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## **SUSTAINABLE WASTE MANAGEMENT FOR CAMPUS CONSTRUCTION PROJECTS - CASE OF UMASS, AMHERST, USA**

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### **ABSTRACT**

The optimum use of resources and the efficient management of waste are the most vital principles of sustainable building, which significantly reduces the negative impacts of construction on the environment and preserves its natural resources. Several institutions supported by local governments in the United States have acquired the experience and the methodology to develop policies, guides, and demonstration projects to enhance construction waste management of building projects in a sustainable way. Massachusetts has specifically presented several green building initiatives with particular regard to construction waste management. The University of Massachusetts (UMass- Amherst) is a prominent state institution with a campus classified as "Green". Thus, this study addresses the management of construction waste at UMass as a model by exploring the governing framework, and highlighting the measures that define the process of construction waste management for campus projects. Throughout the study, waste management considerations, guidelines, and policies are reviewed, field visits are conducted, and conclusions are derived in order to improve the management performance of campus construction waste, thereby advising other institutions on better management practices.

**Keywords:** Sustainable Building, Construction Waste Management, University Campus Projects.

### **INTRODUCTION**

Sustainable building can be defined as that which has minimum adverse impacts on the environment, while sustainable building practices are those which strive for comprehensive quality (including economic, social, and environmental performance) at the local and regional levels. Therefore, the optimum use of resources on one hand, and the appropriate management of waste on the other greatly contribute to the reduction of construction environmental impacts and the depletion of finite resources. Moreover, in light of the current and future increases of landfill fees and taxes, reducing the amount of construction waste and improving recovery options will definitely produce ever increasing financial savings. As for the situation in the United States, reported generation rates and management statistics of construction waste around the country vary considerably from one community to another. However, many local governments and institutions have now acquired the experience and capability to create legal frameworks, model programs, and exemplary projects which set guidelines for resource efficiency and better practices of construction waste management. Given that Massachusetts has presented some of the earliest green building initiatives across the country, this study took place at the University of Massachusetts (UMass, Amherst) for post-doctoral research. Besides reviewing the regulations of construction waste management at the state level, the study addresses the management of construction waste of campus projects at UMass as a leading state institution with a campus classified as "Green".

**Objectives:**

This research aims to present the case of the University of Massachusetts - Amherst as a study model, through which construction waste of campus projects is sustainably managed. By highlighting the procedural measures that have been taken towards a sustainable management of campus construction waste, and investigating the legislative and administrative framework that governs the management process, the research derives conclusions which mean to improve the sustainability of construction waste management on the university campus. Thereby, this study serves to advise the sustainability plans of other universities/institutions on better management strategies of campus construction waste.

**Methodology:**

The research plan is based on an inductive analytical approach as it is conducted through the following sequential stages:

- Background on construction waste management and the green building approach in the US.
- Discussion of the measures associated with the sustainable management of construction waste.
- Overview of UMass sustainability initiatives and green building efforts.
- Identification of UMass legal framework for construction waste management.
- Field visits (committee assemblies – project site – waste management facility).

**CONSTRUCTION WASTE MANAGEMENT AND GREEN BUILDING IN U.S.A.:**

As the new millennium began, more than 15,000 of the 20,000 landfills located in the United States reached full capacity and had to shut down, while construction related waste had a share of more than 25% of landfill contents, which nearly equaled the total municipal garbage waste generated in the United States at that time [7]. As a result of this volume, an increasing number of landfills could not permit, or has been charging extra for, dumping construction related waste. In response, the demand for recycling such debris has been widely increasing. Because of the effort being exerted to develop markets for recovered materials, the number of construction and demolition waste recycling facilities is continuing to grow. A July 1997 status update lists over 1,000 facilities for concrete and masonry recycling, 700 facilities for construction wood recycling, and 300 facilities for recycling various other types of materials, in addition to hundreds of reuse markets for building components and installations all over the country. By the beginning of the millennium, the number of recycling facilities in operation for construction and demolition debris was estimated by more than 3,500 [5]. Furthermore, regulatory ordinances for construction waste recovery have officially been enforced in the United States since 1990, while fees, tax revenues from waste disposal, as well as penalties for violation, have notably increased. On the other hand, American building sectors and research centers have been cooperating with community and environmental organizations in subsidizing construction waste recycling activities by providing training and guides for building specialists, and establishing databases of recycled building products available on the local markets. Among the most prominent of such organizations are the US Environmental Protection Agency, and the US Green Building Council which developed the nationwide rating system LEED (Leadership in Energy and Environmental Design) for building projects [13].

**Green Building Initiatives by Local Governments:**

Multiple tools were developed by local governments in order to operate their building resources in a sustainable manner. Many governments have created programs, policies, contract specifications, incentives, as well as codes that regulate sustainable building practices. Currently, many successful green building initiatives have been developed and are being implemented across the U.S.

**Provisions for Green Building Approach:**

Green building initiatives offer many opportunities for local governments and communities. However, the key to succeed in reaching a green building approach has entailed necessary provisions or start-up actions that can be summed in the following [7]:

- Examine local policies and procurement procedures for the inclusion of green building measures.
- Develop demonstration green building projects or promote local sustainable design competitions.
- Require that government building projects incorporate efficient sustainable building measures.
- Survey and review other initiatives with precedent green building programs and efficient models.
- Assemble multidisciplinary teams to create, develop, and update a local green building program.
- Develop a program for green building awards, and co-sponsor it with local organizations.
- Initiate conferences, tutorials, and training programs on green building issues.
- Assemble a green building resource library, and Initiate a green building online bulletin or website.
- Share the community's green building resources by publishing case studies of local projects.

**Massachusetts – New England:**

Significant volumes of construction and demolition waste are annually generated in the New England region. Such waste used to end up in municipal landfills. EPA (Environmental Protection Agency) of New England has been working continuously with many state and local governments to divert this waste away from disposal by promoting the reuse and recycling of construction and demolition debris, and reducing its generation through green building strategies. According to EPA-New England, in 2002, construction and demolition debris accounted for 36% of all solid waste generated in Massachusetts, and nearly 50% of the state's total commercial solid waste stream. In response to those facts, the Massachusetts Department of Environmental Protection (MassDEP), in its Beyond 2000 Solid Waste Master Plan, committed Massachusetts to a goal of 88% reduction of construction and demolition waste by 2010. To help achieve that goal, in 2006, MassDEP placed a disposal and transfer ban on recoverable construction materials [3].

**MEASURES FOR SUSTAINABLE CONSTRUCTION WASTE MANAGEMENT:**

Many of the barriers and opportunities that relate to construction waste management are usually jurisdiction-specific, and are mostly associated to potential mechanisms and roles of state/local governments, as well as other influential local institutions.

**Common Barriers to Construction Waste Recovery:**

Some aspects of construction waste management present common obstructive issues in many waste recovery programs. Some of the most common issues are listed in the following [4]:

- Some building products and materials are not designed to be recovered (reused or recycled).
- Material waste management might not be efficiently included in the construction plan.
- In some locations, recovery facilities do not exist (or they only exist remotely).
- Even where facilities exist, markets may not be found for some materials for a variety of reasons.
- Cultural barriers may induce an unwillingness to use recycled products in place of traditional ones.
- The lack of a legislative system to regulate waste recovery and the use of recovered materials.

**Opportunities for Construction Waste Recovery:**

Some important procedures that are utilized to improve the performance of waste recovery programs can be found in the following [18]:

- Development and implementation of a site waste management plan with comprehensive procedures that account for all generated waste and prioritize recovery by reuse and recycling.
- Effective segregation of waste types during different construction phases. This is considered a vital key for achieving a good practice.
- Identification of target waste streams for either reduction, recovery, or both. Significant cost savings can be made if waste management contracts are set up to target specific material streams generated during different phases.
- Establishment of key performance indicators and a performance target. This helps to identify and achieve the goals of the waste management plan.

#### **Planning and Monitoring Waste Management Processes:**

One of the most important factors that affect the performance level of construction waste management is early planning and continuous monitoring. For instance, in order to secure required performance targets, the main contractor and any involved sub-contractors should have a contractual obligation to meet these targets. In addition, the waste management performance should be monitored throughout construction, thus establishing trends and databases for opportunities to improve future programs. Furthermore, an early planning for waste recovery requires the project team to think ahead and consider mechanisms or measures (segregation, bin sizes and codes, collection frequency, site access, etc.) that are needed for different construction phases. The site waste management plan can then be shaped to reflect those considerations [18].

#### **UMASS SUSTAINABILITY INITIATIVES AND GREEN BUILDING EFFORTS:**

Building projects at public universities can be regarded as a direct representation of the prevalent local approach toward the concept of sustainable building. By adopting, presenting, and well advertising such projects, local governments have the opportunity to establish models of best available sustainable practices in order to provide precedent guidance for other public, as well as private local projects. The University of Massachusetts (UMass, Amherst) is considered a leading model of state universities in regard to the adoption of sustainability principles and the green building approach. This specifically came in response to the recent bundle of directives, ordinances, and executive orders issued by the Commonwealth of Massachusetts for clean energy, environmental quality, and efficient building. As a result, the University of Massachusetts - Amherst has developed progressive solutions by utilizing strategies, policies, and technologies that directly impact the new construction of buildings, as well as the performance of existing buildings.

#### **UMass Sustainability Committee:**

The UMass Sustainability Committee was established after UMass signed the American College and University Presidents' Climate Commitment in 2007. It comprises multiple subcommittees which all report to an executive team that includes college deans and representatives of administration, finance, development, research, and student affairs. The executive team in turn reports finally to the university chancellor. Analyzing campus potentials and opportunities, the Sustainability Committee has been developing UMass own policies and guidelines to support green efforts on campus [16]. One of the main accomplishments by the committee was creating the Campus Climate Action Plan.

#### **- Campus Climate Action Plan:**

Approved in 2010, the Climate Action Plan was the first campus document to identify strategies that help the campus reach carbon neutrality in 2050 by reducing the environmental impact of campus life and operations.

As evidenced by the 2011 Gold rating in sustainability leadership from the Association for the Advancement of Sustainability in Higher Education (AASHE)'s Sustainability Tracking, Assessment and Rating System (STARS), UMass was one of 27 research universities to receive this distinction in the United States [11]. Campus Action Plan primarily addresses the issues of energy, water and resources, emissions, waste management, transportation, green technology, research, and education for all campus facilities and new projects, proposing solutions which are environmentally and economically beneficial.

**UMass Department of Facility Planning:**

Facility Planning is the technical and vital department at UMass that is responsible for campus existing facilities in terms of running and maintaining them, in addition to building new projects. Information about campus physical conditions is collected for the development of a sustainable and integrated facility plan for UMass. Software called "Sightlines" has been activated to operate all the data of UMass projects by creating and updating building portfolios. Such data can be anonymously compared to other peer institutions that are using the same software [17]. Sightlines software is active in more than 400 campuses, providing services around integrated planning and green building measures.

**UMass Master Plan Sustainability Subcommittee:**

The UMass Master Plan Sustainability Subcommittee combines professionals from the Department of Facility Planning alongside Architecture, Construction and Planning professors, Green Building researchers, and other specialists. The committee has been monitoring and reporting green measurements (such as the use of resources, energy consumption, emission rates, and waste generation) for all campus facilities and projects. Within this context the committee works on how to plan for UMass campus over the next ten - twenty years, thereby recommending actions. So, the continuously developing Master Plan has a full sustainability chapter that summarizes campus efforts up to date, as well as recommended future actions [15].

**UMass Green Building Subcommittee:**

In 2008, a Governor's Executive Order was signed, which included the provision that all state buildings be certified under the LEED rating system. At the same time, UMass made the commitment to achieve LEED Silver or better for all new construction and major renovations on campus. In 2010, the Green Building Subcommittee was created to focus efforts on sustainable design and construction of campus buildings. The committee includes faculty from Architecture and Building Construction Technology, staff from Facility Planning, and Campus Design and Construction, in addition to researchers and graduate students. Since its establishment, four of campus most recent buildings have been awarded LEED Gold certification by the U.S. Green Building Council; many were awarded Silver, while several additional new buildings are pending certification [12]. Other major accomplishments of the Green Building Subcommittee were the Green Building Guidelines, Continuous Commissioning Plan, and Campus Sustainability Explorer.

**- Campus Green Building Guidelines:**

Published in 2011, the Green Building Guidelines were written to provide a framework for all future construction and major renovation projects on UMass campus. Through a careful review of the many LEED requirements, the guidelines were designed to establish priority and feasibility levels for each LEED requirement based on the environmental realities, missions, and goals of UMass. Out of the 60 LEED credits, 29 were identified as high priority by the guidelines [12].

**UMASS FRAMEWORK FOR CONSTRUCTION WASTE MANAGEMENT:**

Contact was established with UMass planners, project managers, green building researchers, and members of related committees in order to explore the framework by which the University of Massachusetts has been implementing its construction projects while meeting its sustainability targets. After acquiring access to policy documents and attending committee meetings by UMass building specialists, the framework of concern could then be identified.

**Construction Waste Management in Light of UMass Green Building Guidelines:**

Among the 29 prioritized LEED credits, the UMass Green Building Guidelines define Credit 2 under the category of Materials and Resources as a high priority credit. However, the category comprises a group of credits which directly address the recovery of construction materials either by reuse or recycling. Discussed through the guidelines, the credits were re-introduced to project teams by UMass as shown in the following (Tables 1 – 5).

- Credit 1.1 Building Reuse - Maintain Existing Walls, Floors, and Roof, 1-3 points (+1 regional) [13]:

**Table 1: LEED Credit 1.1 Building Reuse and UMass Discussion [12]**

LEED credit requirements	Minimum percentage for each point
Maintain the existing building structure: <ul style="list-style-type: none"> <li>• Structural walls</li> <li>• Structural floor</li> <li>• Roof decking</li> </ul> And envelope: <ul style="list-style-type: none"> <li>• Exterior skin and framing</li> <li>• Excluding window assemblies &amp; non-structural roofing material</li> </ul>	<ul style="list-style-type: none"> <li>• 55% 1 point</li> <li>• 75% 2 points</li> <li>• 95% 3 points</li> </ul>
<b>UMass credit discussion</b>	This credit is a high priority for legacy structures, or buildings considered to have historical significance for the University. The feasibility of this credit will vary greatly by project. For major renovations of existing building, the requirements may be easily achievable.

- Credit 1.2 Building Reuse - Maintain 50% of Interior Non-Structural Elements, 1 point [13]:

**Table 2: LEED Credit 1.2 Building Reuse and UMass Discussion [12]**

<b>LEED credit requirements</b>	Use existing interior non-structural elements in at least 50% of the completed building, including additions. <ul style="list-style-type: none"> <li style="width: 50%;">• Interior walls</li> <li style="width: 50%;">• Doors</li> <li style="width: 50%;">• Floor coverings</li> <li style="width: 50%;">• Ceiling systems</li> </ul>
<b>UMass credit discussion</b>	For the most part, major renovations are an opportunity to replace existing materials with newer, more durable materials. As part of UMass commitment to sustainability, major renovations are only scheduled for buildings that are unable to support programmatic needs and/or pass building codes. The existing non-structural elements in such buildings are rarely reusable. In a case where the existing materials are reusable, it is unlikely that the University would completely discontinue occupancy. Per LEED, such a project would not be considered a major renovation or eligible for certification under the New Construction and Major Renovation rating system. In situations where existing walls are maintained after a major renovation, they tend to be structural walls and therefore not applicable to this credit.

- Credit 2. Construction Waste Management, 1-2 points (+1 exemplary) [13]:

**Table 3: LEED Credit 2. Construction Waste Management and UMass Discussion [12]**

LEED credit requirements	Minimum percentage for each point
Recycle and/or salvage nonhazardous construction and demolition debris. Develop and implement a construction waste management plan that, at a minimum, identifies the materials to be diverted from disposal and whether the materials will be sorted on site or co-mingled.	Calculations can be done by weight or volume, but must be consistent throughout. • 50% 1 point • 75% 2 points • 95% +1 exemplary point
<b>UMass credit discussion</b>	Recycling is a high priority on campus. However, waste produced by construction activities is not sorted on campus; rather, it is the responsibility of the contractor to properly dispose of waste. It is the University's position that- due to the location of the campus and the availability of local waste contractors who can recycle and track construction waste - a minimum target of 75% should be met by all projects.

- Credit 3. Materials Reuse, 1-2 points (+1 exemplary) [13]:

**Table 4: LEED Credit 3. Material Reuse and UMass Discussion [12]**

LEED credit requirements	Minimum percentage for each point
Use salvaged, refurbished or reused materials, the sum of which constitutes at least 5% or 10% based on cost of the total value of the project materials (additional point for achieving 15%).	• 5% 1 point • 10% 2 points
<b>UMass credit discussion</b>	The University has standardized building materials in order to simplify alterations, maintenance, and repair. Although re-purposing salvaged materials can save on cost of new materials and has significant environmental benefits, UMass identifies this credit as a low priority. On some small scale projects, it may be possible to reuse building materials. Design teams should track reuse and apply for the LEED credit if the requirements are met.

- Credit 4. Recycled Content, 1-2 points (+1 exemplary) [13]:

**Table 5: LEED Credit 4. Recycled Content and UMass Discussion [12]**

LEED credit requirements	Minimum percentage for each point
Use materials with a total recycled content that constitutes at least 10% or 20%, based on cost, of the total value of the materials in the project. Include only materials permanently installed in the project. Other components and installation items cannot be included (additional point for achieving 30%).	• 10% 1 point • 20% 2 points
<b>UMass credit discussion</b>	For most building projects, there are many ways to incorporate the use of recycled materials into the design. Often, standard building materials contain recycled materials. Structural steel beams and columns produced in the US, for example, have an average recycled content rate of 93%. Since this LEED credit is based on the overall project materials budget, design teams should assess the potential for recycled content of "big ticket items" early on. In many cases, projects may earn this credit simply by tracking recycled materials, so it is important to require the submittal of recycled materials in the specifications. While creativity in design is encouraged, building materials should be chosen for their function and durability above all else.

**UMass Policy for Construction Waste Management:**

The attention of The UMass policy for construction waste management is directed to general contracting conditions and procedural requirements for recycling and disposing of construction waste. The document starts by defining construction waste and the principal means of handling it. Then, it demonstrates performance requirements which are based on an integrated waste management plan that guarantees the achievement of 75% recycling rate or more by weight of the total waste generated by a project. An overview of the UMass regulatory document can be summarized in the following [14].

**- Recycling Requirements:**

For recycling maximization of construction waste, the document elaborately lists all sorts of recyclable materials (from site clearing waste, various material types, and all the way to packaging).

**- Waste Management Plan:**

The required plan comes in two separate sections (recycling and disposal), and it basically includes:

- Waste identification by types and quantities.
- A waste reduction program which indicates the means by which each type of waste is handled along with associated documents (receipts and statements from management facilities).
- Handling and transportation procedures which include methods for separating and transporting construction waste (specifications of containers, vehicles, etc.).
- Appointment of a General Waste Management Coordinator for the project.

**- Plan Implementation:**

The policy demonstrates to project teams how the management plan shall be executed through:

- Site preparation and allocation of collection points, containers, and signage for all waste types.
- Plan distribution and periodic meetings with the project team and contractors for regular reviews.
- Assurance of site access and controls during the management operations with the least possible interference with motor and pedestrian ways, as well as environmental protection measures.

**- Submittals:**

The main submittals required from project teams are listed through the document with time allowances and specifications of submission. The listed submittals include:

- A full waste management plan for the project.
- Periodic reports on the waste management progress.
- All waste management calculations.
- Facility permitting information (whether for recovery or disposal).
- Records of recycling, donations, and sales.
- All required submittals for LEED registration, including a tabulation of total waste material, quantities diverted, and means by which they were diverted.

**- Recycling Procedures:**

The document goes on, specifying the procedures of construction waste recycling for projects on campus. For each waste type, on-site jobs are explained, including mechanisms of separation, storage, collection, and off-site safe transportation to appropriate facilities.

**- Disposal Procedures:**

Except for materials to be recycled or reused, the document finally regulates the removal of waste residues from project sites for legal disposal at landfills located in Massachusetts that are acceptable to authorities having jurisdiction. Safe transportation procedures are indicated as well as measures against waste accumulation, spillage, and contamination.

**Massachusetts Policy for Construction Waste Management:**

In 1990, the Massachusetts Department of Environmental Protection (MassDEP) introduced its first bans on land-filling and combustion of easy-to-recycle and toxic materials. Additional "Waste Bans" have been phased in over time. Among the addressed materials, the following construction-related materials are prohibited from disposal in Massachusetts [8]:

- Asphalt pavement, brick and concrete.
- Clean gypsum wallboard.
- Glass and metal.
- Recyclable cardboard.
- Treated and untreated wood.

Furthermore, the Code of Massachusetts Regulations (CMR) addresses solid waste management particularly in its regulatory document 310 CMR 19.000 which aims to protect public health, safety, and the environment by comprehensively regulating the storage, transfer, processing, treatment, disposal, use, and reuse of solid waste in Massachusetts. 310 CMR 19.000 consists of four main sections as explained in the following [8].

- Part 1. General Requirements, Procedures, and Permits (19.001 - 19.083):

After defining the legal framework, authority, and applicability, this section lists definitions of terms concerning solid waste types, landfill types, disposal and recovery facilities, as well as all associated operations and measures. It also provides definitions for construction and demolition waste (C&D), processing facilities, and transfer stations. Generally, this part of the document clarifies responsibilities, required procedures, mandatory reports and documents, acceptable formats, etc. for every party involved, including owners, operators, inspectors, haulers, and administrators. Furthermore, the rights of MassDEP are indicated (to enter properties and to obtain and review information). Accurate and timely submittals of documents involving solid waste practices are mandated, as well as accurate record keeping and certified engineering supervision.

The document also regulates the establishment and operation of waste management facilities, indicating authorization permits and exemptions, whereas it strongly prohibits open dumps and illegal disposal of solid waste. Suspension, revocation, and closure are enforced in case of violation or fail in compliance, in addition to legal prosecution. Violations are subject to strict penalties, as each day a violation occurs or continues is regarded as a separate violation (a penalty of no less than \$100 and no more than \$25,000 for each day of violation, or imprisonment for no more than two years). As for waste bans, an elaborate list of materials is displayed, while a waste ban plan is required from all waste management facilities to be submitted to MassDEP in compliance with waste restrictions. Submittals, official documents and time frames are indicated as well. For further inspection, the policy sets forth third-party inspection requirements for specific types of facilities including active and closed landfills and handling facilities. It also specifies types of provided inspections, qualifications, and credentials for third-party inspectors that are necessary for registration. Particularly, a third-party inspector is required to examine and evaluate the compliance of a C&D waste processing facility or transfer station with further procedures like:

- Requirements for storm water controls.
- Operation and maintenance requirements like appropriate equipments and weighing facilities.
- Facility's suspect Asbestos-Containing Material (ACM) inspection and management protocol.
- Applicable requirements of any beneficial use determination of C&D waste at the facility.

In addition, the policy states general standards and permit procedures for the authorization of beneficial use activities for all types of waste with regard to safety, public health and environmental protection. Finally this section of the document ends by enforcing a minimum recycling requirement of 25% by weight of waste (aside from waste bans).

- Part 2. Landfill Design and Operational Standards (19.100 - 19.151):

This section establishes design standards and minimum performance of operation and maintenance, as well as closure/post-closure requirements for solid waste landfills by supplementing, modifying, or expanding upon the provisions of part 1.

- Part 3. Transfer Station Design and Operations Standards (19.200 - 19.207):

This section establishes minimum performance as well as design, operation, and maintenance standards for solid waste handling facilities. As demonstrated, handling facility design requirements include several technical aspects like storm water controls, equipments, and weighing methods. Furthermore, for construction and demolition (C&D) waste processing facilities, the document specifies the following additions:

- All handling of C&D waste shall occur indoors unless otherwise approved by MassDEP.
- All processed C&D waste and recyclable materials shall be stored in an appropriate manner to protect the public health, safety, and the environment. In general, all processed C&D waste shall be stored in covered containers or covered piles on impervious surfaces.
- All storm water or water used for site operations that comes in contact with C&D materials shall be controlled and managed in accordance with applicable local, state, and federal requirements.

Moreover, operation and maintenance requirements for handling facilities are listed thoroughly, including supervision of operation, access to facilities, security and safety, signage, controls, fire protection, staffing, recycling operations, record keeping, reporting, and regular inspection.

- Part 4. Class II Recycling Program (19.300 - 19.303):

This section establishes the process and requirements for Waste-to-Energy facilities that were in operation before December 31, 1997 (Municipal Waste Combustors) to qualify as "Waste Energy Generation Units" according to the approved Class II Recycling Program.

Finally, besides indicating all responsibilities, regulations, policies, penalties, and guidance in the 310 CMR 19.000 document, MassDEP offers online services such as electronic forms, exemplary documents and downloadable files that demonstrate compliance assistance for waste generators, haulers, facility operators, and inspectors. An online space is allocated on the MassDEP website for downloading policies, codes, and ordinances, as well as posting inquiries and browsing updates.

## **FIELD VISITS (Committee Assemblies - Project Site - Waste Handling Facility):**

Field visits were conducted for practical verification of the management process on the real ground. The visits included a construction project site on campus and the management facility which processed its waste. This is in addition to checking the administrative structure of roles and responsibilities by attending assemblies of UMass committees, and setting up discussions with building specialists.

### **Campus Waste Management Overview:**

(Master Plan Sustainability Committee Meeting, UMass, Amherst - April 10<sup>th</sup>, 2014) [9]

The meeting agenda of the Master Plan Sustainability Committee included an overview of campus waste management presented by the General Manager of UMass Department of Waste Management. The presentation demonstrated statistics of UMass campus waste for one year (2012 - 2013), how such waste was handled, and what the waste challenges were. The analysis of waste composition identified types of waste, provided an estimate of waste volumes in tons, and indicated the recycling rate achieved as a percentage of the total volume. The waste management overview for this given year accounts for 56.4% as an overall recycling rate.

During the meeting, impediments to the development of campus waste management were discussed, whether infrastructural, behavioral, or institutional. For campus construction waste specifically, the impediments discussed at the meeting mostly involved the difficulty of keeping accurate accounts of construction waste quantities, their management means, and the involved costs. Although building contractors are responsible for reporting, their given statements are not always sufficient. Furthermore, construction waste management might not be as efficient for non-LEED projects on campus (such as some renovation projects for existing buildings) as it is for registered LEED new construction projects. Thus, some suggestions were made by the meeting participants in order to eliminate those hardships in the future as explained in the following:

- Providing every loading truck (that is assigned to haul construction waste for each campus project) with a weighing scale to quantify and record the generated waste on site (Fig. 1).
- Contactors should be required to submit full detailed reports for their waste management plans and results (with necessary documents for the verification of recovery rates) for UMass to keep.
- Accurate information should be reported to UMass on where construction waste of every campus project is sent, accompanied by a complete profile of the facility of destination.
- Creating another guide of sustainable construction practices for non-LEED projects on campus (similar to the Green Building Guidelines for LEED projects). So, non-LEED projects would also have documentation of their construction practices including waste management.

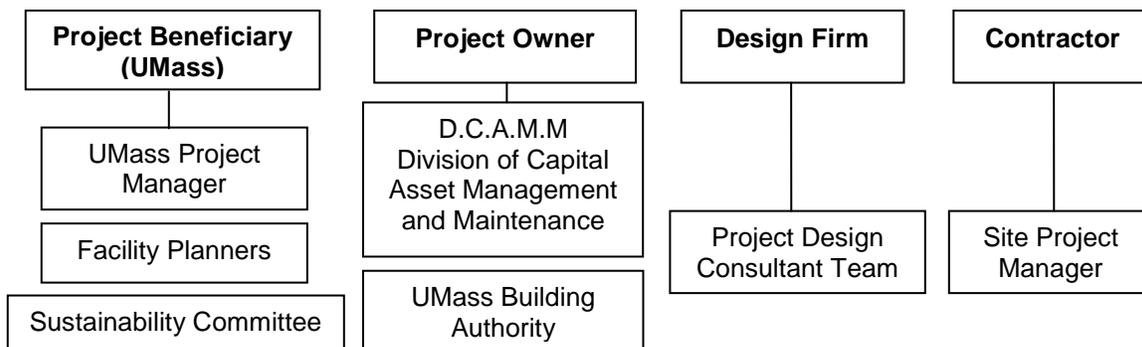


**Fig.1: Models of Portable Truck Scales Used to Weigh Truck Loads on Site [1], [6]**

**Executive Hierarchy of Responsibilities and LEED Registration:**

(Project Team and Facility Planners Meeting, UMass, Amherst - April 10<sup>th</sup>, 2014) [10]

The parties involved in each UMass building project can be summed in four main categories which share responsibility for submitting full documentation upon applying for LEED registration (Fig. 2).



**Fig. 2: Parties Involved in LEED Registration of UMass Projects [10]**

A meeting was arranged to discuss LEED registration for a renovation project on campus (Lincoln Campus Center Dining Hall). Throughout the meeting (between UMass facility planners and the project design team), the scenario of LEED registration for campus projects became defined. By going through every credit and sub-credit listed under each of the LEED categories, each of the concerned parties becomes assigned to a specific credit(s) (the design team, UMass Facility Planning team, UMass Building Authority, Project Manager, etc.). Such appointment of the appropriate party and the right person for the documentation task depends on the availability of resources, expertise, possession of documents, and the mechanism of credit applicability. Everyone responsible for a task is expected to write a narrative supported with documents in order to claim the points for the designated credit. However, one member of the design team is appointed as a Principal Administrator who would be responsible for putting all the LEED documentation together. Overall, credits are listed in a detailed schematic data sheet which states project information, meeting schedules, timeframe, responsible teams with members' information, points assigned to each credit, and task responsibility distribution. Two credits were highlighted during the meeting that concerned construction waste recovery and were appointed to the project team for documentation; Credit 1.2 (Building Reuse) and Credit 2 (Construction Waste Management). Yet, the realization of those credits is reliant on the assigned contractors who would eventually handle the project's waste.

**Field Visit to Project Site on Campus:**

(The New Academic Classroom Building, UMass, Amherst - May 12<sup>th</sup>, 2014)

In conformity with both Massachusetts and UMass building policies, the New Academic Classroom Building project was commissioned to an architecture firm, which subsequently commissioned a contractor for the project construction. The contractor in turn placed bids out to waste contractors for handling the project's waste. Offers were then compared mainly on the basis of cost and reporting (familiarity with LEED documentation and providing submittals). This is how the appointed waste management contractor was eventually selected. According to location vicinity, the waste management company has assigned one of its facilities (located in Wilbraham, Massachusetts) to handle the job. It is also worth to note that there was an additional third-party inspector authorized by the state to monitor the waste management throughout the project construction.

A field visit was paid to the project site of the New Academic Classroom building, and an interview was arranged with the construction manager. Accordingly, the following facts could be established:

- Locations for waste collection were spotted in two accessible areas on site; one is on the west side and the other is at an intermediate spot between the two wings of the building shape (Fig. 3).
- All waste resulting from construction on site is carried in carts to either of the collection points.
- Each collection point has a dumpster (container) with a size of 30 cubic yards.
- Construction waste of all types (co-mingled) is stacked in those dumpsters without discrimination. No identification or sorting by waste type occurs on site.
- The average frequency by which dumpsters are moved off site to the facility is 2 – 3 times a week. Environmental and safety measures are always considered while transporting the project's waste.
- Waste is picked up by a triple axle loading truck on which a full dumpster slides after being replaced with a vacant one; all provided by the waste management facility.
- The decision was made to manage the project's waste as co-mingled since it was an easier option for the construction contractor - in terms of time in relation to cost - to appoint a waste contractor for handling the whole waste management job off site.
- The labor cost of waste separation on site would have been higher in this case, since it is a state project. On-site labor wages for state projects are reported to be up to \$30 – 40 per hour, while the average off-site rate (at non-governmental construction businesses) is estimated by \$10 - 20.
- Another reason why the contractor might have found it feasible to sort the waste off site is that management facilities would provide better techniques for instant and efficient separation (mechanical belts, magnets, air blowers, etc.), whereas sorting on site would only be by hand.

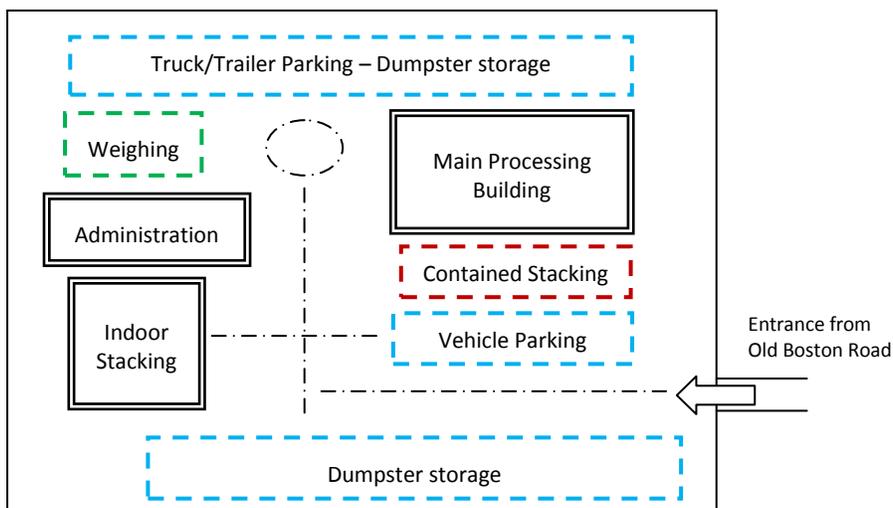


**Fig. 3: Accessible Points for Waste Collection, Provided with Dumpsters and Loading Docks - New Academic Classroom Building Project [2]**

**Field Visit to Waste Management Facility:**

(Waste Management - Western Processing Facility, Wilbraham, Massachusetts - June 6<sup>th</sup>, 2014)

The visited facility has been processing the construction waste from the UMass New Academic Classroom Building project. Arranged by the Construction Services Account Manager at Waste Management New England, a field visit was scheduled to the facility which handles construction waste of all types, mostly co-mingled, with a current recycling rate of 71%. The facility also provides collection and hauling services at project sites, including trucks and dumpsters of several sizes (15 to 50 cubic yards). During the visit, all zones of the facility were toured (Fig. 4). Thus, the scheme by which construction waste is typically processed at the facility could be identified in the following:



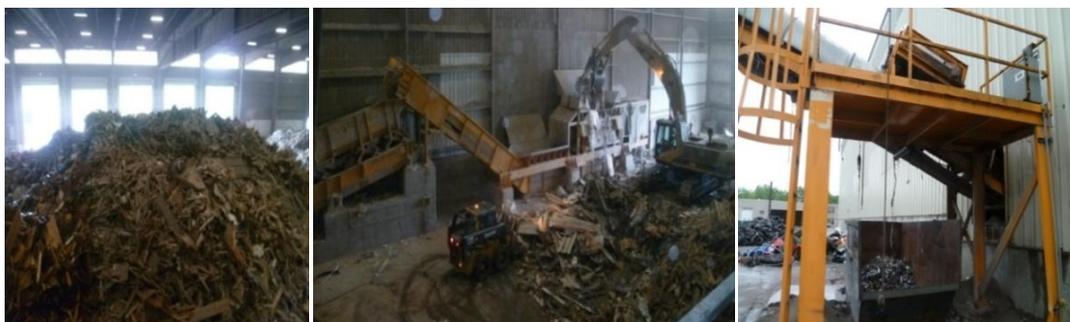
**Fig. 4: Layout Diagram of Waste Management Western Processing Facility, Wilbraham**

- Each of the in-going trucks heads to the weighing zone, gets on the scale to weigh its load, and gets inspected for hazardous substances. Then, the truck dumps its load at the center of the main processing building (Fig. 5).



**Fig. 5: Trucks Weighed and Inspected before Unloading Waste at Main Processing Building**

- As waste is constantly stacked in a big central pile, tractors haul waste from the stack and feed it to the main grinder which crushes the waste primarily to an outcome of 21 inches or less. The grinder is equipped with screens and an underneath pad to receive waste fines, in addition to mechanically-rotating magnets to separate metal objects (Fig. 6).



**Fig. 6: Waste Stacked then Fed to Main Grinder, Equipped with Screens and Magnets**

- The outcome moves on a conveyer built to the upper story where about 12 personnel alongside the belt separate waste items by hand, and place them in distinctive containers. Irrelevant objects are picked up and stored on the side (electric wires, plastics, textiles, appliances, etc.) (Fig. 7).



**Fig. 7: Waste Moving on Conveyor Belt for Manual Sorting**

- Containers are gathered frequently and moved to designated stacking areas (asphalt - brick and concrete - wood - cardboard - drywall gypsum - metal) (Fig. 8 and 9).



**Fig. 8: Outdoor Stacking for Processed Wood**



**Fig. 9: Outdoor Stacking for Aggregates**

- The facility has other processing lines with secondary grinders to minimize the size of the sorted waste. For example, wood waste is conveyed to another grinder with a down-ward belt that minimizes the size of waste fractions to no less than 3 inches.
- Unrecyclable residues are crushed in another grinder to a size of 3 inches or less, and then pumped out onto a pile at the contained area. Such fine waste is hauled constantly to landfill sites in Chicopee (a neighboring town), where it is given as dirt to be used for cover layers.
- The contained area (where fine/airborne waste is stacked) is surrounded with a high screen fence to prevent dirt dispersal in the air (Fig. 10), while the main processing area is equipped with control measures like large fans, automatic water sprinklers, drain water leaching, etc.
- Waste that requires protection from moisture like drywall gypsum and cardboard is stored in the indoor stacking area (Fig. 11).



**Fig. 10: Contained Area for Fine Waste**



**Fig. 11: Indoor Area for Moisture-Sensitive Materials**

- The final processed outcome is stored by type in containers at the dumpster storage area around the perimeter of the facility. Finally, it is hauled by out-going trucks to manufacturing facilities in the area according to type (concrete, metal, wood, etc.) (Fig. 12).



**Fig. 12: Containers Sorted by Type, Picked Up, and Hauled to Appropriate Destination**

**SUMMARY AND DISCUSSION:**

- Many local and state governments in the United States have been earnestly promoting construction waste recycling as part of their green building approach.
- Green building initiatives entail various forms of provisions such as policies and regulations, codes, demonstration projects, assessment systems and awards, professional guidelines, training and educational programs, publication, and sharing expertise.
- An integrated waste recovery plan includes setting goals, identifying and targeting waste types, waste segregation on site, in addition to regular monitoring and assessment of performance.
- As a state university, the University of Massachusetts - Amherst reflects the local approach toward the concept of sustainability through many initiatives that have been presented by the university.
- The UMass Sustainability Committee and its subcommittees aim for the sustainable design and construction of building projects on campus by developing policies and creating executive plans.
- The UMass Green Building Committee has created its own Green Building Guidelines, which were designed to establish priority for LEED requirements based on the realities and goals of UMass.
- The legal/administrative framework which governs construction waste management of UMass projects consists of the Green Building Guidelines, UMass Policy, and Massachusetts Policy for Construction Waste Management.
- The UMass Green Building Guidelines define LEED Credit 2 under the category of Materials and Resources as a high priority credit. The category comprises a group of credits which directly address construction material recovery.
- As the guidelines discuss Credit 2 (Construction Waste Management), recycling is prioritized with no stipulation of waste sorting on site. However a minimum recycling rate of 75% is mandated.
- Although the guidelines identify Credit 3 (Material Reuse) as a low priority, it encourages design teams to pursue and apply for the credit when possible, especially for small-scale projects.
- Although the guidelines encourage project teams to earn Credit 4 (Recycled Content), it emphasizes material function and durability above all else. Within this concern, no minimum requirement of recycled content was stipulated.
- The UMass Policy for Construction Waste Management addresses contracting conditions and administrative/procedural requirements for the waste management of campus projects. In addition, it compels project teams to submit an integrated waste management plan that guarantees the achievement of 75% as a minimum recycling rate.
- The UMass policy demonstrates a framework for the implementation of the waste management plan, indicating specifications of procedures and environmental protection measures. It also lists required submittals, including reports, records, and permits, besides standard LEED submittals.
- The state policy is present in the Code of Massachusetts Regulations and its regulatory document 310 CMR 19.00. In addition to waste bans, it addresses solid waste management by regulating the collection, storage, transfer, processing, treatment, disposal, use, and reuse of solid waste.
- The Code of Massachusetts Regulations defines waste types, landfill types, disposal and recovery facilities, and all associated operations and measures. It also clarifies responsibilities, required performance, and submittals for every party involved in waste management.
- The state document regulates the establishment and operation of waste management facilities indicating standards, authorization permits, exemptions, and penalties of violation. It also specifies rules for the beneficial use of waste, enforcing a minimum recycling requirement of 25%.
- The lack of waste accurate accounts, as well as the lack of waste sorting and separation on site, was among the main impediments for UMass construction waste management.
- Responsibilities of registration for each campus project are distributed in a scheme, so that each of the parties involved becomes assigned to the documentation of a specific LEED credit(s).
- All waste resulting from the UMass New Academic Classroom Building was treated as co-mingled waste. The project's waste was collected in dumpsters at two main points on site, and then picked up regularly by the management facility trucks.

- The Waste Management Facility in Wilbraham handles construction waste of all types, providing all needed services. Besides the main processing zone, the facility layout comprises a weighing zone, indoor and outdoor stacking areas, truck parking areas, and dumpster storage areas.
- The waste processing line begins with weighing loads and inspection of bans. Then, it moves on to crushing and downsizing waste, screening, scaling and manually sorting the outcome, grinding remainders, and stacking the final outcome by type in designated areas. Eventually, the processed materials are hauled to manufacturing facilities, whereas unrecyclable residues are sent to landfills.

## **CONCLUSIONS:**

For more sustainable management of construction waste on project sites, effective considerations should be incorporated within waste management plans, such as:

- Identifying common waste types on site during different construction phases in order to prioritize waste recovery by material type at each phase (whether structural, internal, or finishing), thus directing waste management plans and regulating contracting conditions in accordance.
- Developing measures to improve the waste management plan and achieve better targets essentially by, but not limited to, waste segregation on site, providing color-coded bins, liaison with waste management contractors, better coordination, and site accessibility.

For the UMass Green Building Guidelines, some alteration could be made to enhance the sustainability of construction waste management on campus as in the following:

- Credit 2: Stipulating waste sorting on site by compelling project teams to have designated areas for the collection of separate material types in distinctive bins or containers. Thereby, the volume of co-mingled waste would be minimized.
- Credit 3: Encouraging project teams to investigate records of reusable materials which resulted from previous or simultaneous projects on campus or in the area. Contractors should also sort and store their own reusable materials, then post notice and submit records of them at UMass for other projects on campus to be notified. Thereby, the efficiency of reuse would highly increase.
- Credit 4: Incorporating a minimum requirement of recycled content as a percentage of the material value used in construction projects, which could simply be the lower benchmark identified by LEED (10%), without compromising the function and durability of building components.

For policies and regulations of construction waste management, the following measures could be considered to overcome the lack of accurate waste accounts and the incomplete records of waste data for construction projects on UMass campus:

- Providing truck scales to weigh waste loads on site before loading trucks haul the waste off site, thus constantly calculating and keeping records of all generated waste for every campus project.
- Enforcing the UMass Policy for Construction Waste Management in terms of contracting conditions to guarantee UMass possession of complete waste reports for campus projects. This should include the required full management plan, waste quantities by type, facility information, all involved services, associated records, and billing information (not only LEED submittals).
- Record keeping by UMass of all waste management data for construction projects on campus by which UMass may build its own domestic database. This is vital for future green building research, as well as planning the sustainability of new campus construction projects.

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