,422,712,512</td>
</tr>
<tr>
<td>April</td>
<td>124</td>
<td>101</td>
<td>2,494,483,200</td>
<td>1,188,535,680</td>
</tr>
<tr>
<td>May</td>
<td>130</td>
<td>97</td>
<td>2,702,356,800</td>
<td>1,179,513,792</td>
</tr>
<tr>
<td>June</td>
<td>140</td>
<td>101</td>
<td>2,816,352,000</td>
<td>1,188,535,680</td>
</tr>
<tr>
<td>July</td>
<td>138</td>
<td>100</td>
<td>2,868,655,680</td>
<td>1,215,993,600</td>
</tr>
<tr>
<td>August</td>
<td>141</td>
<td>110</td>
<td>2,931,017,760</td>
<td>1,337,592,960</td>
</tr>
<tr>
<td>September</td>
<td>118</td>
<td>100</td>
<td>2,373,782,400</td>
<td>1,176,768,000</td>
</tr>
<tr>
<td>October</td>
<td>99</td>
<td>112</td>
<td>2,057,948,640</td>
<td>1,361,912,832</td>
</tr>
<tr>
<td>November</td>
<td>75</td>
<td>99</td>
<td>1,508,760,000</td>
<td>1,165,000,320</td>
</tr>
<tr>
<td>December</td>
<td>66</td>
<td>88</td>
<td>1,371,965,760</td>
<td>1,070,074,368</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>27,052,402,080</td>
<td>14,521,317,120</td>
</tr>
</tbody>
</table>

Table 3: Monthly Insolation in Worcester, Massachusetts.

**Structure**

The mill building type is characterized by a very repetitive structure, with a regular gridded pattern of columns. Because I am interested in determining the possible changes that can be made to the physical structure, I will need to evaluate the existing building.
Since this particular mill is no longer used for the production of textiles, the allowable live load cannot be determined based on the loads of the equipment used in the factory. The Massachusetts Building Code can be used to find the allowable live load for industrial buildings. Chapter 16 (Structural Design) contains Table 1607.1, which describes those loads:

<table>
<thead>
<tr>
<th></th>
<th>Uniform (psf)</th>
<th>Concentrated (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light manufacturing</td>
<td>125</td>
<td>2000</td>
</tr>
<tr>
<td>Heavy manufacturing</td>
<td>250</td>
<td>3000</td>
</tr>
</tbody>
</table>

Table 4: Allowable live loads for industrial buildings in Massachusetts.¹

Based on some rough calculations from a generic mill building ², the columns are spaced about 30’ away from the long walls, and about 8’ away from the shorter walls. The following calculations are based on a primary system of beams extending over the grid of columns. The wooden beams are about one foot deep and six inches wide. The tributary area for each beam is 270 square feet (8 feet x 90 foot span). Each beam supports 1000 pounds/linear foot (8 feet x 125 lbs/square foot, for light manufacturing).

² Andrzejewski, Building Power, p. 65.
Adaptive reuse projects are sometimes difficult to find funding for; there may be environmental problems with the site that are costly to clean up, or the expenses involved in bringing an existing structure up to code may be prohibitive. To that end, there are sometimes state grants and subsidies that can make the reuse of an older building more attractive.

Often, there are funding opportunities for projects that are related to affordable or senior housing, such as the Massachusetts Affordable Housing Trust Funds and the Housing Stabilization Fund that is available through the Massachusetts Department of Housing and Community Development. Because there is not a housing component to this project, neither of these sources is appropriate. However, there are categories of funding that are more useful for this project.

First among these funding sources is financing related to the assessment and cleanup of brownfields. Brownfield lands are not necessarily contaminated, but there must be a perception of probable pollution at the site. Massachusetts established a Brownfields Redevelopment Fund in 1998 that provides up to $100,000 in financing to assess environmental damage, and loans of up to $500,000 to clean up brownfields. Grants from multiple sources can be combined. For example, in a reused textile mill in Taunton, Massachusetts, the following grants and loans related to brownfields were used to subsidize the costs:
<table>
<thead>
<tr>
<th>Funding source</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>US EPA Brownfields Revolving Loan Fund Subgrant to City of Taunton</td>
<td>$148,000</td>
</tr>
<tr>
<td>US EPA Brownfields Revolving Loan Loan to City of Taunton</td>
<td>$140,000</td>
</tr>
<tr>
<td>US EPA Cleanup Grand to WEIR Corporation (CDC)</td>
<td>$52,000</td>
</tr>
<tr>
<td>Mass Development Environmental Assessment Funds</td>
<td>$54,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$394,000</strong></td>
</tr>
</tbody>
</table>

Table 5: Funding sources for brownfields in Taunton mill reuse.³

In addition to grants and loans that can be used for assessing and cleaning up environmental damage, tax credits for the property owner can be used, as long as the property is used for business purposes. In Massachusetts, the specified land must be classified as an “economically distressed area;” as of 1 March 2010, Hardwick is described as such.⁴ The Brownfields Credit for Rehabilitation of Contaminated Property permits taxpayers to take a tax credit for their costs in cleaning up environmental damage to a site that is used for business. Associated costs may be incurred before 1 January 2012. While the tax credit cannot exceed 50% of the taxpayer’s total tax for any calendar year, unused credit may be applied for up to four following years.⁵

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CHAPTER 7

DESIGN

Design intention

Façades as responses to external conditions

The original mill building has several physical characteristics that I wanted to respond to and to elaborate on. All four façades present themselves in relatively the same way: large brick masonry walls punctuated with evenly spaced punched window openings. Levels were clearly and distinctly separated by repetitive floor plates. There is a strong sense of organization in the mill building, but that rigid orderliness seems to have been applied unthinkingly throughout the building.

Over the years, functional renovations provided additional production and support space. For this project, I chose to work with a regular, rectangular portion of the mill with the hope that lessons learned from this particular site could be applied more generally to fit other disused mill buildings in the region.

Figure 23: North and west façades; both have large, evenly spaced window openings.

Because this building has a program that directly relates to people learning the skills needed for green building, I wanted for the mill itself to demonstrate that intent.
Solar conditions throughout the year and throughout the day are different on each of the four sides of the building, so I created four separate responses to those conditions. Also included within the program is a component that suggests that students and builders working within the mill could fabricate elements that would be used on the building itself. Such shading and grating elements could be modularized and used to shade the building.

The mill building itself is sited with a nearly perfect east-west orientation. The south side of the structure has the best potential for reliable heat and light. My design proposes the conversion of the south side of the mill to a trombe wall. In this system, glazing is set around four feet from the building, and steel grating is placed at floor level on each of the three levels above the ground. A shading study showed that this grating needed to be four feet wide in order to completely shade the floor-to-floor distance from the hot summer midday and late afternoon sun. This width also allows people to walk between the glazing and the masonry wall to conduct maintenance. The grating can also be used to hold plant containers in the greenhouse atmosphere.

Figure 24: Shading of the south wall during summer midday and afternoon.
In New England, the primary benefit of the trombe wall occurs during the winter. In this type of passive solar heating system, a thick masonry wall heats up slowly, then releases heat slowly throughout the day. Winters in this climate are characterized by low sun angles that provide more normal radiation than in the summer. Peak normal radiation is reached in March and in October, months that are approximately the start and the end of the heating season.

By using a thick thermal mass, a dramatic swing between high and low temperatures is modulated. External glazing helps to contain the solar radiation while the masonry mass absorbs the heat. The thermal mass that is used in trombe walls can be made of materials other than brick; adobe, concrete, and water can all be used. Water and earth both store heat energy more efficiently than brick does, so while water walls and earthen walls can be only 6-8 inches thick, brick and concrete masses should be 10 to 16 inches thick. The walls of this mill are around 12 inches thick, so a trombe wall is a good application here.¹

Using a trombe wall is also an attempt to mitigate the need for applied insulation, whether batt or foam, on the interior of the building. Because the exposed brick interior is such a dominant material within the mill, I wanted to preserve that texture as much as possible. By using the wall itself as the insulation system, this form of insulation is also instructive to those studying within the building.

Ideally, the thermal mass is painted a dark color, as dark colors prove to absorb more heat energy than do lighter colored materials. If the darker colored masonry is considered unsightly, the glazed layer can be composed of textured panels so that the
masonry is not as visible. Because a trombe wall system is most beneficial when solid thermal masses are used, a hybrid system, such as the one proposed for this mill building, is more appropriate. In this case, occupants of the building have access to river views through the existing window openings and through the layer of external glazing. A direct gain system allows for these views.\(^2\)

Summers, even in New England, are characterized by long periods of sun; the sun rises to higher angles in the sky than it does during the winter and provides more horizontal energy. Although this area has a long heating season, heating is generally unwanted during the summer. Because the sun rises to higher angles during the summer, horizontal shading devices that project from the masonry wall serve to prevent much of the solar energy.

However, heated air within the building still needs to escape. When louvers at the top of this trombe wall are opened during hot summer days, the solar chimney effect is evoked. The existing windows are buffered by the glazing and become interior windows. When these windows are opened, hot air from the masonry walls and from inside the building rises through the grating in the buffer zones and exits through the open louvers. In this way, the mill can be ventilated naturally, at least in part.\(^3\)
1 heat from sun hits glazing, which is then focused onto brick wall thermal mass
2 thermal mass releases heat through grating and warm air rises through buffer area
3 operable windows can be opened to allow movement of air through building
4 solar chimney effect pulls hot air from buffer area + from building interior through open louvers

Figure 25: Diagram of solar chimney effect (summer condition).
Figure 26: Sample wall section of similar system; this section also features operable openings on the exterior portion of the buffer zone (scale is correct when printed on 8.5”x11” paper with no margins).  

I looked at the size and spacing of the existing windows as data that formed the basis of the organization of the mullions used in the trombe wall’s glazing. Glazing directly in front of the existing windows must be transparent, but glazed panels that are not in the immediate line of sight can be textured or otherwise translucent. By adding a transparent surface to the existing mill, the building is changed, but it is not changed so
drastically that townspeople will not recognize it as the local landmark that has stood for decades.

In similar ways, I have made changes to the north, east, and west faces of the mill building to better respond to the sun’s movement. On the north, I have created a light scoop that protrudes from the mill’s existing roof. Light and heat from the south is guided into the corridor and offices on the north side of the fourth floor. As a gesture to parallel the trombe wall on the south side, glazing is set a few feet on the interior side of the existing brick walls. This technique is used in entry areas that do not have interruptions by floor plates between the lowest level and the roof. Because these buffer areas cannot be heated naturally by the sun, they must be heated artificially. However, because the existing walls are not obstructed by other physical forms of insulation, that material is still visible.
On the east side, fin projections block the morning sun from directly hitting the existing windows, while south-facing glazing is added. On the west side of the building, slats that are at a 42° angle (the same as the site’s latitude measurement) block the summer’s harsh late afternoon sun from the window openings. Here, too, south-facing glazing captures the light and heat provided in winter so that it can be used when needed.

Structure

The mill’s interior is filled with a dense 8’x30’ grid of timber beams and columns. In order to better understand the feeling of that structure, I created a study model of the mill’s beams and columns at the scale of 1/16” = 1’-0”. Although my
overarching intention was to respect the basic form of the mill, I did not feel that every single beam and column needed to be preserved. In fact, because the original structure was so dominated by the rigid system of floor plates, I felt that it was important to establish sectional connections between the program elements and to carve spaces out of the whole interior space. As a result, maintaining the floor plates became less important to the design. Giving inhabitants a sense of the full building, regardless of where they stood within the mill, became a focus.

Figure 30: Photographs of structural study model.

As I organized the programmatic spaces, I found that columns were desirable in some areas, but detracted from the functional purposes of other spaces. In small lecture halls and in corridors, the presence of visible timbers provides visible reminders of the mill’s former use. Students can look at these materials and be aware that they are studying in a building that has already shown its longevity. However, columns running through the center of a large auditorium are distracting and prevent clear sight lines between seating and the focal point at the front of the hall. To that end, I looked at how similar modifications were made in the Massachusetts Museum of Contemporary Art
(MASS MoCA), located in North Adams, Massachusetts, designed by Bruner/Cott & Associates.

Rather than completely remove the columns, the large gallery spaces at MASS MoCA retain some part of the existing columns while converting them into trusses with the addition of metal cables. The use of industrial metal recalls the previous use of the museum, which also inhabits mill buildings. The truss-like forms allow for larger spans that create large public spaces.

Figure 31: Photographs of gallery and detail at MASS MoCA.

Program

In thinking about the programmatic elements of this project, I wanted to consider how the different functions would be used by the different groups of intended users. I thought about the activities that each group would be engaged in, the types of spaces they would need to do those activities, and the types of people that should be nearby. Although nearly all the programmed spaces had some connection to each of the user groups, these connections are not as strong for each of the groups. For example,
researchers may spend a lot of time in offices, while homeowners visiting the center may use the offices only during consultations.

Because the mill is quite a large building, and because there is a variety of sizes of program components in my project, I drew from the program diagram and thought about ways of organizing some of the smaller spaces in relation to each other. The small lecture halls, classrooms, and offices seemed to have a close affinity to each other, and belong in close proximity to each other. I tried to organized these spaces into modular clusters that could be repeated throughout the building; the study models in Figure 33 illustrate those attempts.

Figure 32: Program diagram.
In organizing these clusters alongside the larger program pieces such as the retail and machine shops and large auditorium, I found that breaking up the clusters would allow there to be a moderation in the changes of scale, so that large spaces were not completely separated from the smaller spaces. It became useful to create three circulation cores, containing public stairwells, elevators, and restrooms, that divide the mill into four nearly equal pieces and aid in visual wayfinding even from outside the mill. (Fig. 34) After establishing these cores as the primary organization for the building, I decided that the larger spaces were intended to be more accessible programmatically, so these spaces were located on the lower portion of the mill. Newcomers who were less familiar with the intention of the building could stop by the
retail shop for a quick purchase of a compact fluorescent light bulb, for example, or they could take in a public lecture in the ground floor auditorium.

Figure 34: Circulation cores in the mill building.

Figure 35: Division of public and less public areas.
**Entrances**

On the site level, I wanted to provide a single clear entrance onto the site, rather than the multiple entrances that currently exist. Instead of the busy intersection of roads and business entrances that exists directly in front of the mill building, I propose rerouting the primary automobile entrance so that drivers follow a side road before entering the site. Drivers can park in a lot that has permeable pavers. Seating areas outside the mill allow people to sit and look at the river. Deciduous trees planted on the southern side of the mill block some of the summer sun.

![Figure 36: Proposed site plan.](image)

Southern projections that are aligned with each of the circulation cores are glazed, but are wrapped with narrow wooden strips. On the western side of these southern entrances, the wooden strips are angled to divert late afternoon summer sun. I
found inspiration for this entrance in the Herz Jesu Church in München, designed by Allmann Sattler Wappner Architekten. Although that project is of a completely different building type, it is successful in creating a sense of a light-filled volume. (Fig. 37) On the northern side of the mill, existing windows are covered to reduce the amount of glazing; overhangs guide visitors into this less public face of the building.

Figure 37: Herz Jesu Church, Allmann Sattler Wappner Architekten.
Walkthrough of building

The first level of the mill contains the most public spaces in the program. The retail shop is a double height space that contains small objects for sale, but may also be a location for green certified lumber and for larger construction needs. Consultation offices related to the shop are located on the second floor. A void space allows shoppers to stand on the first floor and see columns leading up to and continuing on the second floor. The first-floor café is a general location for people within the building and from nearby homes to gather, eat, and talk about green building.

The auditorium with entrances on the first and second floors can be used generally by the larger neighborhood community for movies; alternatively,
organizations devoted to green building may have conferences based within this space. The machine shop is located on the first and second levels. People there can fabricate products that are related to green building: perhaps they create the grating that is used in the southern trombe wall or modular shading devices that are used on the western side of the mill. This activity recalls the original purpose of the building, but it has been updated for contemporary needs.

A gallery space spans the northern side of the building. Here sponsors can show the materials they sell, or there may be assembled wall sections for people to examine. Throughout the building, partitions are generally transparent or translucent, so that occupants can still feel the large scale of the building, rather than smaller subdivided partitions that do not convey the same feeling. The stairwells in the circulation cores are enclosed on two sides by transparent Kalwall system walls. The first-floor gallery space is partitioned by glazed modular walls that can be moved and removed for larger exhibitions or public events.

On the second level, classrooms, offices, and conference spaces begin. Again, the partitions separating the classrooms can be folded up to reconfigure the space for larger classes or demonstrations. The conference rooms on this floor permit researchers and builders to discuss individual projects with homeowners. Small double height lecture halls on the third and fourth floors tie together the offices on the northern side and the classrooms on the southern side of the building.
Comments from final review

At the final review on 13 April 2010, many of the critics offered suggestions for future directions of this project. Some recommended that I use computer energy modeling software such as Ecotect to measure the mill’s current energy usage and the energy usage of the proposed design to derive realistic performance goals. Others recommended that I take an economic approach to determine the phased development of such a building, perhaps putting more emphasis on the revenue generating parts of the program such as the manufacturing piece, and reducing the emphasis of pieces such as the café.

Because this project is sectional in nature and includes void spaces throughout, another systems-based approach to take with this project relates to how ventilation circulates through the spaces, especially the entrances. Tying the building to the larger site was also mentioned by some critics. Rather than showing a strict delineation between building and landscape, a modulation between the two would be beneficial; perhaps the architecture could support a winter garden in the entry void spaces.

Finally, the forms of the architectural responses on the north, east, and west sides of the building need further development.

Design documents

Following are design drawings that have not been included in the previous section.
Figure 39: Level 1 floor plan.
Figure 40: Level 2 floor plan.
Figure 41: Level 3 floor plan.
Figure 42: Level 4 floor plan.
Figure 44: Section A.
Figure 45: Section B.

Figure 46: Section C.
Figure 47: Section D.

Figure 48: Section E.
Figure 49: View from northwest.
Figure 50: Presentation board 1: site/context.
Figure 51: Presentation board 2: roof and green building: south.
green building: west, north, east

west:
vertical slats are angled 42° in a screen to prevent sun rays from entering the building

north:
a light scoop provides light to the fourth floor corridor, and existing windows over the northern entrances have been covered up to minimize northern glazing

east:
corten steel is used to redirect glazing to the southern side, so that southern heat is gained as the sun moves
variations on cluster modules of lecture hall, classrooms, and offices

core circulation: stairs and elevators

gradations of publicness

Figure 53: Presentation board 4: program.
Figure 54: Presentation board 5: structure.
Figure 55: Presentation board 6: entrances.
Figure 56: Presentation board 7: level one.
Figure 57: Presentation board 8: level two.
Figure 58: Presentation board 9: level three.
Figure 59: Presentation board 10: level four.

2 Ibid.

3 Ibid., p. 259.


7 Image from Creative Commons, Till Niermann.
BIBLIOGRAPHY

Intent/thesis


Site Selection


Program


Precedents


Cohn, David. “Herzog & de Meuron manipulates materials, space, and structure to transform an abandoned power station into Madrid's CaixaForum.” Architectural Record (June 2008, vol. 196, no. 6), pp. 108-117.


**Regulatory**


Town of Hardwick Zoning Bylaws. Section 4, Land Intensity Regulations.


**Systems**


**Funding Resources**


