Opportunities for Building Design and Construction Resulting from Local Resources

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Bachelor of Science in Art and Design (2003)
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Submitted to the Department of Architecture in Partial Fulfillment of the Requirements for the Degree of Master of Architecture at the Massachusetts Institute of Technology, June 2007.

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Abstract

Current and future generations of architects must learn to operate effectively in an era of unprecedented resource constraints if they want to achieve their design intentions. This thesis addresses the architect's role in resource consumption. Specifically, it explores the potential for design and construction constrained to local resources.

This research encompasses the following questions: What are the material resources local to MIT? What are the architectural and logistical limitations of using those resources in buildings? How might this research shape a building at MIT?

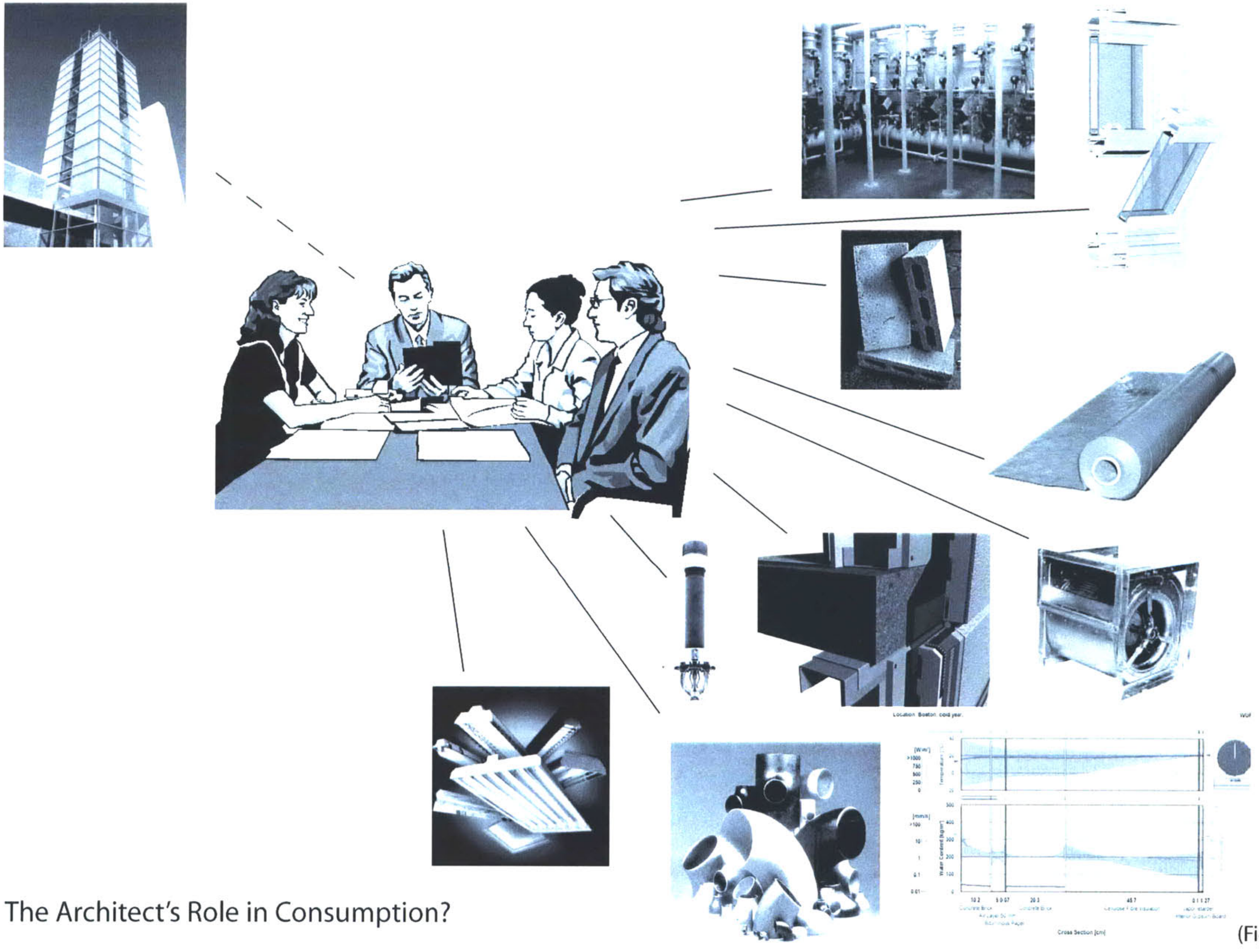
By auditing local resources and industries, this thesis highlights unique opportunities for an architect to mobilize sustainable materials for MIT's growth. The subsequent design exercise transforms this knowledge into building strategies responsive to material and energy constraints. This new building serves to increase the density of MIT's east campus, developing underutilized lots on the edge of a future quad and rehabilitating a condemned structure. A framework of fixed and fluid components allows for sustainable adaptation, creating a flexible environment sought by emerging interdisciplinary groups.

Thesis Supervisor: John E. Fernandez
Title: Associate Professor of Building Technology

To Emily

Opportunities for Building Design and Construction Resulting from Local Resources

Contents



The Architect's Role in Consumption?

(Fig. 1)

Introduction: The architect's role in resource consumption

Architects have always played a significant role in mobilizing resources for building endeavors. Minor design changes in a sketch or digital model translate into massive changes in the consumption of materials and energy, both initially and for the life of the building. These are not trivial amounts of resources. According to Arpad Horvath, director of the Consortium on Green Design and Manufacturing, "construction has been the largest documented consumer of materials in the United States by weight for almost a century." The architect's role in resource consumption is changing. Modern building techniques and expectations for occupant comfort demand a broad range of expertise. The design process is increasingly subjugated to bureaucratic rigor employing a variety engineers and consultants. A similar division of labor is shaping the sustainable design movement, whereby design teams elicit the expertise of green consultants or prepackaged guidelines.

In coming decades the building industry will be shaped by an increase in material constraints due to global warming, mineral depletion, limited fresh water supply, predictions for rapid world population growth and unprecedented building activities.[1] These environmental challenges will inspire a variety of technical, political, and economic solutions that will profoundly influence the utility and meaningfulness of the built environment in years to come. These solutions will involve collaboration and input from a variety of industry stakeholders including architects, owners, developers, real estate financers, sureties, manufacturers, engineers, inspectors, builders and labor unions. For an industry resistant to change, its adaptation to resource constraints will rely on conscientious professionals and owners who can champion new strategies for building design and construction. It is in this vein that this thesis strikes the following question, one that current and future generations of architects will grapple with:

> In the coming decades of resource constraints, how might architects engage their role in resource consumption in a productive and meaningful way?

This thesis seeks a role for architect's which challenges their creative talents and their capacity to function as leaders in an overwhelmingly dispassionate building industry. As buildings become increasingly energy efficient, the material burdens of their physical construction will be the focus of concern. Knowing where and how to encourage resource conservation within the national and global supply chains of building materials requires an understanding of technical and institutional barriers to sustainable alternatives to the status quo. The following section outlines some of these barriers. This knowledge helps focuses this research by highlighting strategies available to architects:

Material Substitution: A process devoted to finding alternative construction materials that are renewable, benign and allow for reuse or biodegradation. This strategy is typically founded through the research of material and chemical scientists in non-building related fields.[2] After satisfying extensive toxicity, safety, and performance regulations, a substitute material may become part of the architect's palette and slowly integrated into standard practice.

Dematerialization: Decreasing the net material and energy consumption of human activities. This relies heavily on consumer restraint and public policy. The United States has historically championed dematerialization only as a provision of war. (The efforts of sustainability within the United States tend to be limited to recycling, renewable energy and a decrease in pollution and toxicity of industrial processes.[3]) This strategy has the best chance of success when it does not alter the perceived standard of living. Architects have a unique opportunity to mold perceptions of quality. The architect who can convey an acceptable design quality with fewer resources is in effect promoting dematerialization.

The typical hallmarks of dematerialization include the miniaturization of computer chips, the displacement of large tonnages of copper by fiber optics, and the improved energy and material efficiency of buildings.[4] However, research in the field of industrial ecology performed by Robert U. Ayres, Leslie W. Ayres and Benjamin Warr reveals a startling realization: the per capita consumption of resources is steadily climbing. Their study suggests that increased efficiency in manufacturing, product design, or building practices typically lowers the price increasing the purchasing power of the average American, which in turn fuels greater consumption. Among a number of indices, Ayres highlights the steadily increasing ratio of built floor area per capita and the increasing size of the average American house. Dematerialization ultimately requires a cultural shift beyond the scope of the architect and beyond the scope of this thesis.

Resource Recovery: A process that extends the useful lifespan of highly processed materials and assemblies. As virgin sources of minerals become prohibitively expensive to extract from the natural environemnt the industry will increasingly tap reserves stored in our built environment. [6] This will place an increased emphasis and perhaps a priority on retrieving minerals from obsolete buildings, construction wastes, and municipal solid waste. This strategy can target resource recovery from an entire building, its constituent parts, as well as post-industrial and post-consumer waste streams. Resource Recovery entails three major strategies: Building Reuse, Component Reuse and Recycling, which are further defined below:

Building Reuse, sometimes known as adaptive reuse, appropriates obsolete buildings for new occupancy. This strategy retains substantial portions of the building intact to maintain the initial investment of resources. Ideally the modifications will be limited to interior finishes and non bearing partitions. Changes to the building envelope may be necessary to protect investments in new interior finishes. The structure should be left intact when possible to retain the highly engineered value of those components.

Component Reuse finds new uses for superfluous or decommissioned components. These components are ideally left intact and used locally in order to maintain the initial investment of raw materials, energy, and transportation. With unbridled budgets, most building components can technically be reused.

Aside from antique fixtures and old-growth wood, reuse is prohibitively expensive, requiring extra labor, management, transportation and storage that clients are hesitant to fund. There may also be a need for hiring an engineer to vouch for the structural integrity of salvaged components in order to win approval from cautious building inspectors. Also, few salvaged components dealers are willing to offer a warranty, leaving the risk to the builder and owner. Builders that also perform demolition have a unique opportunity to internally transfer salvaged components to new construction to reap the full financial benefits of avoiding disposal fees and offsetting material purchases. One contractor developed a cost saving technique which "de-panelizes" traditional timber homes using modified demolition equipment. Laborers disassemble the building sections away from the jobsite in a safer, more productive setting. [7] Component reuse can be advocated by architect, but requires the owners commitment to possible risks and premiums associated with this endeavor.

Recycling requires collecting, sorting and reprocessing specific types of materials to serve as feedstock for manufacturing finished components. Most people are familiar with curbside recycling of household wastes. Many municipalities and school campuses boast their improved recycled rate. However, like any commodity, supply is only part of the equation. The demand for recycled content products plays an underappreciated role in driving the efficacy of recycling efforts. The containers washed and sorted for curbside pickup must undergo further processing at a Materials Recovery Facility (MRF) who sort and package these materials to the specific requirements of "re-manufacturers" who purchase these materials. Alana Levine, MIT's Recycling, Solid Waste, and Moving Coordinator, explains that "if it weren't for MRFs, every business and household would have to separate their recycling to re-manufacturing industry needs, package their recycling for efficient shipment, and market their recycling to re-manufacturers." As is the case with any commodity, the international trade in recyclable materials allows countries to exercise their "comparative advantages."[8] Paper industries in developing countries partially rely on the paper waste from developed countries to obtain higher grade fibers for producing an acceptable quality of paper for resale to developed countries. Conversely, foreign labor offers cost advantages that allow recycled products to compete with subsidized virgin materials.

A 1996 study by Alexander Volokh blames government building codes and construction standards for sidelining a number of viable opportunities for recycling waste material. Volokh sites a number of cases in which prescriptive standards eliminate the use of any recycled content, despite evidence that the recycled alternative provides equivalent or superior performance.

The US Green Building Council's Leadership in Energy and Environmental Design (LEED) provides incentives for recycling that can be counterproductive as designers seek to optimize available points in the rating system. For instance, a project in Boston might earn a point in the LEED rating system for purchasing and transporting large quantities of gypsum wall board from the USG's Quebec plant, where this product certifiably made with 98% recycled content, neglecting the opportunity to purchase USG board manufactured a few miles away from Boston in Charlestown, where recycled content is typically no more than 60%. Unfortunately, building professionals are typically unprepared or uncompensated for tracking the source of every product they deploy in a building, or in the case of LEED credits, the first source that meets the standard is selected without further investigation into comparing the relative benefits of alternative sources.

To the extent that an architect's control of material specifications allows them to mobilize recovered resources, this thesis seeks opportunities for mobilizing underutilized resources for building design and construction. This research privileges locally available resources in order to minimize transportation emissions associated with consumption, an under-scrutinized source of environmental burden.

The Massachusetts Institute of Technology offers a unique setting for this research. It is a large entity responsible for managing consumer wastes as well as a portfolio of aging and newly constructed buildings. Most importantly, MIT is invested in its reputation as a sustainable campus.[9] The process for discovery unfolds with three sequential inquiries: What are the material resources local to MIT?
What are the architectural and logistical limitations of using those resources in buildings? How might this research shape a building at MIT?

A Note on Economics

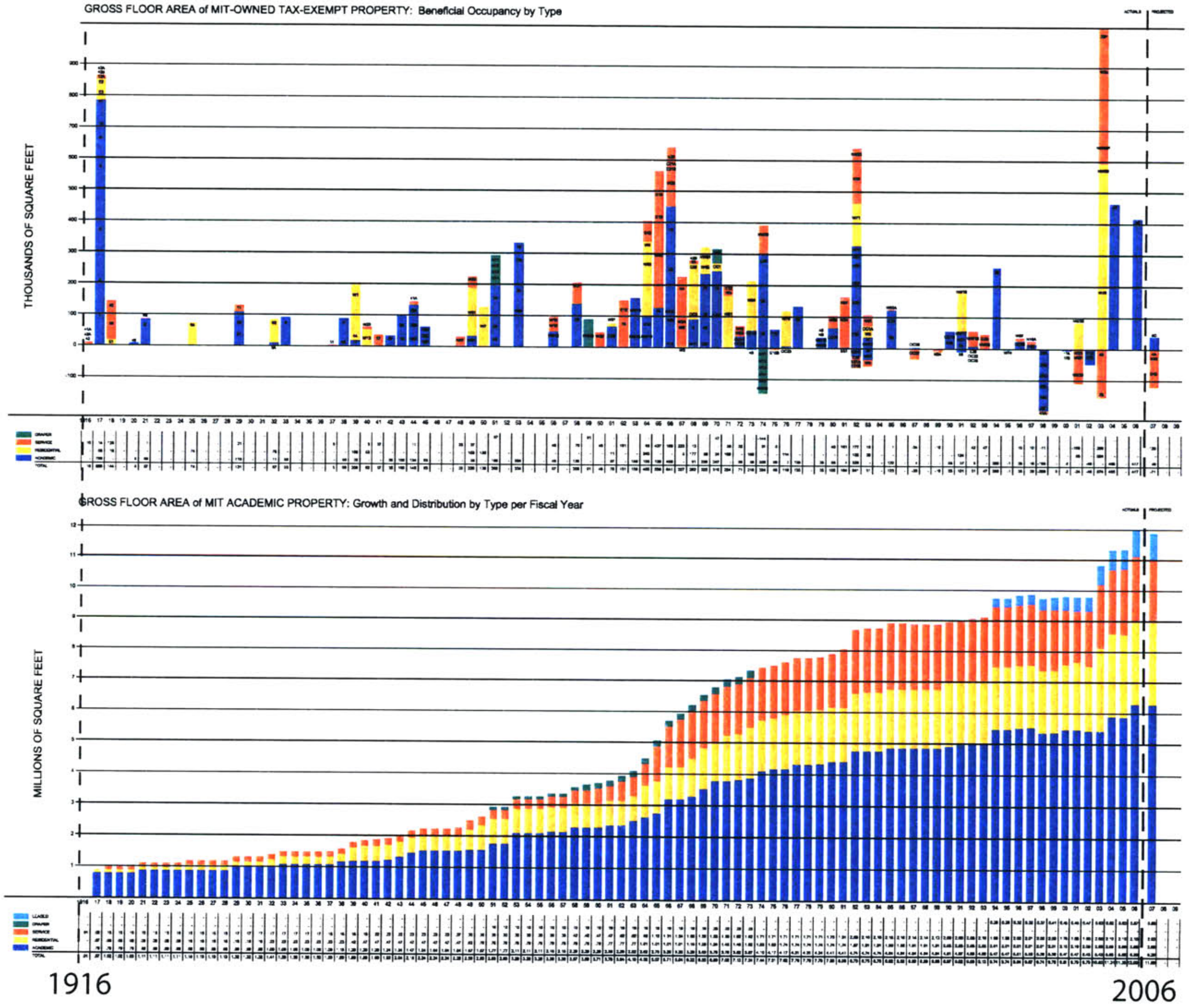
Carnegie Mellon's Green Design Institute created a web based tool for compiling Economic Input-Output Life Cycle Assessments (EOI-LCA) based on the 1997 US economy. This type of analysis highlights the circular nature of our economy. For instance, purchasing $1000 of ready mix concrete triggers direct and indirect activity of at least $1 in 127 sectors of the US economy including another $20 of ready mix concrete.[9] The economics of resource recovery are hardly transparent. The matter is further complicated by the subsidization of traditional building materials with which sustainable measures are expected to complete. The illusive nature of direct and indirect subsidies cloud the full cost of material choices. A thorough and useful economic analysis is beyond the scope of this thesis.

Material Accounting: MIT and Regional Sources

MIT is responsible for two major types of material flow: a punctuated flow of construction and demolition waste (C&D) and a continuous flow of consumer and maintenance waste. The C&D waste is managed by subcontractors and tracking this flow has only happens for large scale projects pursuing LEED certification. A variety of US waste statistics are used to compile a rough estimate of the C&D waste generated with respect to the volume of construction activity at MIT.

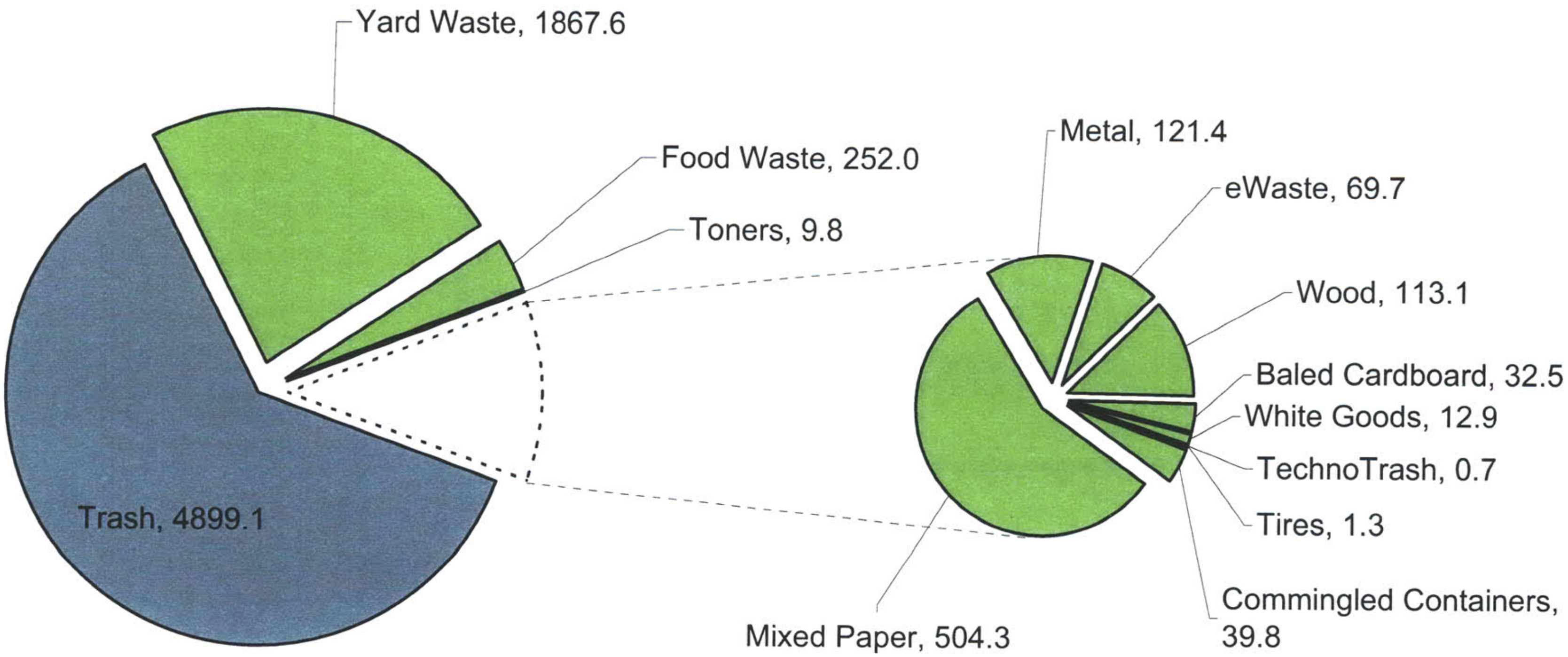
(Fig. 2)

This is a space chart for MIT from 1916 to 2006. The top chart marks individual construction projects above the datum line and demolition below. MIT has rarely demolished buildings at MIT until recently. The demolished structures are typically reinforced concrete, which are not candidates for disassembly. These structures, like the one pictured to the left, are crushed so metal can be removed for recycling. The leftover concrete rubble can be used as aggregate for new concrete but typically is used as road sub-base or backfill. There is an increasing interest in recycling these types of materials at the site of demolition. Mobile concrete plants can be deployed to combine a the cement, water, recycled aggregate, and any required additives.



(Fig. 3)

In 2006 MIT achieved its goal of recycling 40% of its municipal solid waste. MIT's Department of Facilities is responsible for managing this waste. The interest in recycling performance provides an incentive for closely tracking the amounts, which is done on a monthly basis. Consequently, obtaining this data was a simple matter of opening an Excel file prepared by the Department of Facilities. The chart on the facing page shows the tracking from 2006. The chart magnifies a group of waste materials for which documented recovery opportunities exist in Massachusetts. These highlighted materials can be recycled into building materials.



2006 MIT Municipal Solid Waste Management by Weight (tons)

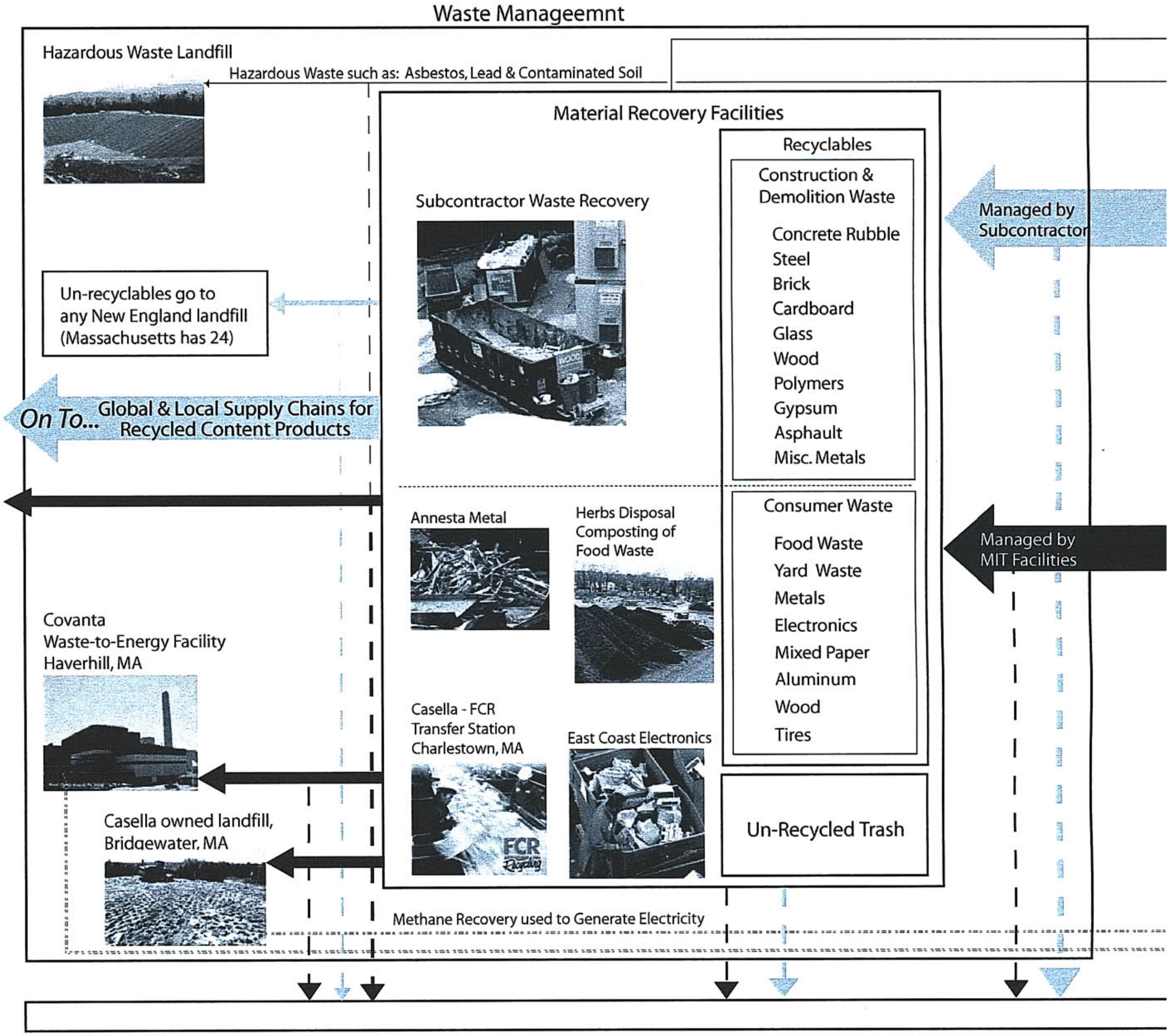
(Fig. 4)

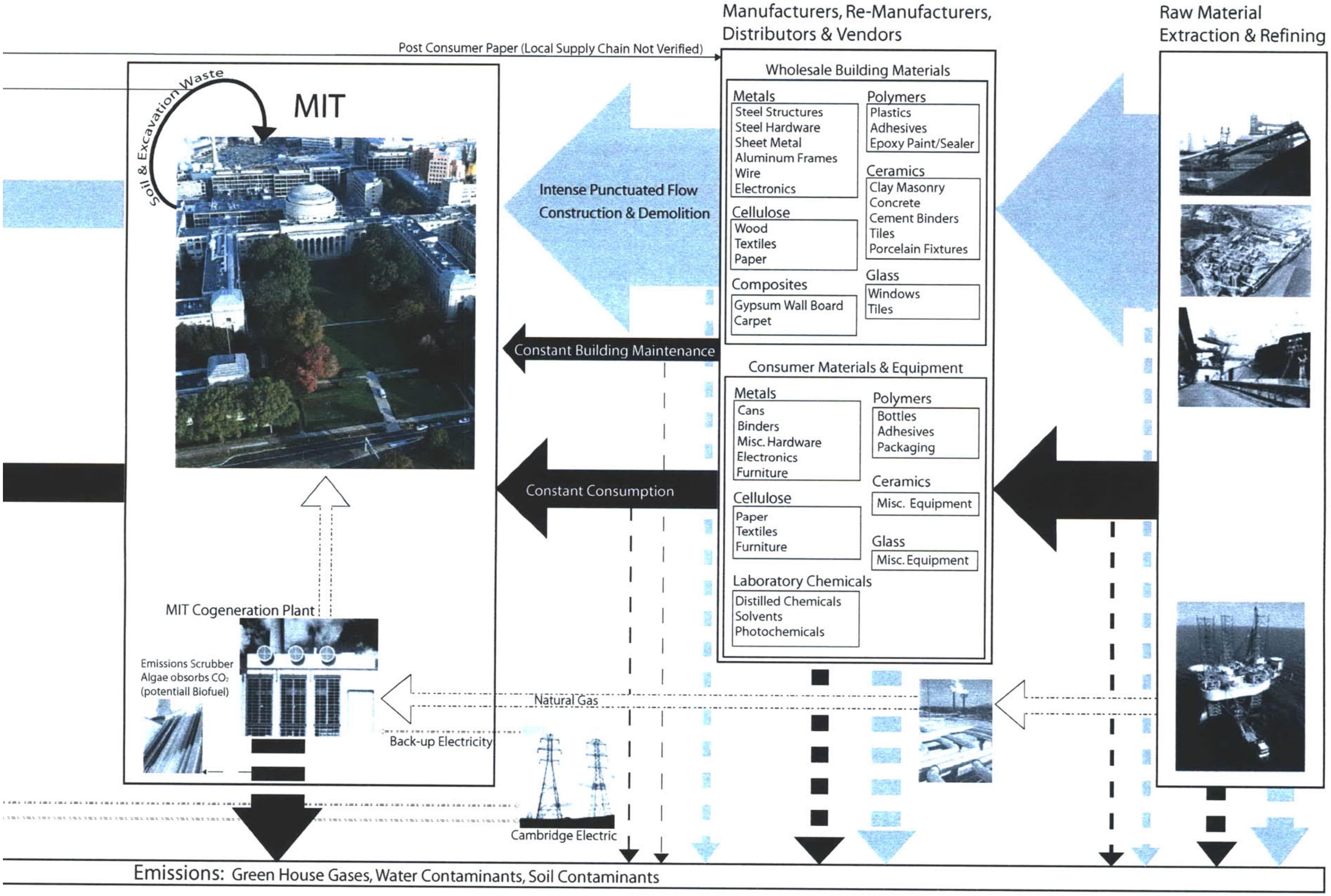
🟩 Recyclable Waste

🟦 Waste Sent to Landfill or Incinerator

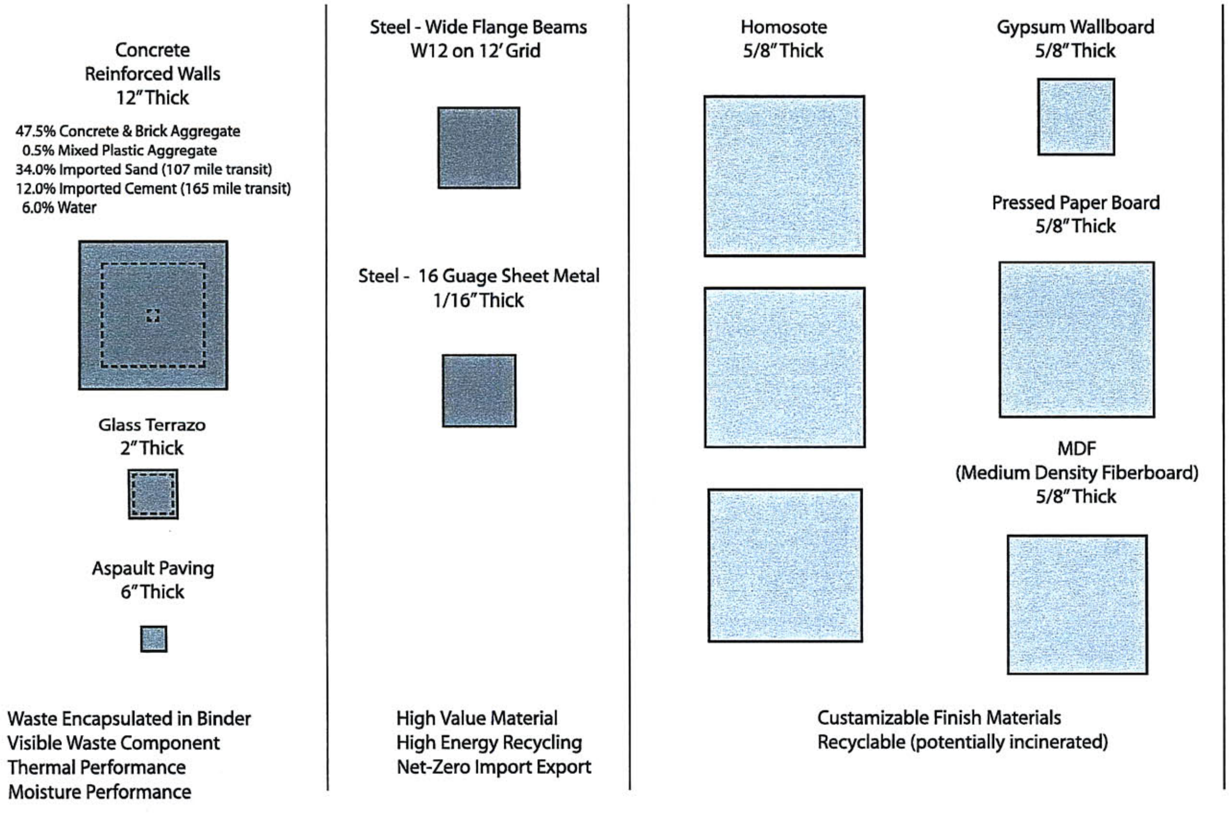
MIT's Role in Resource Consumption
(Fig. 5)

This is a diagram of MIT's role in resource consumption. This diagram represents resource flows with arrows, scaled to represent proportional relationships for similar types of flow. Solid gray and black arrows represent the relative volumes of materials transported into and out of MIT. Vertical dashed arrows represent emissions for each phase of resource consumption as well as the transportation between phases. Outlined arrows represent the energy directly consumed by MIT. Punctuated C&D flows are solid gray. Constant consumer and maintenance flows are solid black. The materials exported from the waste management phase are typically dissipated into global and national reyccling markets. This thesis identified opportunities for locally recycling these exports, which offsets the emissions from typical transportation and supports the local economy. The portion of MIT's waste that gets recycled is linked to the demand for recycled content products. Therefore, supporting the recycling industry will motivate Material Recovery Facilities to separate greater quantities of recyclable materials from MIT's waste stream, allowing MIT to further improve its recycling rate.




Manufacturers, Re-Manufacturers, Distributors & Vendors
Raw Material Extraction & Refining
Post Consumer Paper (Local Supply Chain Not Verified)
Soil & Excavation Waste
MIT
Intense Punctuated Flow
Construction & Demolition
Wholesale Building Materials
Metals
Steel Structures
Steel Hardware
Sheet Metal
Aluminum Frames
Wire
Electronics
Polymers
Plastics
Adhesives
Epoxy Paint/Sealer
Ceramics
Clay Masonry
Concrete
Cement Binders
Tiles
Porcelain Fixtures
Cellulose
Wood
Textiles
Paper
Glass
Windows
Tiles
Composites
Gypsum Wall Board
Carpet
Constant Building Maintenance
Consumer Materials & Equipment
Metals
Cans
Binders
Misc. Hardware
Electronics
Furniture
Polymers
Bottles
Adhesives
Packaging
Ceramics
Misc. Equipment
Cellulose
Paper
Textiles
Furniture
Glass
Misc. Equipment
Laboratory Chemicals
Distilled Chemicals
Solvents
Photochemicals
Constant Consumption
MIT Cogeneration Plant
Emissions Scrubber
Algae obsorbs CO$_2$
(potentiall Biofuel)
Natural Gas
Back-up Electricity
Cambridge Electric
Emissions: Green House Gases, Water Contaminants, Soil Contaminants

Potential Material Yield from One Year of MIT Waste



Long-term, Recyclable Components

Concrete
Reinforced Walls
12" Thick

47.5% Concrete & Brick Aggregate
0.5% Mixed Plastic Aggregate
34.0% Imported Sand (107 mile transit)
12.0% Imported Cement (165 mile transit)
6.0% Water

Glass Terrazo
2" Thick

Aspault Paving
6" Thick

Waste Encapsulated in Binder
Visible Waste Component
Thermal Performance
Moisture Performance

Steel - Wide Flange Beams
W12 on 12' Grid

Steel - 16 Guage Sheet Metal
1/16" Thick

High Value Material
High Energy Recycling
Net-Zero Import Export

Short-term Recyclable Components

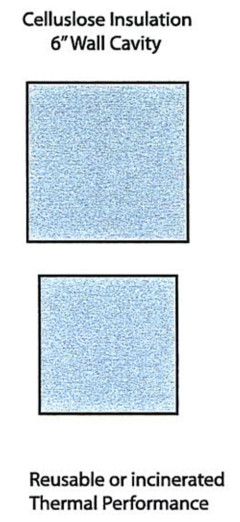
Homosote
5/8" Thick

Gypsum Wallboard
5/8" Thick

Pressed Paper Board
5/8" Thick

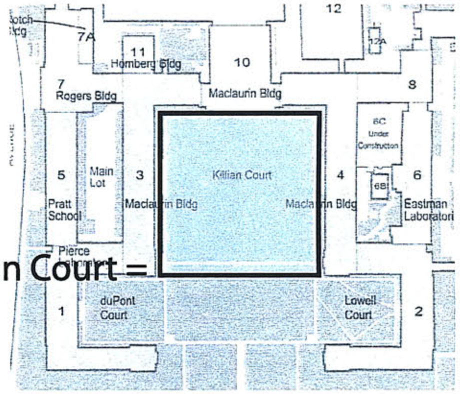
MDF
(Medium Density Fiberboard)
5/8" Thick

Custamizable Finish Materials
Recyclable (potentially incinerated)



Cellulose Insulation
6" Wall Cavity

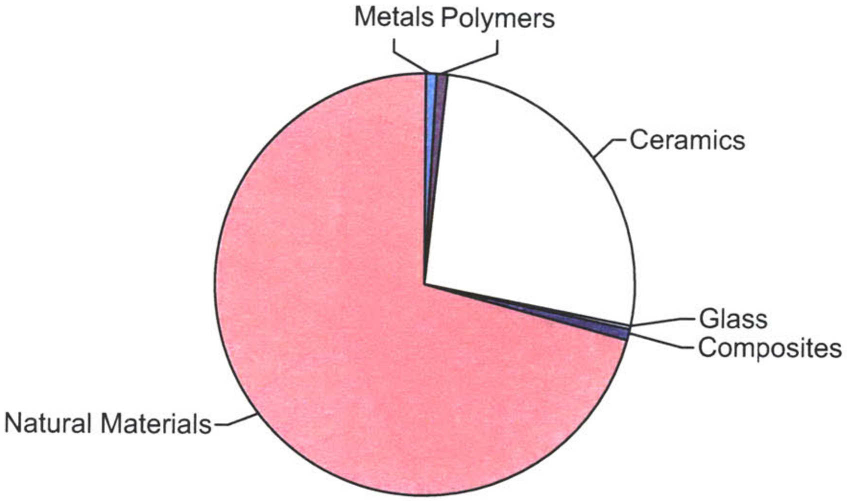
Reusable or incinerated
Thermal Performance



Scale = 1 Hectare = 107,636.76 ft^2 = Killian Court =

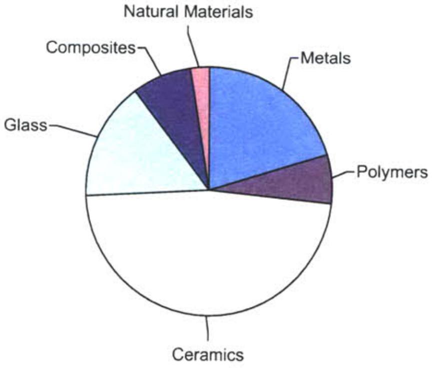
(Fig. 6)

The diagram on the left shows the potential yield from a years worth of recycled MIT waste. The diagram lists a variety of potential building products MIT's waste could end up in. The scale in terms of surface coverage is related to MIT' Killian Court, approximately one hectare. This diagram was useful for establishing the significance of these material flows. The scale of materials is on the magnitude of a building. The chart on the right organizes the same resources into material families, showing the proportional quantities. The major waste streams that can be recycled into buildings turned out to be natural materials (paper products) and ceramics (concrete rubble). The chart below shows the proportional quantities of materials in a contemporary concrete building. There is not one to one relation between these two charts. However, comparing them reveals that the discovered materials require additional sources of glass, polymers and metals to create a material pallet in the proportions of a contemporary concrete building.

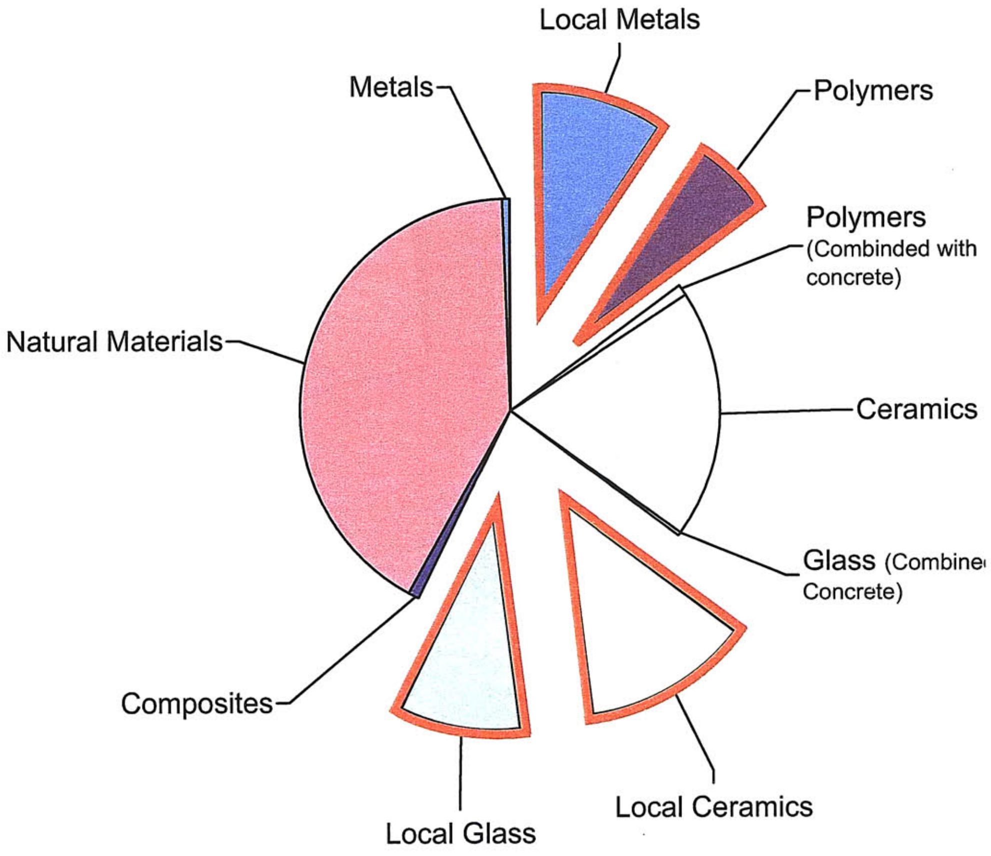


Proportional Chart of MIT Resources

(Fig. 8)



Proportional Chart of Materials used
in a Contemporary Concrete Building (Fig. 7)



Proportional Chart of MIT Resources
With
Additional Resources Found Within 320 Miles of MIT
(Fig. 9)

This final chart of the material audits the proportions of materials with additional materials sourced as close to MIT as possible. By auditing local resources and industries, this thesis highlights unique opportunities for an architect to mobilize sustainable materials for MIT's growth. The following design exercise transforms this knowledge into building strategies responsive to material and energy constraints.

Design Priorities

- Re-appropriate large quantities of materials local to MIT

- Promote a long building lifecycle:
  - Design fixed components for durability and longevity
  - Design adaptable components for recyclability

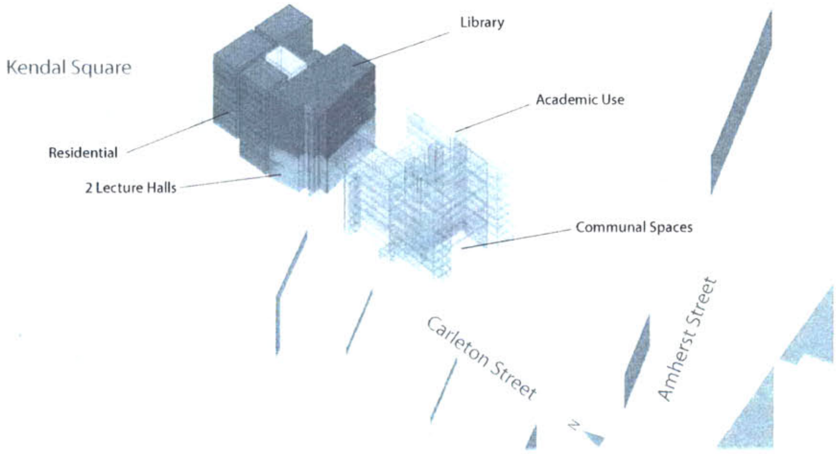
- Meet the emerging standard for green building performance:
  - Promote passive cooling and heating
  - Harness natural daylighting
  - Minimize the builder and occupant's exposure to toxins

A Design Exploration: Strategies for the MIT Campus

While cost has not been the focus of this research, the motivation for returning these resources a building at MIT is driven by the newness of some of these strategies and the need for a large client, such as MIT, to leverage purchasing power to instigate manufacturing of building materials from the designated material flows within the shortest possible distance to the construction site. That distance turned out to be 320 miles for the vast majority of building materials, including mechanical, electrical and plumbing systems.

The design priorities listed to the left frame the subsequent design exploration. Mobilizing the discovered material flows is the first priority. Using the materials to their potential life expectancy is the next priority. The concrete and metal lends themselves to durable systems while the paper based products are destined to be replaced more regularly as the finish degrades. The paper can then be recycled and used elsewhere in the building or another building at MIT.

Long term planning for the MIT campus will likely include a process of infill and renovation. This new building serves to increase the density of MIT's east campus, developing underutilized lots on the edge of a future quad and rehabilitating a condemned structure, MIT building E34.



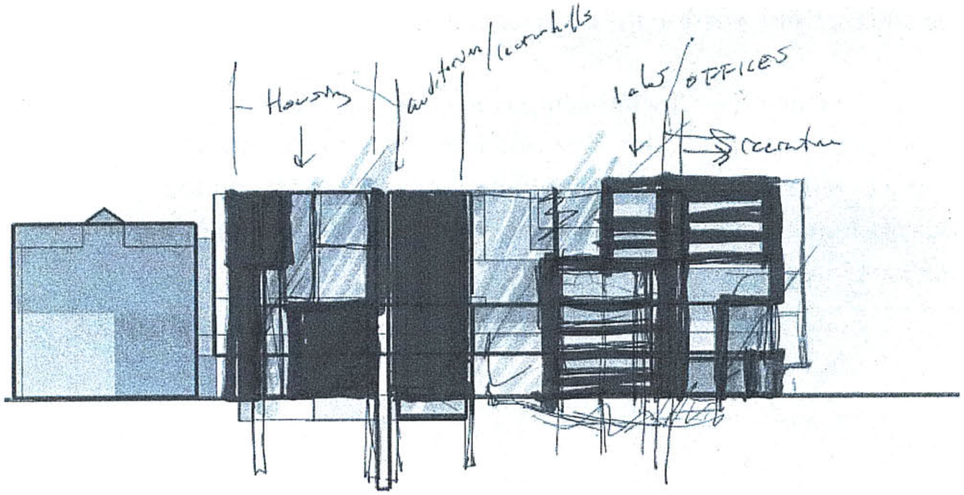
(Fig. 10)

Windows & Daylighting Considerations

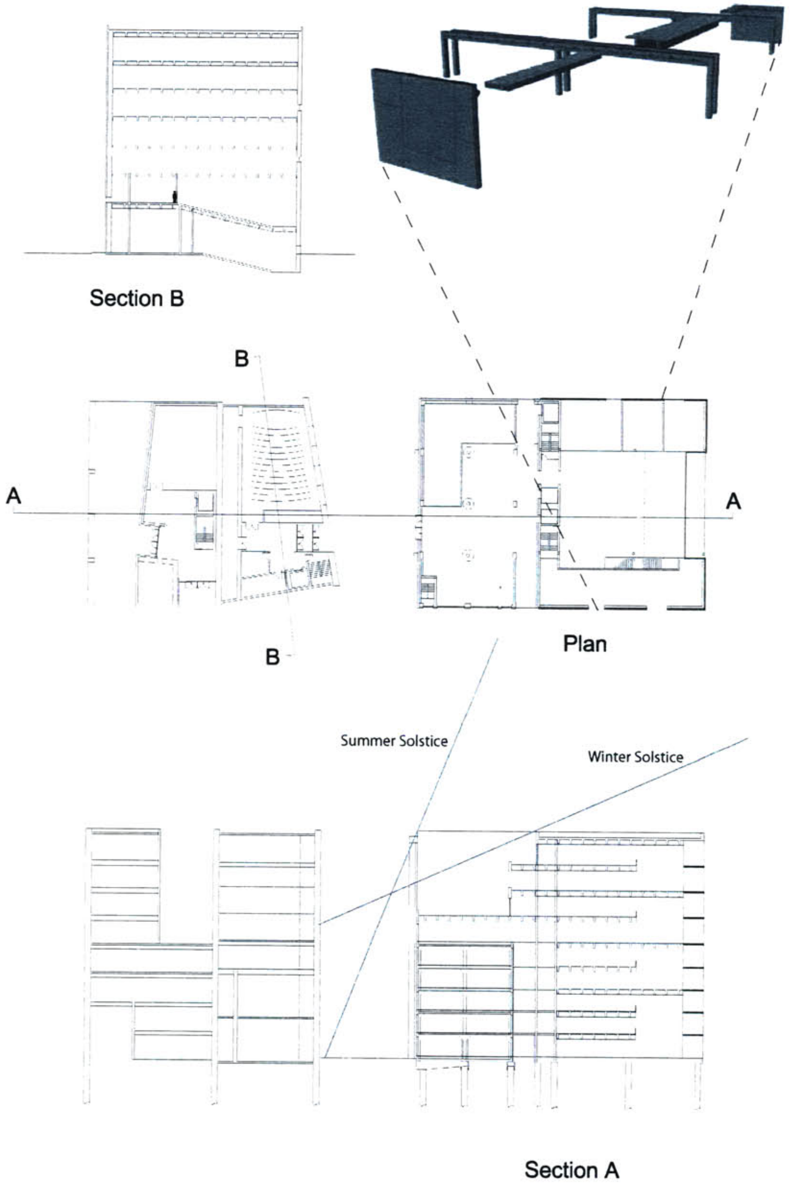
The orientation of the building dictated several strategies for dealing with daylighting. The Southern façade uses large light shelves to block the summer sun but allowing the winter sun to penetrate and heat the concrete. The slender site suggested the need to create large cuts in the building allow daylight to activate spaces deeper in the building. The daylighting strategy did not evolve beyond schematic strategies.

Skylights were avoided for this project. At Boston's latitude (.xx) skylights are detrimental to thermal performance. During the Boston winter, the cold night sky whisks away radiant heat and the daylight is mostly reflected by an acute glazing angle, limiting the potential for solar heat gain. Conversely, the high summer sun faces directly towards the typical skylight, pumping in large quantities of heat that can tax an already burdened cooling system. Additionally, there is a liability for water damage associated with any roof penetration, making skylights a poor strategy for bringing daylight into a building designed to conserve resources.

The research focuses more on strategies for the insulated portions of the building envelope that allow the enormous quantities of paper to be utilized.



Section Looking East(Fig. 11)



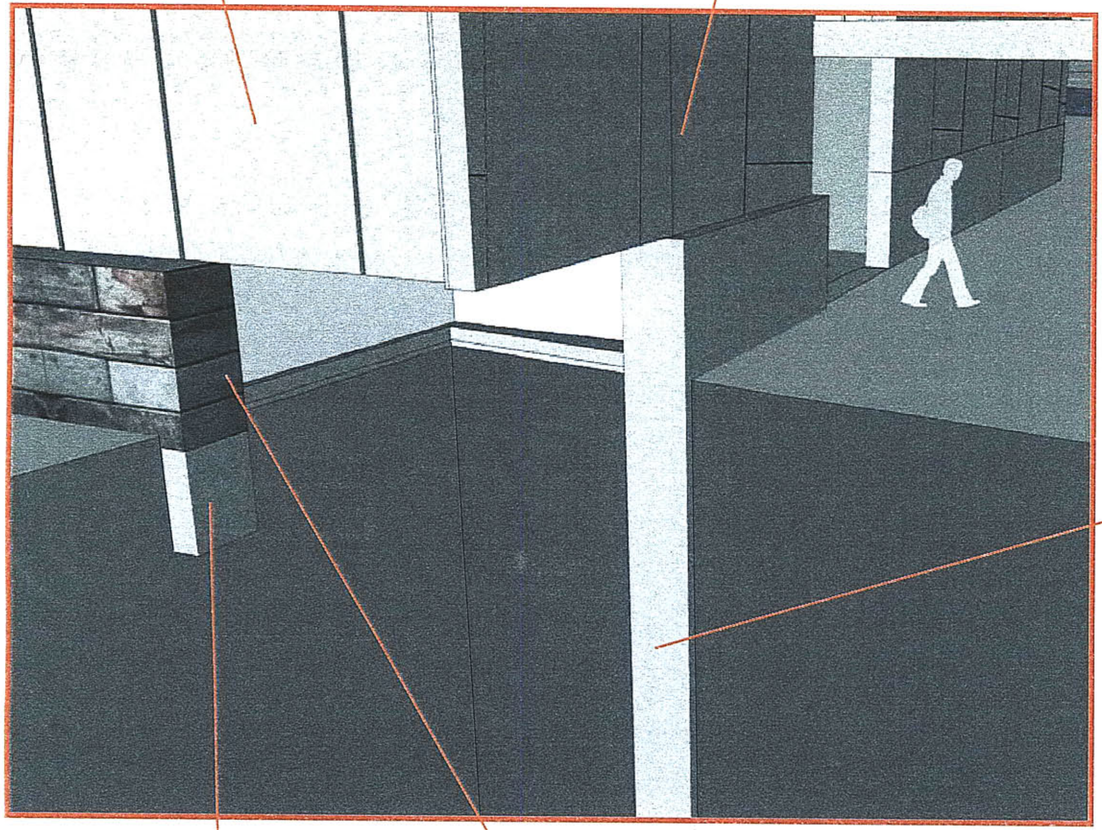
Drawings not to scale (Fig. 12)

Designing for Longevity

Materials have a finite lifespan within buildings. The duration of a material's service life is influenced by a handful of chemical, mechanical, and human factors. Building engineers and material scientists are increasingly able to manage the chemical and mechanical decay, typically learning from previous mistakes and borrowing from the knowledge gained in unrelated fields such as aeronautics or nanotechnology. The human factors are more elusive and fickle. Changes in the perceived value of a building are typically divorced from the physical state of building materials. Real estate valuation entails a subjectivity that can lead to the untimely obsolescence of intact building materials. Sustainable design must partake in developing an appropriately durable or recyclable building to transcend its vulnerability to real estate trends. Even resource intensive components can be sustainably deployed if designed and installed to last 50, 100, or even 500 years with minimal maintenance. The reduced maintenance can offset initial cost premiums for above average durability. Designing a long-life building requires some consideration for adaptable interiors. In this case, all interior finishes are recyclable to allow sustainable adaptations.

Wall Assemblies

The major threat to buildings and component longevity is water. As a vapor, water is mostly harmless to building materials, but as a liquid it can support mold growth, corrode metal, rot wood, leave unsightly stains, and diminish the performance of insulation. Aside from staining, these conditions may start out in small instances, but if the source is left unchecked, the initial damage can further diminish the assembly's resistance to moisture infiltration, thereby escalating the potential for catastrophic damage. The proposal to use massive quantities of cellulose (paper based insulation) in a building requires careful consideration of the potential for water damage. Cellulose is purposefully moistened to a 30% moisture content to facilitate installation. The Cellulose Insulation Manufacturers Association recommends a drying period of no less than two days for freshly applied cellulose. Construction schedules needs to factor this in to minimize the potential risk and liability associated with construction moisture, which is particularly high for cellulose. Computer models that analyze long-term moisture performance offer an invaluable tool for developing an appropriately detailed wall section. WUFI-ORNL is one such design tool that models the interrelated behaviors of heat, air, and moisture for a building assembly in relation to location specific parameters such as climate and solar orientation. This model helps establish key dimensions for the current design endeavor in which the science of building envelopes is intrinsically bound to an architectural proposition. The assembly design became unusually thick to accommodate large volumes of cellulose and manage the associated moisture risks. The overall dimensions of this wall assembly provide a distinct opportunity for windows and doors to become inhabitable spaces.



Building Envelope Type 3

Building Envelope Type 1

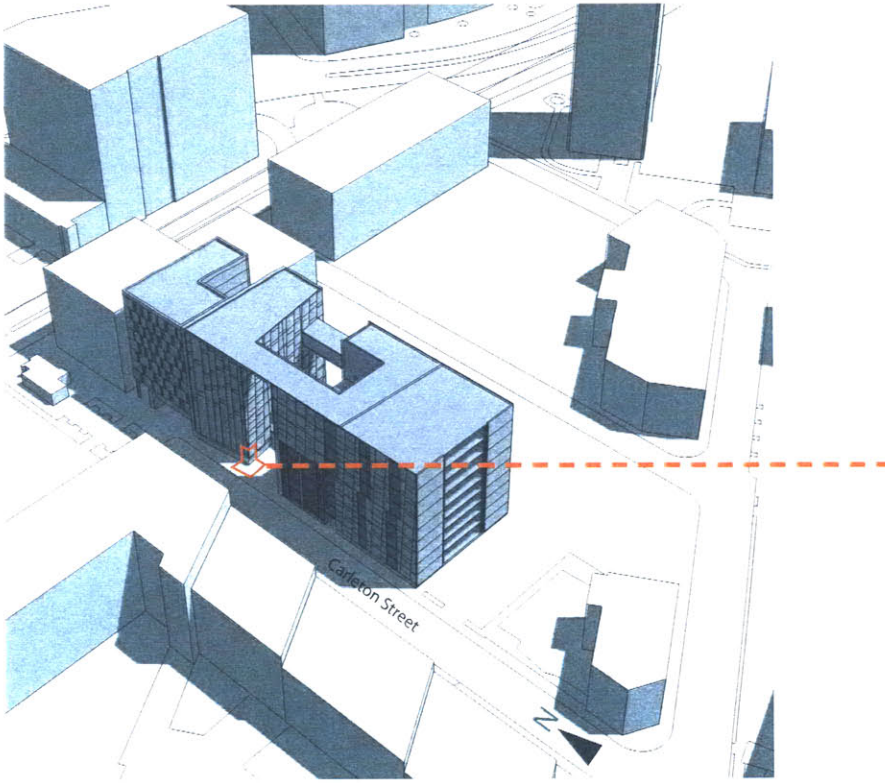
Concrete Foundation
Slurry Wall (Site Cast)
- Concrete
    - *Recycled Aggregate - MIT*
    - Cement - Ravena, NY
    - Fly Ash - Somerset, MA
    - Perlite - Lawrence, MA (Outer Wythe Only)
- Steel Reinforcement
    - *MIT Steel Scraps - US Steel - Clairton, PA*

Concrete Grade Beam (Site Cast)
(Spans between Slurry Walls)

Non-Bearing Blocks - Zero Cement
(Site Cast)
Recycled Aggregate - MIT
Fly Ash - Somerset, MA

Foundation Design

The Foundation design consists of slurry walls and grade beams, to minimize disruption to the existing structure of building E34. The major slurry walls traverse the site from East to West, carrying major load bearing concrete panels or columns. MIT tries to maintain excavation spoils on campus, perhaps to avoid the cost of disposing contaminated soil. Grade beams help establish the edge for floor slabs, minimizing formwork.

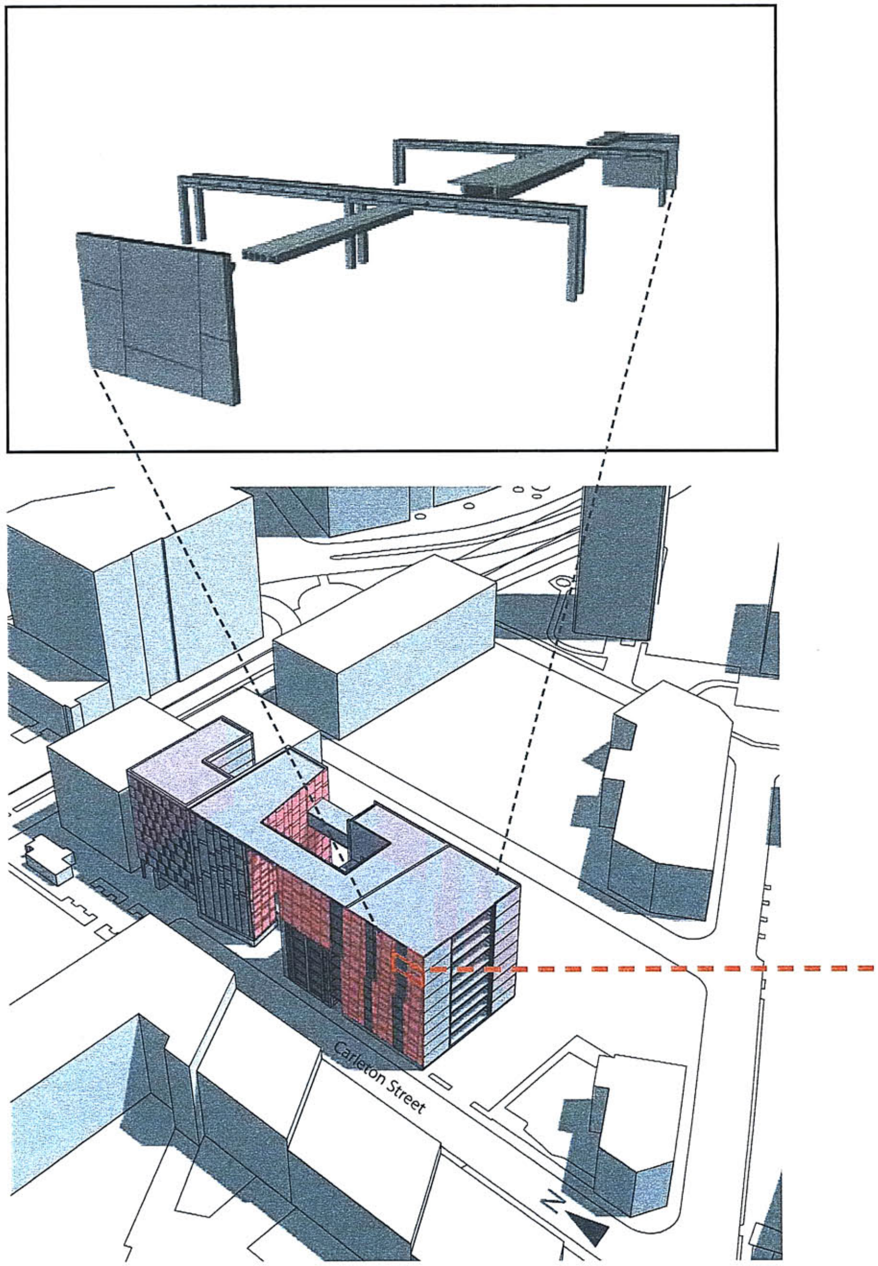


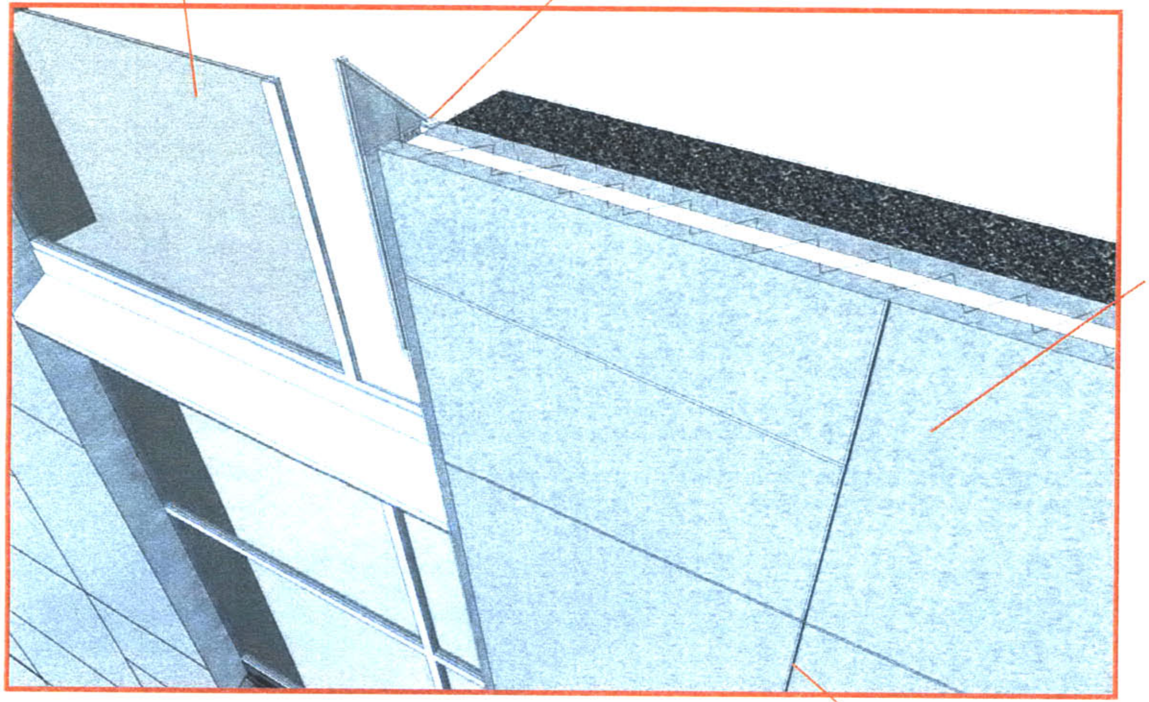
Building Envelope Design

The building envelope acts as the major reservoir for materials and critical to the thermal and moisture performance of the materials. Four strategies were considered that utilize pre-cast concrete to minimize formwork. The following diagrams illustrate the design strategies for the building envelope.

Building Envelope Type 1:

Load Bearing Precast Concrete Sandwich Panel





Low-E Insulated Window Units
Silica - US. Silica - Mauricetown, NJ
Low-E coated Flat Glass - AFG Glass - NJ
Frame - AFG Glass - MA

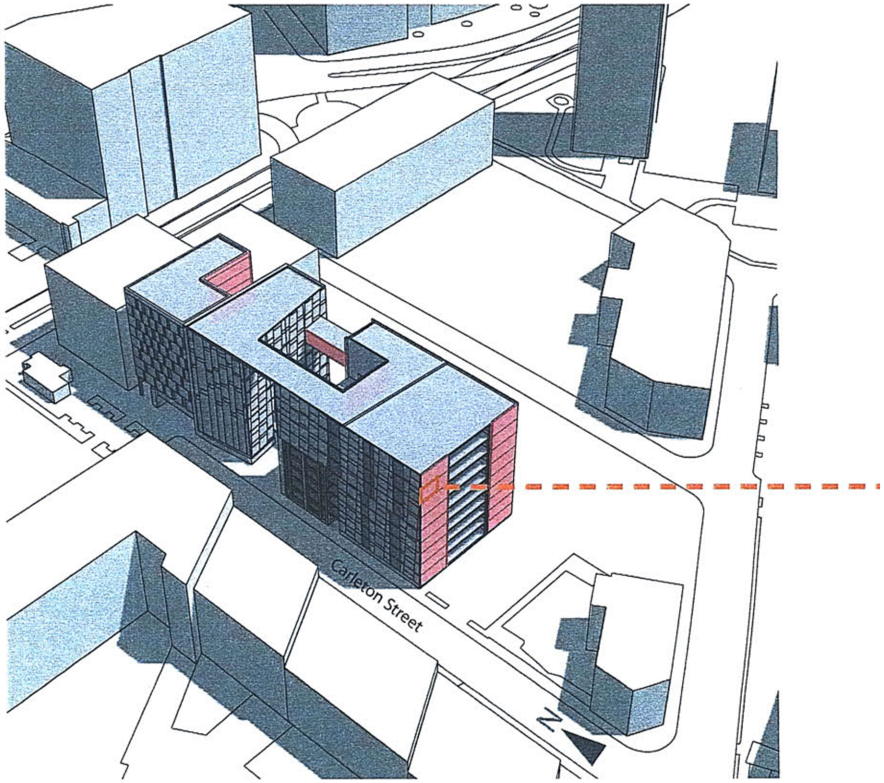
Silicone Weather Seal
GE - Silicones - Waterford, NY

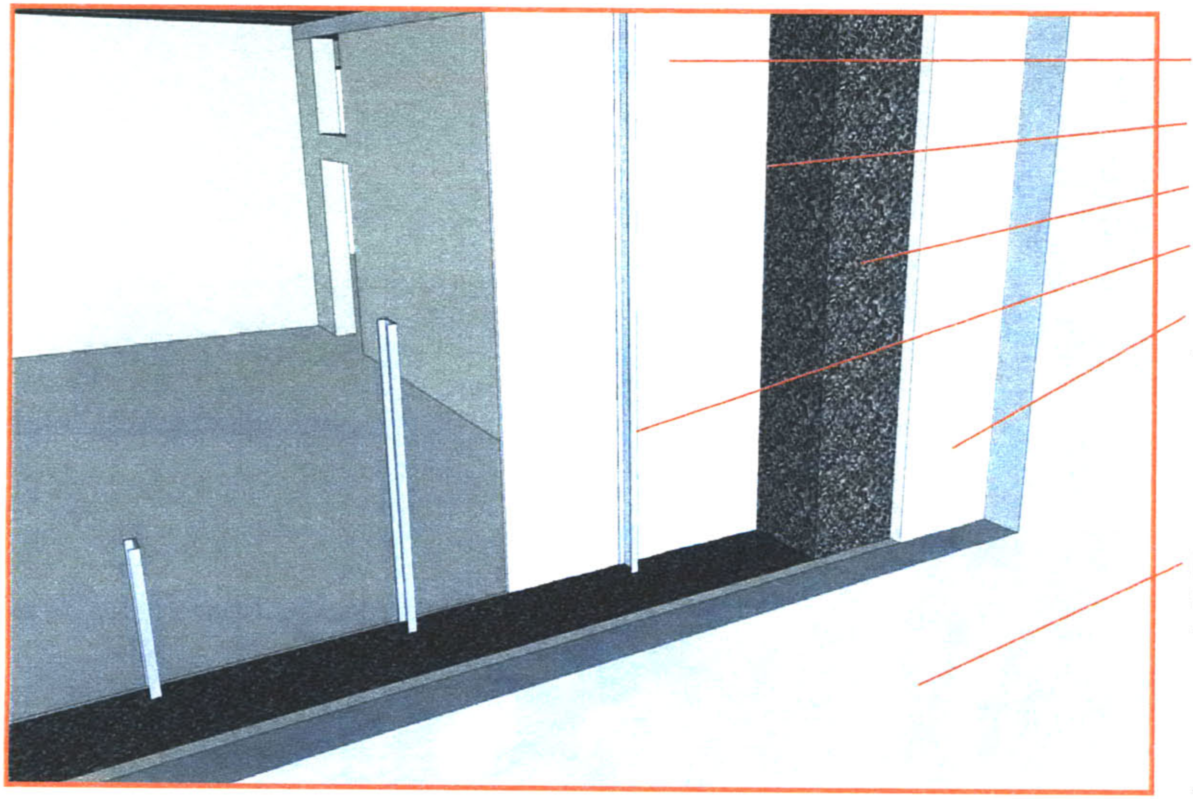
Bearing Precast Sandwich Panels
- Concrete
    - *Recycled Aggregate - MIT*
    - Cement - Ravena, NY
    - Fly Ash - Somerset, MA
    - Perlite - Lawrence, MA (Outer Wythe Only)
    - Curing Compounds - Ridgefield Park, NJ
    - Sealant - North Easton, MA
- Steel Reinforcement
    - *MIT Steel Scraps - US Steel - Clairton, PA*
- Insulation
    - *Recycled Polystyrene - MIT & Boston*
    - Cement binder - Ravena, NY

Diagonally Cast Drainage Groves
(Designed to prevent staining)

Building Envelope Type 2:

Non Bearing Precast Concrete Panel





Homasote
MIT Paper Waste - Homasote Company - Trenton, NJ

Smart Vapor Barrier
Certainteed - Valley Forge, PA

Cellulose Insulation
MIT Paper Waste - Cambridge

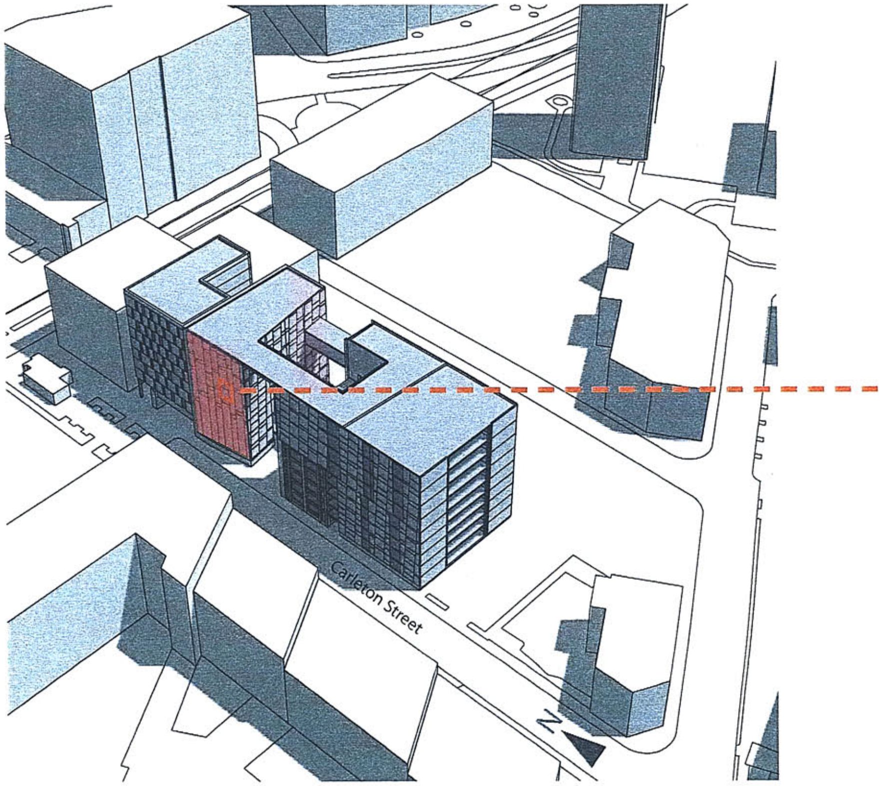
Light Gauge Steel Studs
MIT Steel Scraps - US Steel - Clairton, PA

Polyisocyanrate Insulation
Johns Mansville - Portland, ME

Non Bearing Concrete Panels
(Single Wythe)
- Concrete
    - *Recycled Aggregate - MIT*
    - Cement - Ravena, NY
    - Fly Ash - Somerset, MA
    - Perlite - Lawrence, MA
- Steel Reinforcement
    - *MIT Steel Scraps - US Steel - Clairton, PA*
- Curing Compounds - Ridgefield Park, NJ
- Sealant - North Easton, MA

Building Envelope Type 3:

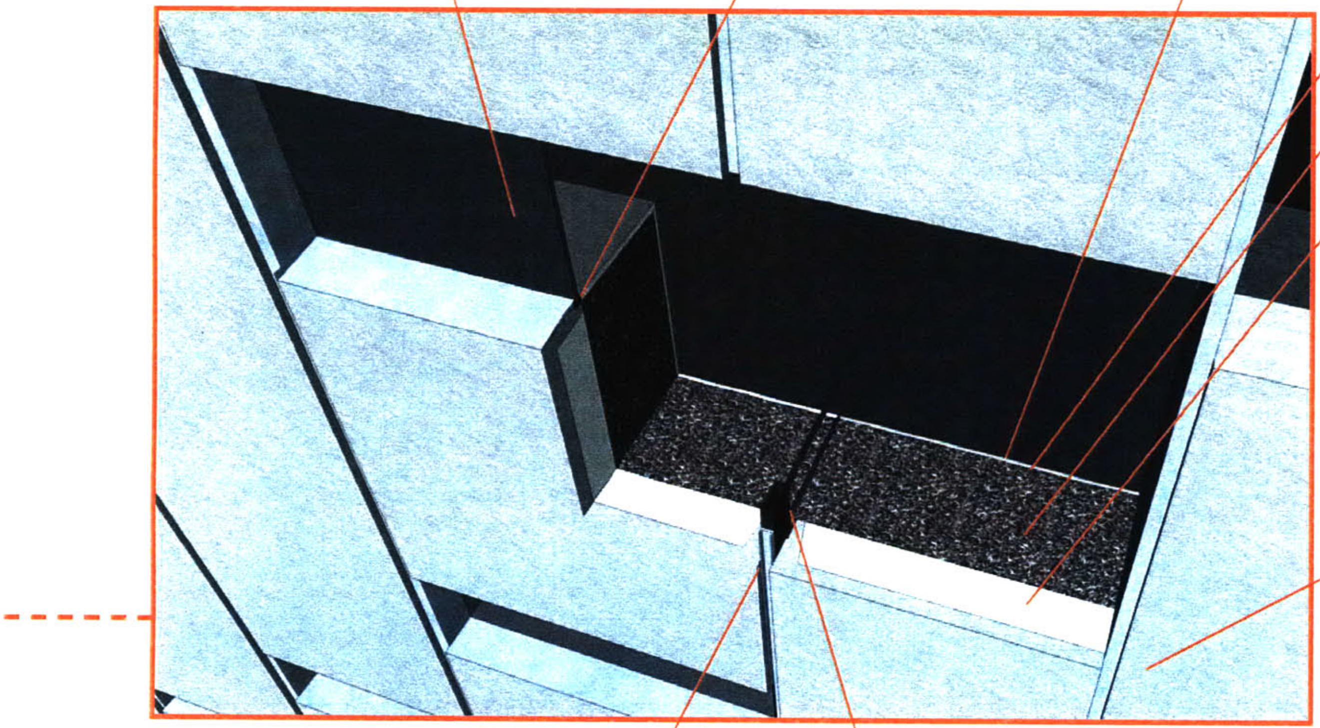
Non Bearing Precast Concrete Panel



Low-E Insulated Window Units
Silica - US. Silica - Mauricetown, NJ
Low-E coated Flat Glass - AFG Glass - NJ
Frame - AFG Glass - MA

Silicone Weather Seal
GE - Silicones - Waterford, NY

Homasote
MIT Paper Waste - Homasote Company - Trenton, NJ



Smart Vapor Barrier
Certainteed - Valley Forge, PA

Cellulose Insulation
MIT Paper Waste - Cambridge

Polyisocyanrate Insulation
Johns Mansville - Portland, ME

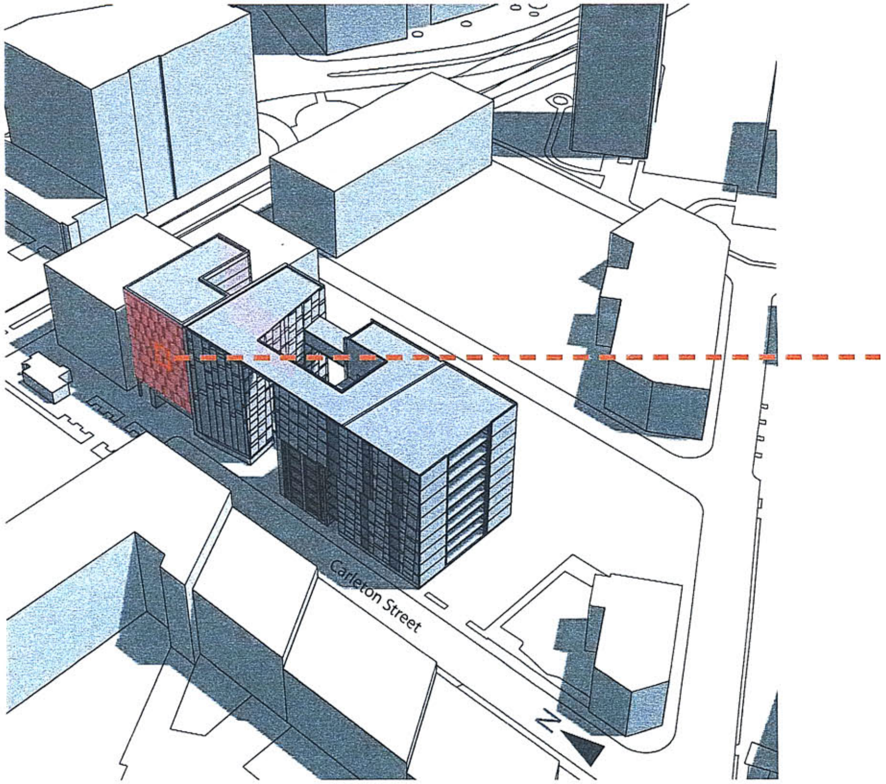
Non Bearing Concrete Panels
(Single Wythe)
- Concrete
    - *Recycled Aggregate - MIT*
    - Cement - Ravena, NY (Lime - Lee, MA)
    - Fly Ash - Somerset, MA
- Steel Reinforcement
    - *MIT Steel Scraps - US Steel - Clairton, PA*
- Curing Compounds - Ridgefield Park, NJ
- Sealant - North Easton, MA

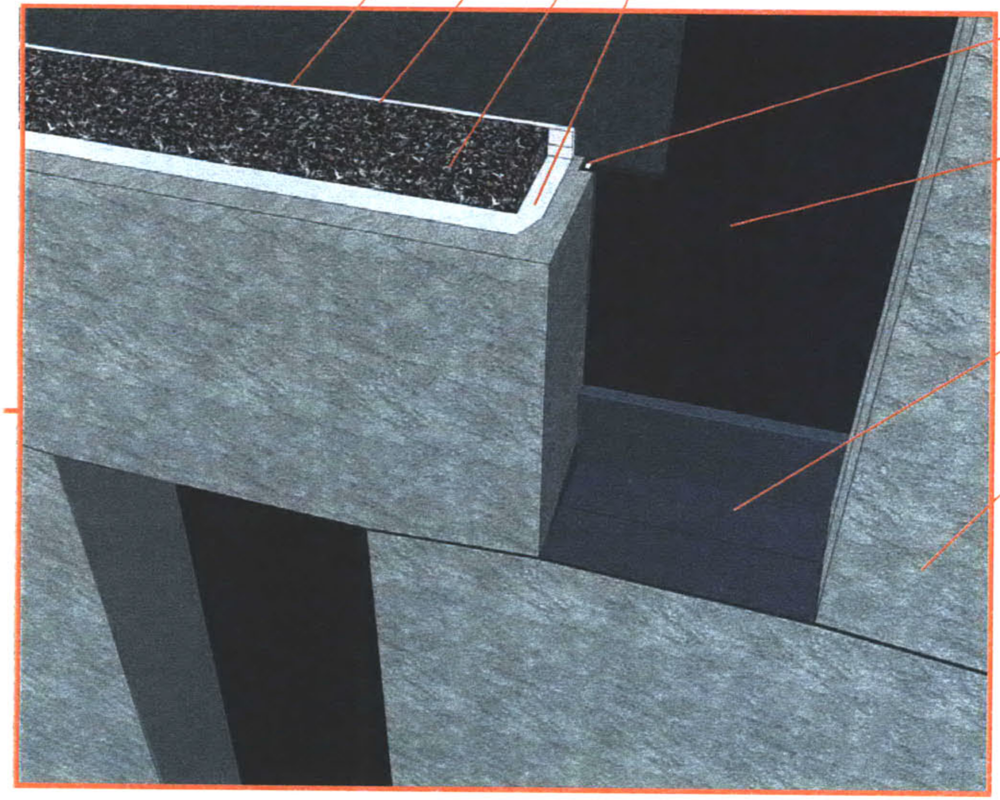
Silicone Weather Seal
GE - Silicones - Waterford, NY

Steel Tube & Threaded Rods
MIT Steel Scraps - US Steel - Clairton, PA

Building Envelope Type 4:

Non Bearing Precast Concrete Panel





Homasote
MIT Paper Waste - Homasote Company - Trenton, NJ

Smart Vapor Barrier
Certainteed - Valley Forge, PA

Cellulose Insulation
MIT Paper Waste - Cambridge

Polyisocyanrate Insulation
Johns Mansville - Portland, ME

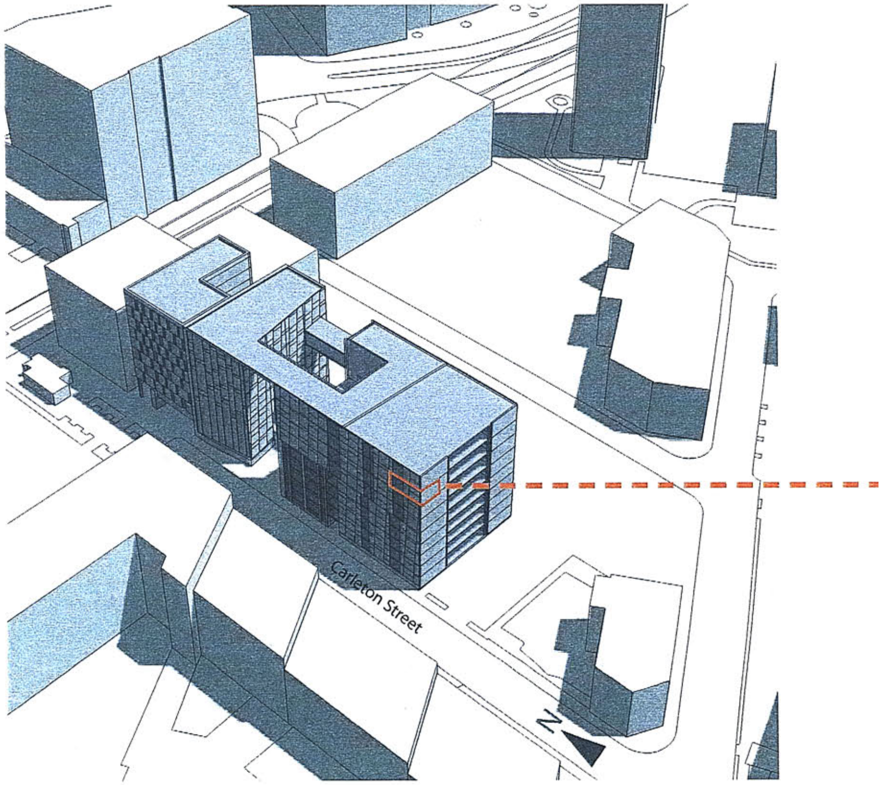
Silicone Weather Seal
GE - Silicones - Waterford, NY

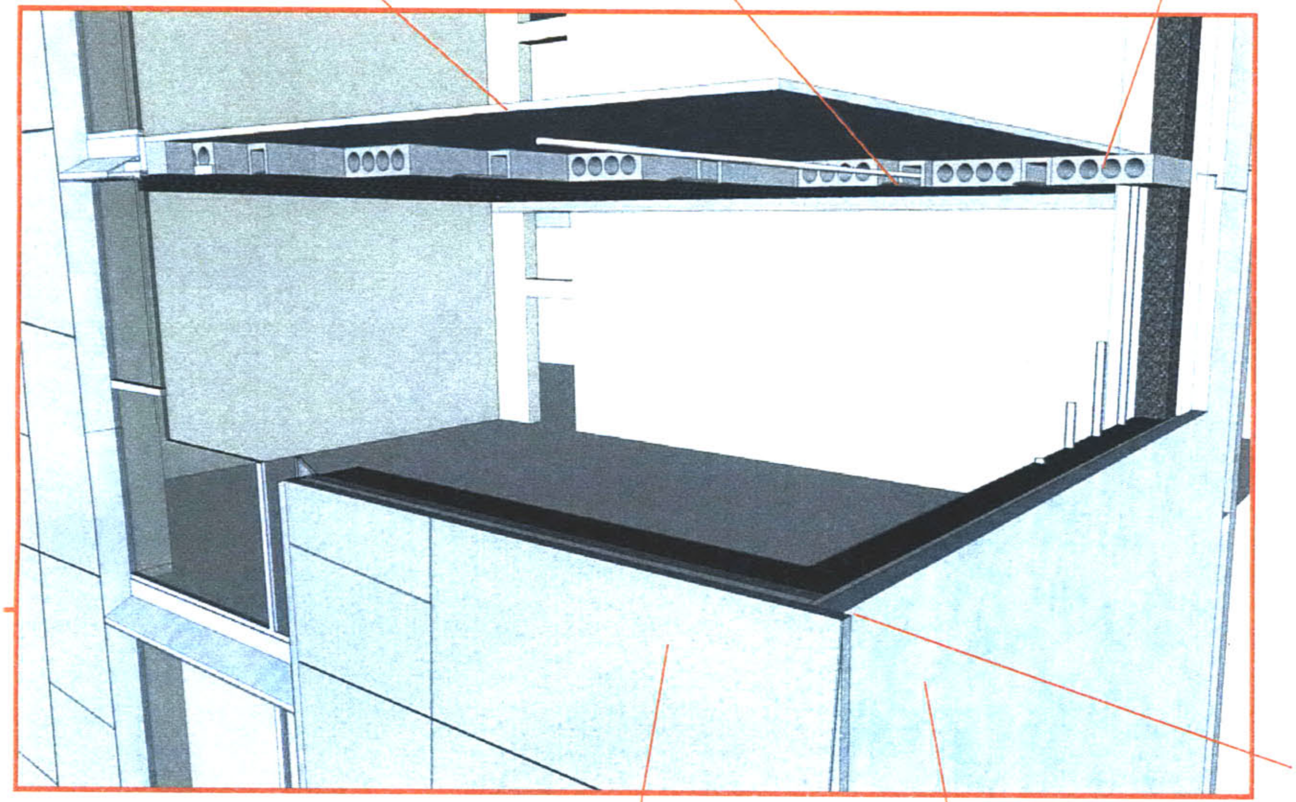
Low-E Insulated Window Units
Silica - US. Silica - Mauricetown, NJ
Low-E coated Flat Glass - AFG Glass - NJ
Frame - AFG Glass - MA

Copper Flashing & Spandrel
MIT Copper Scrap - Revere Copper - New Bedford, MA

Non Bearing Concrete Panels
(Single Wythe)
- Concrete
    - *Recycled Aggregate - MIT*
    - Cement - Ravena, NY
    - Fly Ash - Somerset, MA
    - Perlite - Lawrence, MA
- Steel Reinforcement
    - *MIT Steel Scrap - US Steel - Clairton, PA*
- Curing Compounds - Ridgefield Park, NJ
- Sealant - North Easton, MA

Office Detail Showing Precast Lightweight Structural Concrete Floor System





Terrazo Floor (Site Cast)
Recycled Glass Aggregate - MIT
Cement - Ravena, NY

Fired Rated Homasote
(Accoustic Panel at C-Channels)
MIT Paper Waste - Homasote Company - Trenton, NJ

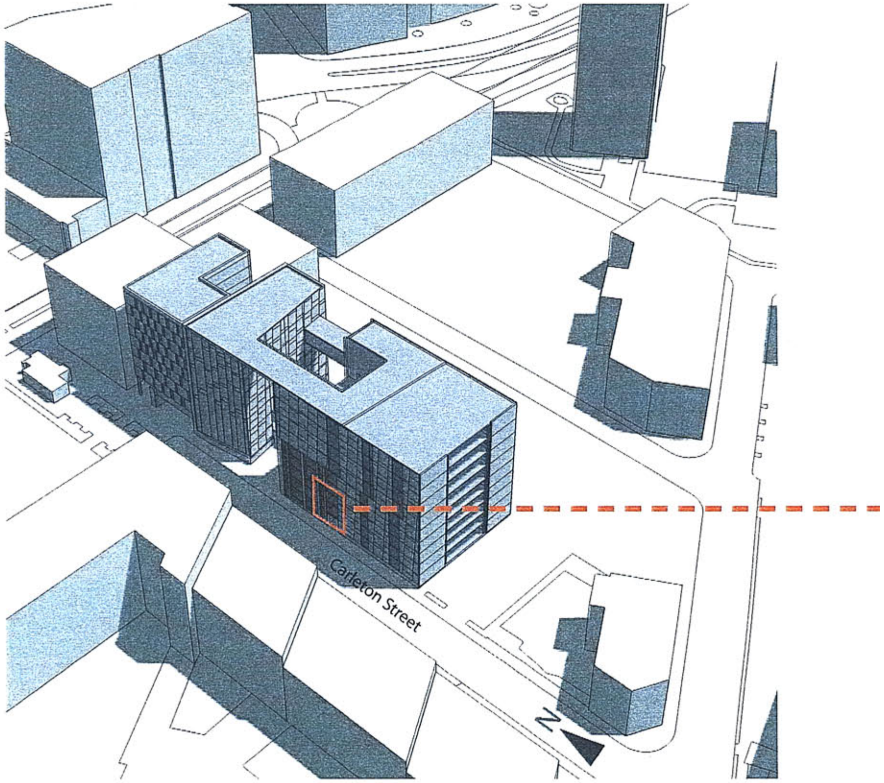
Lightweight Precast FLoor Structure
(Hollow Core & C-Channel Sections)
- Concrete
    - *Recycled Concrete Aggregate - MIT*
    - *Recycled Mixed Plastics - MIT*
    - Cement - Ravena, NY (Lime - Lee, MA)
    - Fly Ash - Somerset, MA
- Curing Compounds - Ridgefield Park, NJ
- Sealant - North Easton, MA

Silicone Rainscreen Weather Seal
GE - Silicones - Waterford, NY

Building Envelope Type 1

Building Envelope Type 2

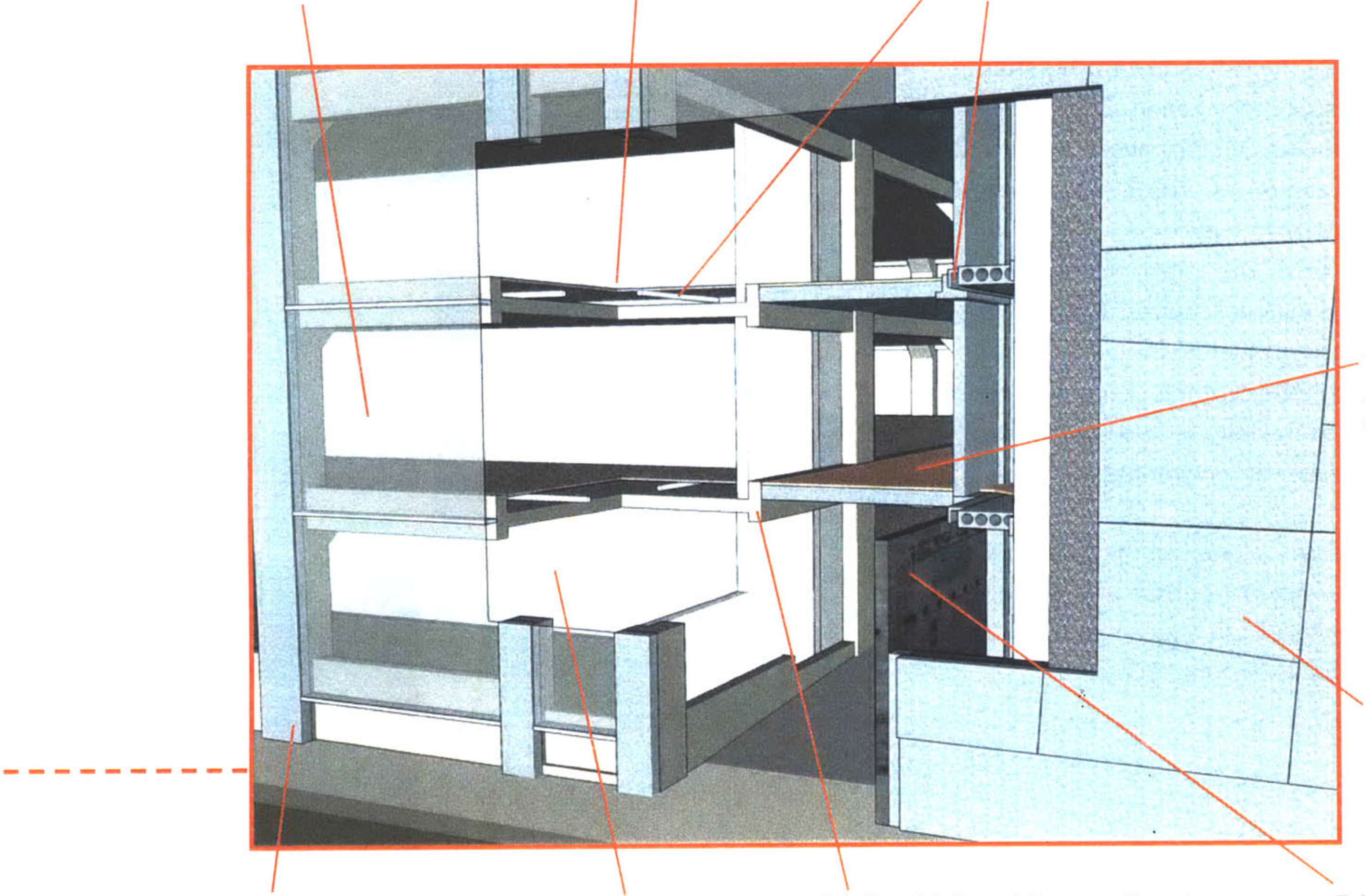
Reuse of Existing Structure (MIT Building E34)



Low-E Insulated Window Units
Silica - US. Silica - Mauricetown, NJ
Low-E coated Flat Glass - AFG Glass - NJ
Frame - AFG Glass - MA

Raised floor
(at existing structure only)

Space for Plumbing and Electrical Conduit



Terrazo Floors (Site Cast)
Recycled Glass Aggregate - MIT
Cement - Ravena, NY

Building Envelope Type 1

New Concrete to support additional floors above existing structure

Homasote
(Interior Finish)
MIT Paper Waste - Homasote Company - Trenton, NJ

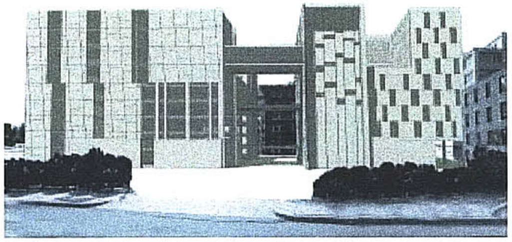
Existing Reinforced Concrete Structure

Existing Masonry Wall

Conclusions

This research illustrates a design process that leverages the architect's role in consumption to mobilize sustainable materials for MIT's growth. The proposed design intensifies the purchase of recycled content products, offering a critical departure from recycling quotas that focus on the supply side of the recycling industry. This research methodology can equally apply to a variety of building typologies as well as clients, including municipalities, federal agencies, universities, and corporate campuses. These entities are able to leverage their purchasing power to overcome a variety of institutional barriers to recycling efforts. The initial process may incur extra costs for management and material choices. However, a premium for sustainable design is not very different from the federal subsidization of virgin material industries, except this client initiated charity is truly democratic and leads to the long term sustainability of the building industry in the face of environmental crisis.

The architect can not facilitate this process alone, but they can offer definitive solutions from the unique material palette of a client's waste burden. Most importantly, architect's can offer a vision and a roadmap for championing this sustainable design process.


Rendering Looking West from Hayward Street


Rendering Looking East from the atruim of the MIT Medical Center


Rendering Looking South from Kendal Square

End Notes

1. The Brookings Institution predicts that half the buildings of 2030 will be built after 2000. (Nelson)

2. John Fernandez, *Material Architecture: Emergent Materials for Innovative Buildings and Ecological Construction,* (Architectural Press, 2006)

3. Marina Fischer-Kowalski, and Walter Huttler, "Society's Metabolism: The Intellectual History of Materials Flow Analysis, Part II 1970-1998." Journal of Industrial Ecology Volume 2, No. 4 (1999)

4. Robert U. Ayres et al., "Is the U.S. Economy Dematerializing? Main Indicators and Derivers" in *Economics of Industrial Ecology.* (Cambridge, MA: MIT Press, 2004)

5. Ibid

6. Kenneth Geiser, "The Economy of Industrial Materials" in *Materials Matter,* (Cambridge, Massachusetts and London England: The MIT Press, 2001)

7. Deconstruction: "Back to the Future for Buildings?" Environmental Building News, May 2000.

8. Pieter J. H. van Beukering, "International Trade, Recycling, and the Environment" in *Economics of Industrial Ecology: Material, Structural Change and Spatial Scales,* MIT Press, 2004

9. MIT invests in tracking LEED ratings of new building projects despite never obtaining a LEED Certification (communications with Milan Pavlinic, Manager of Construction Administration, MIT Department of Facilities)

10. Arpad Horvath, "Construction Materials and the Environment" in *Annual Revue of Environment and Resource*, Palo Alto, Calif. : Annual Reviews, 2004.

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Figure 1– A collage of images from the following sources accessed 5/17/07:
http://www.wales.nhs.uk
http://www.speclightsolutions.com/Products/fixture-images/basegfx.gif
http://www.diversehvac.com/York%20HVAC/HVAC-equipment.jpg
http://img.alibaba.com
http://www.cpsc.gov/
http://www.koetterfire.com
http://www.aymcdonald.com
http://www.acscontrols.net
http://www.envirotec.co.uk
http://www.allproducts.com
http://www.greenspec.co.uk
http://www.insulationsolutions.com
http://www.buildingenvelopeforum.com
http://www.qltx.com/images/workingconstruction1.jpg
http://www.bedfordplastics.com/images/pultrusion-machine.jpg
http://www.quadlock.com/insulated_concrete_forms/floors_tilt-up.htm
http://opkansas.org
Figure 2 – Author
Figure 3 – MIT Department of Facilities website: http://web.mit.edu/facilities/index.html
Figure 4 – Communications with Alana Levine, Recycling, Solid Waste and Moving Supervisor of MIT's Department of Facilities.
Figure 5 – A collage of images from the following sources accessed 4/23.07:
https://alum.mit.edu/postcards/ViewPicture.dyn?id=78&returnLink=%2Fpostcards%2FViewCollection.dyn%3Fid%3D11
http://web.mit.edu/newsoffice/2005/recycling-campus.html
http://www.casella.com/
http://www.davidandgoliathtrust.org/
http://www.industcards.com/wte-usa.htm
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http://www.loe.org/
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http://web.mit.edu/newsoffice/2002/ellenzweig-0612.html
http://www.scienceclarified.com/
http://www.gmigasandflame.com/
http://www.msnbc.msn.com/id/5437079/
"Steel & Coal" - Edward Burtynsky