# Building Debris

by

Joseph Dahmen

BA College of Letters
Wesleyan University 1997

Submitted to the Department of Architecture in partial fulfillment
of the requirements of the degree of
Master of Architecture
at the
Massachusetts Institute of Technology
June 2006


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## Abstract

This thesis relates architectural practices to intelligent use of resources and the reuse of derelict spaces. The initial investigation of rammed earth as a building material is followed by site-specific operations at the courtyard of MIT building N51 and on sites located along a three mile stretch of Interstate 93 in Dorchester.

Thesis Supervisor: Yung Ho Chang
Title: Professor of Architecture

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# 1. INTRODUCTION

## Overview

This thesis investigates four hypotheses relating resource-intelligent construction to site-specificity and the reuse of derelict spaces. The thesis grows out of a rammed earth wall that I built at the courtyard of MIT building N51 (at 275 Massachusetts Avenue) during the summer preceding the thesis. The rammed earth wall replaced an existing broken chain link fence at the back of the courtyard, improving an outdoor space for use by the School of Architecture for arts and fabrication while investigating an environmentally sustainable building method. The initial investigation of rammed earth was followed by the sequential development of three more hypotheses. The four hypotheses are organized here as antecedent, thesis, antithesis and synthesis. They are in large part an attempt to understand and elaborate on issues relating to site-specific building practices and reclamation of abandoned spaces that were raised by earth wall project. The projects investigating the hypotheses are tested in physical terms, as opposed to the speculative means of exploration often employed in architectural theses. This orientation of the thesis means that design is sometimes located in the processes by which the various investigations are carried out, rather than in the formal design of objects themselves. For this reason, the text accompanying the projects in these pages explains the process by which the objects were created. This kind of work, which involves budgets and selling a project, might be thought of as being the other half of architecture, which is rarely addressed in schools of architecture. It seems that schools focus almost exclusively on the design of buildings because this is commonly regarded as the most interesting work of an architect. But my contention is that the business end of architecture, or how projects are financed, is also a potential avenue of design and creativity. Moreover, I contend that this activity at least as important to the survival of the architect professionally as her skill as a designer.

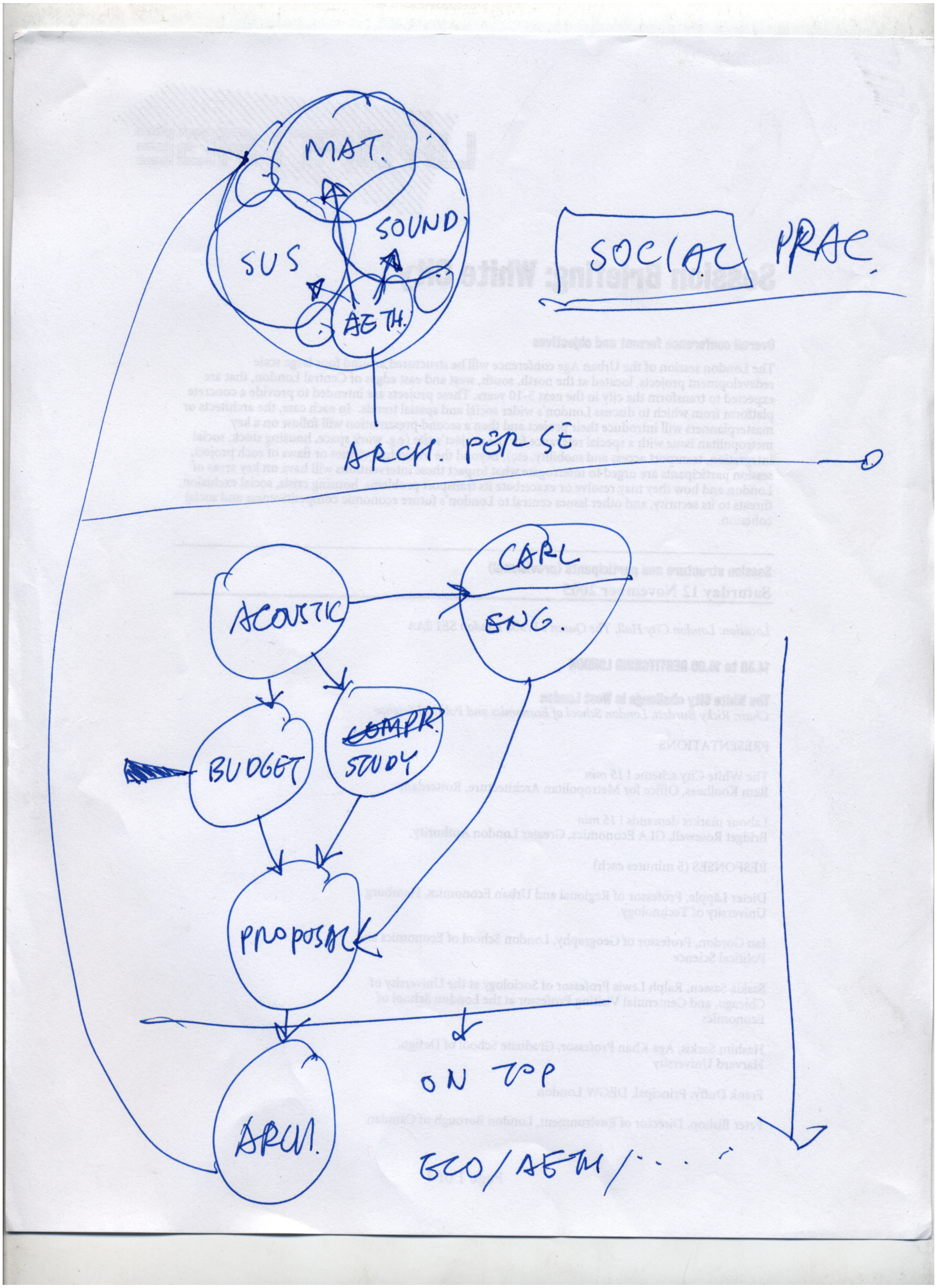
## Site

The projects following the rammed earth wall generally take place on specific sites along a three mile stretch of I93 in Dorchester. I chose these sites for several reasons. The initial objective of the thesis was to carry forward the rammed earth research through the development of a rammed earth sound barrier, and the machinery that its construction would require. The Dorchester neighborhoods along Interstate 93 are characterized by excessive noise generated by the highway. As the project progressed, it became increasingly evident from meetings and conversations with transportation officials that the construction of a rammed earth sound barrier in this location would be out of the question in the near term. By then, however, I had developed an interest in a number of marginal spaces in close proximity to the highway through site investigations conducted in the service of the earlier project. These sites I

refer to as "marginal" for several reasons. They are marginal spaces by definition, due to their location at the edge of the highway. They are also marginal in a conceptual sense, in that their status is undesirable relative to other, more coveted real-estate. The delay encountered in the rammed earth sound barrier project presented the opportunity to acknowledge the presence of these marginal sites as one of the spaces of post-industrial production, rather than attempting to cordon them off by erecting a barrier. The shift from the design of a rammed earth sound barrier to an ad hoc occupation of the marginal spaces through the testing of site-specific practices along the highway represents a desire to engage the sights and sounds of the highway, rather than to wall it off.

The conceptually marginal status of the sites investigated is attested to by their derelict condition. The sites on which the interventions occur were either abandoned, or used informally by marginalized segments of the population, such as homeless people, whose inhabitation of them occurs in an ad hoc manner and is permitted partly because the sites are generally seen as worthless. The lack of control or administration exercised over the sites was another part of the reason that I was drawn toward them. There are few, if any, public spaces where one is able to build permitless ad-hoc structures investigate bounded building operations. The marginal spaces along the highway are one notable exception.

The underlying assumption of the thesis is that the production of these marginal spaces along the highway is characteristic of the post-industrial period in which we currently live. Reclaiming, or at least bringing about a reevaluation of these sites using material found on them could be thought of as a reclamation of a space- resource in much the same way that the rammed earth wall at MIT re purposed a previously derelict courtyard. It is precisely in such cast-off sites, the leftovers from infrastructural activities , that we can see a reflection of the contemporary view toward resources. My hope is that the development of


MAT.
SOUND
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CARL
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ECO/AETH/...

October 17, 2005

**CONTRACT**

Between Yung Ho Chang, Head of Dept. of Architecture, MIT
and
Joe Dahmen, Master of Architecture Candidate 2006, MIT

Yung Ho will be Joe's thesis preparation instructor during the present semester. Maintaining bi-weekly meetings to discuss research for upcoming thesis.

Yung Ho will be Joe's thesis advisor in the spring semester. He will meet with Joe on two week intervals, under the understanding that certain meetings may have to be rescheduled due to travel. Schedule will be agreed upon at the beginning of the semester to avoid scheduling conflicts where possible.

The conceptual basis for the thesis work will be to further develop the themes raised by the rammed earth wall at N51. Work may go significantly beyond the content of the rammed earth wall to investigate other aspects of the relationship of architecture to time and sustainability. Project could also become a further development of those themes as they were expressed in that project.

**Deliverables**
By the end of this semester, Joe will deliver to Yung Ho the following:

Completed rammed earth wall
Documentation of rammed earth wall project
Plazma exhibition of the project
Website for rammed earth project.
Illustrated book outlining research for upcoming Graduate thesis

sketches & rough models of intervention ideas

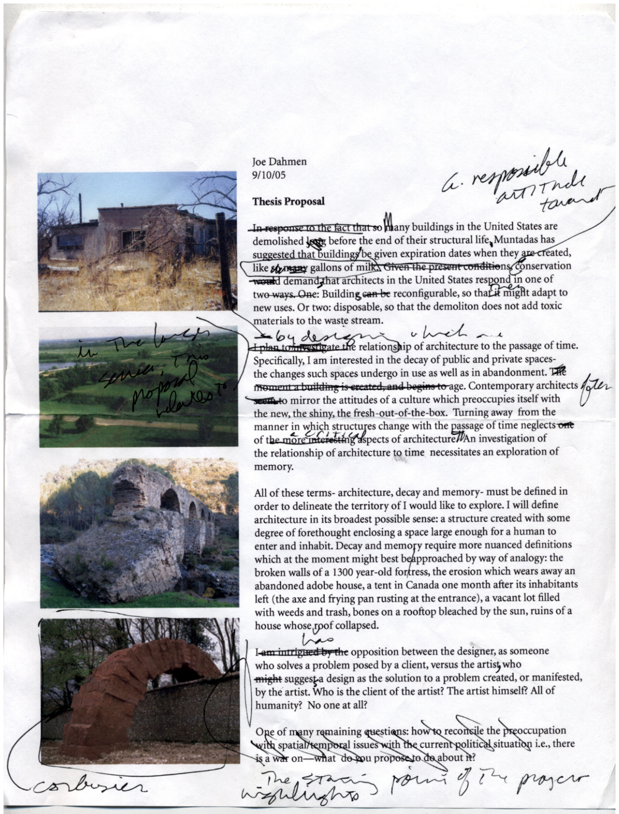
By the end of next semester:

One to Two site-specific structural interventions related to, but not the same as, rammed earth project
Accompanying documentation of these projects.
Rammed earth wall project plus one-two other interventions will be put together in a book in fulfillment of the graduate thesis requirements

Signed,

Yung Ho Chang

Joe Dahmen



Joe Dahmen
9/10/05

**Thesis Proposal**

a responsible attitude toward

~~In response to the fact that so~~ Many buildings in the United States are demolished ~~long~~ before the end of their structural life, Muntadas has suggested that buildings be given expiration dates when they ~~are~~ created, like ~~so many~~ gallons of milk. ~~Given the present conditions~~, conservation ~~would~~ demands that architects in the United States respond in one of two ~~ways. One~~: Buildings ~~can be~~ reconfigurable, so that ~~it~~ they might adapt to new uses. Or two: disposable, so that the demoliton does not add toxic materials to the waste stream.

by designing which are

~~I plan to investigate~~ the relationship of architecture to the passage of time. Specifically, I am interested in the decay of public and private spaces- the changes such spaces undergo in use as well as in abandonment. ~~The moment a building is created, and begins to~~ age. Contemporary architects often ~~seem to~~ mirror the attitudes of a culture which preoccupies itself with the new, the shiny, the fresh-out-of-the-box. Turning away from the manner in which structures change with the passage of time neglects ~~one~~ of ~~the more interesting~~ a critical aspects of architecture. An investigation of the relationship of architecture to time necessitates an exploration of memory.

All of these terms- architecture, decay and memory- must be defined in order to delineate the territory of I would like to explore. I will define architecture in its broadest possible sense: a structure created with some degree of forethought enclosing a space large enough for a human to enter and inhabit. Decay and memory require more nuanced definitions which at the moment might best beapproached by way of analogy: the broken walls of a 1300 year-old fortress, the erosion which wears away an abandoned adobe house, a tent in Canada one month after its inhabitants left (the axe and frying pan rusting at the entrance), a vacant lot filled with weeds and trash, bones on a rooftop bleached by the sun, ruins of a house whose roof collapsed.

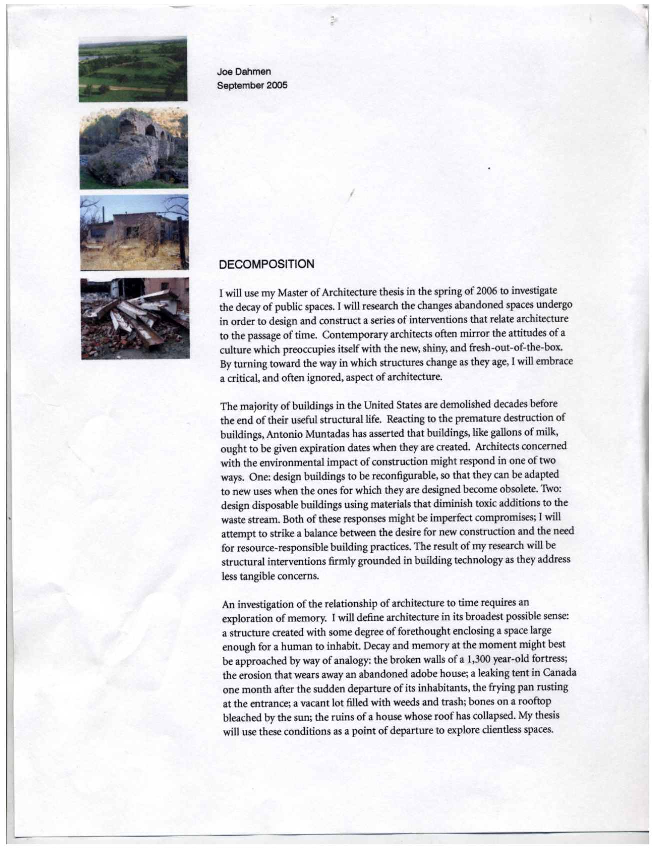
has

I ~~am intrigued by the~~ opposition between the designer, as someone who solves a problem posed by a client, versus the artist, who ~~might~~ suggests a design as the solution to a problem created, or manifested, by the artist. Who is the client of the artist? The artist himself? All of humanity? No one at all?

~~One of many remaining questions: how to reconcile the preoccupation with spatial/temporal issues with the current political situation i.e., there is a war on—what do you propose to do about it?~~

The starting point of the project highlights

corbusier



Joe Dahmen
September 2005

DECOMPOSITION

I will use my Master of Architecture thesis in the spring of 2006 to investigate the decay of public spaces. I will research the changes abandoned spaces undergo in order to design and construct a series of interventions that relate architecture to the passage of time. Contemporary architects often mirror the attitudes of a culture which preoccupies itself with the new, shiny, and fresh-out-of-the-box. By turning toward the way in which structures change as they age, I will embrace a critical, and often ignored, aspect of architecture.

The majority of buildings in the United States are demolished decades before the end of their useful structural life. Reacting to the premature destruction of buildings, Antonio Muntadas has asserted that buildings, like gallons of milk, ought to be given expiration dates when they are created. Architects concerned with the environmental impact of construction might respond in one of two ways. One: design buildings to be reconfigurable, so that they can be adapted to new uses when the ones for which they are designed become obsolete. Two: design disposable buildings using materials that diminish toxic additions to the waste stream. Both of these responses might be imperfect compromises; I will attempt to strike a balance between the desire for new construction and the need for resource-responsible building practices. The result of my research will be structural interventions firmly grounded in building technology as they address less tangible concerns.

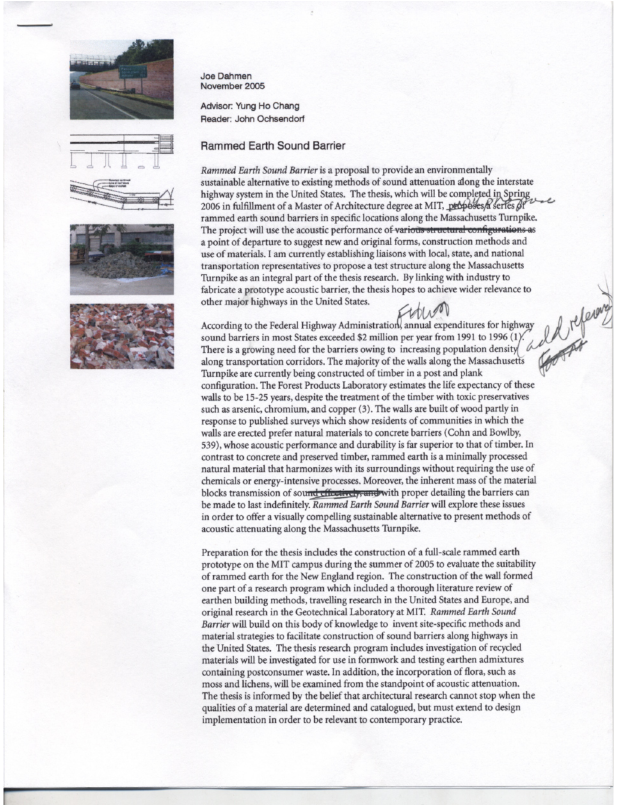
An investigation of the relationship of architecture to time requires an exploration of memory. I will define architecture in its broadest possible sense: a structure created with some degree of forethought enclosing a space large enough for a human to inhabit. Decay and memory at the moment might best be approached by way of analogy: the broken walls of a 1,300 year-old fortress; the erosion that wears away an abandoned adobe house; a leaking tent in Canada one month after the sudden departure of its inhabitants, the frying pan rusting at the entrance; a vacant lot filled with weeds and trash; bones on a rooftop bleached by the sun; the ruins of a house whose roof has collapsed. My thesis will use these conditions as a point of departure to explore clientless spaces.

ad-hoc architectural installations investigating resource use in these marginal spaces will function in a dual manner: a commentary on our use of space as well as the use of other resources in the construction processes.

## Four Hypotheses

The four hypotheses investigated are as follows
***1: Antecedent***
*Hypothesis*
Rammed earth can be used as an energy-efficient alternative to concrete in New England.
*Investigation*
Conducted material research and constructed a test wall at MIT enclosing the courtyard of building N51 during the spring and summer of 2005.
*Conclusion*
Initial hypothesis is correct, with a caveat: although site soils in Southern New England requires the addition of a binder because natural clay content is insufficient. Augmenting soils with material imported to the site will prove important later.

***2: Thesis***
*Hypothesis*
Rammed earth must be standardized for widespread use.
*Investigation*
This portion of the thesis involved the development of a proposal for 1560' long rammed earth sound barrier along I93 in Dorchester. It included conceptual and physical modeling of mechanization strategy and form, and meetings with civil engineers and other officials of Massachusetts Department of Transportation (MassHighways) and Federal Highway Administration to discuss rammed earth sound barriers.
*Conclusion*
The initial hypothesis, which claimed that rammed earth must be standardized for widespread use, was valid, but working toward the standardization revealed that time efficiency and resource efficiency are often inversely proportional to each other. This led to the third hypothesis, which compares these two sometimes antithetical forms of efficiency.



Joe Dahmen
November 2005

Advisor: Yung Ho Chang
Reader: John Ochsendorf

Rammed Earth Sound Barrier

*Rammed Earth Sound Barrier* is a proposal to provide an environmentally sustainable alternative to existing methods of sound attenuation along the interstate highway system in the United States. The thesis, which will be completed in Spring 2006 in fulfillment of a Master of Architecture degree at MIT, ~~proposes~~ a series of rammed earth sound barriers in specific locations along the Massachusetts Turnpike. The project will use the acoustic performance of ~~various structural configurations as~~ a point of departure to suggest new and original forms, construction methods and use of materials. I am currently establishing liaisons with local, state, and national transportation representatives to propose a test structure along the Massachusetts Turnpike as an integral part of the thesis research. By linking with industry to fabricate a prototype acoustic barrier, the thesis hopes to achieve wider relevance to other major highways in the United States.

According to the Federal Highway Administration, annual expenditures for highway sound barriers in most States exceeded $2 million per year from 1991 to 1996 (1). There is a growing need for the barriers owing to increasing population density along transportation corridors. The majority of the walls along the Massachusetts Turnpike are currently being constructed of timber in a post and plank configuration. The Forest Products Laboratory estimates the life expectancy of these walls to be 15-25 years, despite the treatment of the timber with toxic preservatives such as arsenic, chromium, and copper (3). The walls are built of wood partly in response to published surveys which show residents of communities in which the walls are erected prefer natural materials to concrete barriers (Cohn and Bowlby, 539), whose acoustic performance and durability is far superior to that of timber. In contrast to concrete and preserved timber, rammed earth is a minimally processed natural material that harmonizes with its surroundings without requiring the use of chemicals or energy-intensive processes. Moreover, the inherent mass of the material blocks transmission of so~~und effectively, and~~ with proper detailing the barriers can be made to last indefinitely. *Rammed Earth Sound Barrier* will explore these issues in order to offer a visually compelling sustainable alternative to present methods of acoustic attenuating along the Massachusetts Turnpike.

add reference

Preparation for the thesis includes the construction of a full-scale rammed earth prototype on the MIT campus during the summer of 2005 to evaluate the suitability of rammed earth for the New England region. The construction of the wall formed one part of a research program which included a thorough literature review of earthen building methods, travelling research in the United States and Europe, and original research in the Geotechnical Laboratory at MIT. *Rammed Earth Sound Barrier* will build on this body of knowledge to invent site-specific methods and material strategies to facilitate construction of sound barriers along highways in the United States. The thesis research program includes investigation of recycled materials will be investigated for use in formwork and testing earthen admixtures containing postconsumer waste. In addition, the incorporation of flora, such as moss and lichens, will be examined from the standpoint of acoustic attenuation. The thesis is informed by the belief that architectural research cannot stop when the qualities of a material are determined and catalogued, but must extend to design implementation in order to be relevant to contemporary practice.

Joe Dahmen
September 2005

Rammed Earth Sound Barrier

I will use my MIT Master of Architecture thesis in the Spring of 2006 to develop an environmentally sustainable alternative to existing methods of sound attenuation along the Interstate Highway system. *Rammed Earth Sound Barrier* will propose a series of sound barriers constructed of rammed earth along the Massachusetts Turnpike. The project will begin with the form of the barriers, and extend to the acoustic performance of the rammed earth, as well as methods of fabrication. More than theoretical exercise, the project intends to establish a program with the Massachusetts Department of Transportation to erect test structures on site as an integral part of the thesis research. By designing and constructing environmentally sustainable solutions for specific sites along the Massachusetts Turnpike, it is hoped that the project will offer similar solutions for other major highways in the United States.

The need for sound barriers is growing as communities expand and population density increases along transportation corridors. By the end of 2005, the Massachusetts Turnpike Authority will have built _ feet of sound attenuation barriers along the Massachusetts Turnpike. There are plans to build _ more in the next _ years. The budget for these measures is _ . The majority of the walls will be constructed of timber in a post and plank configuration. According to the National Forest Products Laboratory, the life expectancy of these structures is 15-25 years, despite the treatment of the timber with toxic preservatives such as chromium and arsenic. The walls are built of wood partly in response to published surveys which show residents of communities in which the walls are erected prefer natural materials to concrete barriers, whose acoustic performance and durability is far superior to that of timber. In contrast to concrete and preserved timber, rammed earth is a minimally processed natural material that harmonizes with its surroundings without requiring the use of chemicals. Moreover, the inherent mass of the material blocks transmission of sound effectively. *Rammed Earth Sound Barrier* proposes to build a test wall along the Turnpike to evaluate its use in this capacity.

*Rammed Earth Sound Barrier* will invent site specific methods and material strategies to facilitate construction of the new barriers. Recyled materials will be investigated for use in formwork and earthen admixtures containing postconsumer waste will be tested. In addition, the incorporation of flora, such as moss and lichens, will be studied for acoustic attenuation. Preparation for this thesis includes the construction of a full-scale rammed earth prototype on the MIT campus. The purpose of the prototype was to evaluate the suitability of rammed earth for the region. In addition to a thorough literature review, the project followed testing in the geotechnical laboratory at MIT and extensive travelling research. The suitability of rammed earth for this application is supported by the test wall at MIT as well as first-hand observation of rammed earth projects in a variety of climates in Europe and the United States.

***3: Antithesis***

*Hypothesis*

The most materially-efficient approach is bounded by the site.

*Investigation*

The principal means of investigation for this section was the creation of five building blocks based exclusively on materials that were found on particular sites. These activities introduced the "bounded operation" in which the activities and materials were wholly circumscribed by a specific location, utilizing no off site material processing, or introduction of outside materials. The blocks created are small in scale, generally measuring no larger than two feet by three feet and formally simple, due to the constraints of the process.

*Conclusion*

The initial hypothesis was proven true, although the limitations of building on a particular site only with the material found there limits the expressive potential of such activity severely. Where a reevaluation of marginal sites is desired, such a reevaluation requires more than the site materials alone can offer.This leads to the fourth hypothesis, which considers a site as both a source of materials, as well as a material in its own right.

***4: Synthesis***

*Hypothesis*

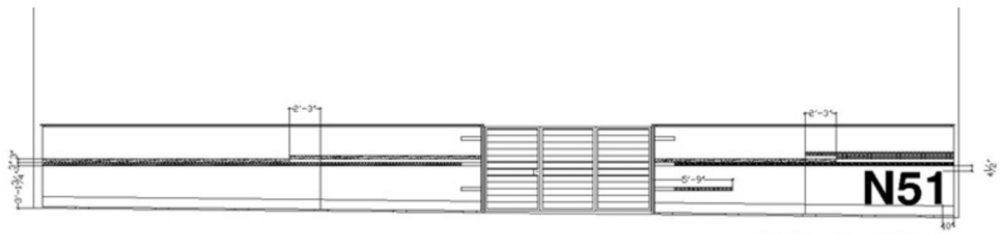
Reevaluating marginal sites requires a hybrid approach in which the binder is imported.

*Investigation*

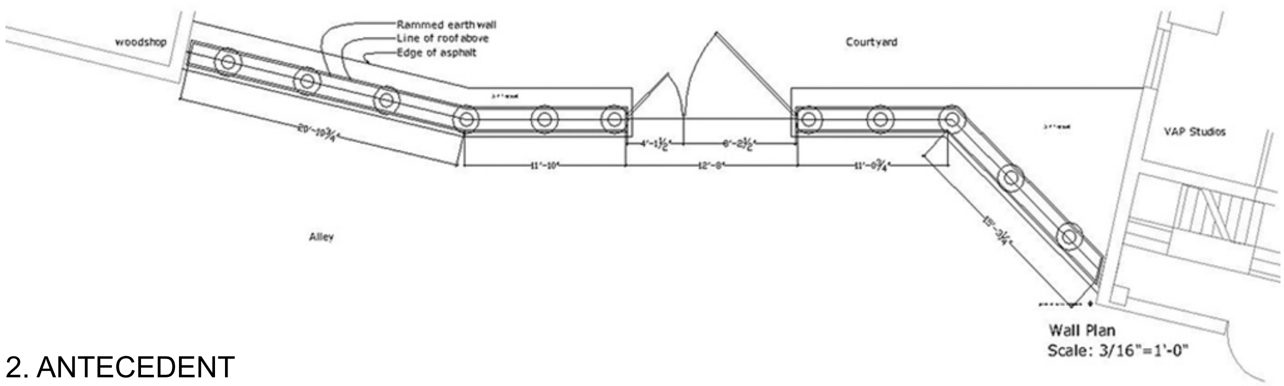
The form that the investigation took was the occupation of three marginal sites along Interstate 93 in Dorchester, close to the original site of the rammed earth sound barrier proposed in the second section. The occupation was built with minimal means, using my car as formwork.

*Conclusion*

Hypothesis is true but the site must be considered as both a source of material as well as material in its own right




Wall Elevation: Soil types
Scale: 3/16"=1'-0"




Wall Plan
Scale: 3/16"=1'-0"

## 2. ANTECEDENT

### BUILDING A RAMMED EARTH WALL AT MIT

Location: N51 Courtyard
Dimensions: 70'x6'x1.5'
Materials: Wall: engineered soil mix (Boston blue clay, sand, ¾ inch gravel, reinforced concrete foundation, weathering steel cap. Gate: salvage tropical hardwood, weathering steel, stainless steel screws and hinges. Formwork: Dimensional lumber, plywood, cardboard tubes, clamps, screws.
Tools: gasoline mixer, diesel compressor, hydraulic loader, pneumatic rammer, hand tools
Distance driven: 2170 miles
Electricity used: 94kWh
$CO_2$ emitted in construction: 5,400lbs

Assumptions
Rammed earth = .7 MJ/kg
Sitecast Concrete= 1.3MJ/kg
20lbs $CO_2$/ Gallon Diesel Fuel

#### Introduction

During the spring and summer of 2005 I led a team of students and staff to construct a rammed earth wall MIT building N51. The wall is located at the back of MIT building N51 (275 Massachusetts Ave), the present home of the Visual Arts Program and undergraduate architecture at MIT, in addition to the wood and metal shops of the Department of Architecture. The wall replaced a chain link fence in a state of disrepair at the back of the courtyard, improving an outdoor space for use by the School of Architecture for arts and fabrication. The rammed earth wall measures seventy feet long, a foot-and-a-half wide, and six feet tall. It was constructed in two sections, divided in the middle by a twelve-foot wide gate. The objective of the research was to prove that existing methods of rammed earth elsewhere in the world can be adapted to the climate and soils of New England, reducing dependence on reinforced concrete, which is environmentally harmful. In keeping with traditional methods, as well as contemporary rammed earth techniques Europe, no portland

cement was used in the rammed earth portions of the wall.

## Laboratory Testing

The intent of the laboratory research was to identify a local soil that could be used for rammed earth in New England. During this phase I identified suitable soil types and created rammed earth samples to obtain data about compaction density, compressive strength, and erosion behavior.

The books describing rammed earth construction never mentioned that it can be hard to find dirt in a city. I drove to suburb surrounding Boston, stopping whenever I saw a hole being dug to ask if I could collect a sample. Often, the contractors in charge of the site would not let me take anything away. They were worried about liability that would result from someone finding out that the soil from an excavation was contaminated. It aroused further suspicion if I told them that I was from MIT. In the end, it didn't matter so much that people were not willing to let the soil go, because nothing collected within a fifteen mile radius of Boston had the necessary clay content anyway.

Numerous sources consulted in the literature review suggested that a mineral subsoil consisting of thirty percent clay and seventy percent sand, gravel and fines was the material best suited to rammed earth. I described this problem to Dr. Germaine, who runs the geotechnical lab at MIT. We was decided to create an engineered soil consisting of thirty percent Boston Blue Clay mixed with commercially available sand and gravel. The appeal of the clay is that there is a great deal of it in the metropolitan Boston area. The only drawback is that it is 30-60 feet below the surface. However, the clay is a dependable byproduct of construction in the area, where excavation contractors often must contend with its disposal when digging a deep foundation for a large building.

Once we had agreed on the material to use, I had to find a source for it that I could use for testing. Finding a source for the clay was even

harder than finding ordinary soil in the city. The clay is virtually everywhere under Boston at a depth of 30 feet, and excavation contractors pay to get rid of it. It seemed like it would be easy enough to get. However, there is no market for it, which makes it difficult to buy, and excavation contractors were wary of letting any amount off the site for fear that it might be tested and found to be contaminated. Furthermore, any job that involves excavation over 20 tons of material must prepare a bill of lading for every truckload of soil that leaves the site. Around this time I spoke with pool excavation contractors, gas tank removal specialists, Frankie Pile installers, auger excavation companies, small time equipment operators, road construction specialists, local stone quarries and gravel pits, landscapers, trucking companies, soil engineers, soil consultants, general contractors, and geotechnical engineers. Eventually I found a soil consultant who was willing to work with me. I borrowed Ramage's Land Rover and headed down to the site, on Boysleton Street in downtown Boston. I brought a hardhat and a plastic crate with me. They lowered the crate down into the pit in the bucket of an backhoe the size of a house. The crate full of clay was so heavy I could barely get it into the truck. The clay was plastic, greenish like modeling clay, and smelled faintly like the sea.

I took the crate back to the soil lab. I started out trying to add water to the clay to get it to the consistency of pudding to combine it with the sand and gravel.. This mixed well with the sand but the resulting material as too wet to allow for compaction, and it was hard to get the clay to turn to pudding right away. It just turned into smooth stubborn balls in the mortar mixer. I let it run for several hours and came back after lunch to find the same thing. I found an industrial bread mixer in the basement of MIT and that worked better than other methods. Around this time I hired Omar Rabie to help me with the laboratory research. We wore white lab coats to try to convince ourselves to be scientific and created a number of different soil blends and compacted them at various moisture contents, weighing the results before and after baking them in an oven to determine the moisture

content resulting in the densest compaction.  We took the samples to Stephen Rudolph in the civil engineering rock mechanics laboratory for testing. About twenty people showed up to see the testing occur.

The best results were a maximum unconfined compression of close to 300 psi, somewhat lower than expected, but easily strong enough to build walls of up to 10m high or more. Proctor compaction tests, which measure the moisture content necessary for maximum soil compaction, showed that mixing moist clay with dry sand and gravel in their natural states produced a soil whose moisture content was almost ideal for maximum compaction. Three rounds of freezing and thawing led to no noticeable degradation of samples, although further testing would be required to fully evaluate resistance of rammed earth to spalling. The results of initial laboratory testing were promising enough to warrant the construction of a full-scale wall on the campus of MIT.

I was making many phone calls trying to find around twelve tons of the blue clay that I had calculated would be necessary to build the project. The engineer through whom I had gotten the clay sample previously had left that job and his replacement was unwilling to consider donating that amount of clay to the project. I was getting nervous about the schedule. Just before leaving on a trip that I had scheduled to interview rammed earth builders in Europe, I cut the chainlink fence down separating the courtyard from the alley to ensure that a tri-axle truck could back its way in to deliver the clay. I had a few prospects that I hoped would come through and I did not want them to be prevented from delivering the clay because they couldn't get the truck through the gate while I was away.  After spray painting the location of the excavation for the dig safe inspectors (to make sure that there were no cables or electrical lines running beneath the proposed foundation) I returned home to pack for the trip to Europe.  I was on the plane later that afternoon.

## State of the Art: Europe

I traveled to the southwestern United States and Europe During the spring and summer of 2005 to meet with a number of successful contemporary architects specifying the technique, as well as the specialized construction firms who carry out the work.

I travelled to Austria, Switzerland, and England and Southern France to interview leading rammed earth builders in those countries. Rowland Keable and Martin Rauch, two leading rammed earth practitioners in England and Austria respectively, both claimed in independent interviews and site visits during June 2005 that the addition of portland cement was unnecessary in a properly detailed rammed earth structure if the natural clay content was high enough in the soil used for compaction. This claim is especially impressive in the case of Rauch, whose projects in high alpine regions of Austria and Switzerland must withstand annual precipitation exceeding that of New England, and more extreme wintertime temperatures. Rauch has experimented with augmenting natural clay content of the soil with other sources of clay to achieve the desired ratio. Keable has also experimented with a number of different materials, including walls of rammed chalk at the Pines Calyx project in Dover, England where the chalk occurs naturally at the project site.

Driving across Switzerland to Austria I stopped to see a number of early reinforced concrete bridges by Robert Maillart. The structures were amazing, but part of what interested me was the structural problems a number of them were having with spalling, due mostly to the reinforcing steel being placed to close to the edge of the concrete. Maillart was one of the most brilliant engineers of the 20th century, but his bridges were falling apart. I think that the problems are testament to the challenges of bringing a new material and method of working to construction practice. When I saw Maillart's bridges, I thought that it might take some time to build with rammed earth without fear of failure. It also brings up another point about our expectations about the longevity of structures. Rammed earth might age rather quickly if it is

not properly detailed, but the same might be true of concrete and wood as well, thought the effects might take somewhat longer to show up.

### Historical precedents

On the same trip I traveled to the Rhone Valley in southern France, where rammed earth buildings have been constructed for three hundred years. First-hand observation of the rammed earth structures in the Rhone Valley confirmed what I had seen at the archeological site in southern Spain: buildings constructed of natural soils without the addition of portland cement can achieve service lives of well over 250 years. Nearly all of the traditional earth structures visited in the Rhone Valley were built with unadulterated soil taken directly from the building site. Many residences and agricultural buildings are still in use in this region in varying states of repair. Observation shows that roof leaks and shear stresses at the corners of structural rammed earth buildings account for the majority of failures. Regional builders have developed methods for coping with degradation of rammed earth, although construction and repair of rammed earth structures is in danger of becoming a lost art in the region. Important work is currently carried out in construction and preservation of rammed earth structures by CRATerre, a research group at the University of Grenoble. The group, which the author visited while performing research in the region, maintains an archive of rammed earth structures and trains students in the theory and practice of building in a variety of earthen methods.

### State of the Art: America

A few weeks after I returned from the trip to Europe I flew to Tucson, Arizona to inteview Rick Joy , one of the leading architects specifying rammed earth in the Southwest. I interviewed Rick Joy and visited projects in the area. The interview took place in Joy's rammed earth office and yielded a unique perspective on the dissemination of a technique through current practice. Although the

price of rammed earth is competitive with CMU construction in the Tucson area, Joy maintains that cultural issues are as important as the price of construction in determining whether rammed earth is likely to become more widespread in the United States. His projects for high-profile clients may increase the desirability of the technique among a wider public. Nevertheless, Joy is adamant that he is not only a rammed earth architect, asserting that he uses it only when it is appropriate for a particular project and client.

On the same trip I also visited Jones Studio in Phoenix, AZ, another architecture practice utilizing rammed earth. Neil Jones, the principal, expressed frustration with local building inspectors, who treat rammed earth as an experimental construction technique, despite standards governing rammed earth construction. The interview took place in Jones's residence, a striking contemporary load-bearing two-story rammed earth structure which utilizes only natural soils from the site. Jones's refusal to add Portland cement to the soil mix put the project in opposition to the building codes of Arizona, which generally mandate the addition of three percent Portland cement to soil mixes used for rammed earth.

A visit a rammed earth project under construction by a Tucson-based contractor showed that southwestern builders often increase the amount of Portland cement to double the amount specified to avoid a shortage of cement in the mix, which is measured by approximate means in the field. Standard practice in the region is to mix cement with structural road base used in road building, commonly known by the name of "ABC (aggregate base course)" with small hydraulic loaders (e.g. the skidsteer or "Bobcat") and compact it using pneumatic soil backfill tampers. This engineered soil is sometimes mixed with iron oxide or other agents to tint the soil to a desired color. The resultant strength of the soil mixes compacted in this way generally range between 300-800 psi, and building code requires that soil samples generally be tested by a certified engineer prior to the beginning of construction. The project visited utilized modular formwork manufactured for site-cast concrete, with no modification for use with rammed earth.

## Environmental Advantages

The addition of Portland cement appears to be the major difference between American and European rammed earth practice: American building codes generally require the addition of Portland cement, while European builders frequently leave it out altogether. From an environmental standpoint, reducing or eliminating Portland cement is advantageous because it lowers the energy embodied in the final product. Research indicates that the embodied energy of stabilized rammed earth construction amounts to .80 MJ/kg, as opposed to .94 MJ/kg for concrete block, and 1.3 MJ/kg for site cast concrete (Chaturvedi and Ochsendorf 2004). Using soils directly from the site represents an environmental advantage for the same reason. Over seven percent of global CO2 emissions come from the production of cement, and concrete represents nearly one half of the 136 million tons of construction waste generated each year in the United States. (United States Green Building Council 2005) It was evident that a variety of methods of building with rammed earth are in place in various regions of the world. Some add Portland cement; others omit it entirely. Virtually all of those interviewed claimed that building with earth is a forgiving process tolerant of many different approaches, allowing the use of a wide range of soil types and fabrication strategies, especially when conservative design guidelines (e.g. width to height ratios) are followed.

## Construction of the Full-Scale Prototype

We broke ground on July 15th. I still did not have the clay, or even all of the funding in place that the wall would required, but if we waited for those things before beginning, it would throw the whole schedule off, which was tight as it was. Furthermore I was worried that if we waited too long people might change their minds about letting us build the rammed earth wall at the

JIM SUKEFORTH - CEO

MEREDITH
ELBOUM

CHAD MACHEN

Joe,
Here are a few of the issues that we would like to address at tomorrow's meeting:
Relevance - In what ways do you see rammed earth construction benefitting our practice? It may be helpful for you to bring some background material demonstrating precedents (including your work in the field and what you have seen on site visits). Any examples from climates similar to New England would be welcome. Also, are there scale limitations for rammed earth construction? Is the material appropriate given the size and typical program make-up of our projects? Are there LEED implications?
Expectations - What results do you expect to achieve with the construction of this wall and the subsequent tests over time? Do you think that the effects of freezing can be mitigated through appropriate detailing?
Contribution - How can Sasaki participate in the process in a role greater than that of financial supporter?

These are just a few examples of queries that have come up over the last few days when I've discussed this project with others in the research group. Just let the receptionist know when you arrive, and I will come down and take you to the conference room and help set up. Let me know if you need directions, or anything else. Again, I look forward to meeting you tomorrow and learning more about the project.
Regards,
Chad Machen

Relevance - In what ways do you see rammed earth construction benefitting our practice?

support of slides

Aesthetic virtues, proven performance and environmentally sustainable attributes of rammed earth will prove Sasaki's strong commitment to the environment and cutting-edge design.

They will be

1³⁵

Investment in rammed earth research will benefit Sasaki Associates' practice by placing it at the forefront of knowledge base in New England for future projects.

Bang for buck - small investment - large return

Materials are evaluated increadingly in terms of their embodied energy, or the amount of energy that has gone into their production, as well as their performance.

Take soil directly from site and create walls with it (show Martin Rauch houses and walls).

Walls could be structural or landscaping elements

Proven in climates similar to New England, such as Austria.

Do you think that the effects of freezing can be mitigated through appropriate detailing?
Any examples from climates similar to New England would be welcome.

MIT - leader in Building tech
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offic 617 594 6052
Willis Garage =>
July 5th
Fillicar
John Phillicar
for Derenzo
617-823-4224
2 weeks

Possible Materials Suppliers/Contacts

Rick Brown sculptor
Hands on HOuse
781 826 7314

Howard Bourdelais
Mondern Continental General Superintendent
617 201 7392 (cel)
hbourdelais@moderncontinental.com
recommends roadbase for subsoil substitute. Recommends looking at roadbase suppliers on cape cod where they often use subsoil

**Macomber Construction**
Emerson Field Office 617-357-0190
Corner Boyleston and Tremont
Phil Aquadro

John Cole cel
617-799-9271

**Will Sand in Canton: (781) 828 6300**
Contact: Jeff White
Sells subsoil blends intended as fill for $10/ton. $146 to delever to CAmbrdige
Sand pits in plymouth and Carver.
5/18: Going to inquire and call back
Often have subsoil but blend it with other materials for use as fill. Maybe poss. to special order unadulterated subsoil.

**Larrousso in Walpole 800 547 7600-**
Sells only crushed rock no subsoil
(no good)

**West Roxbury Crushed Stone Co. 617 323 6380**
Walpole yard (331 West St Walpole) has huge supply of clay for $4.25/ton.
(Could be silt)
Delivery $130 extra
Clay comes from washing rock and gravel and may contain much silt
Contact in Walpole: **800 547 7600** Mr. Stafford or Billy Morgan

**PA Landers 781 826-8818 for subsoil**
Contact: Jude
Palanders.com in hanover MA.
Does not have anything over 10% clay. Roadbase normally <10% clay. Mostly sand and crushed rock with some silt whose origin is rock flour.

AA Will excavation

At 11:37 AM 5/24/2005 -0400, you wrote:
> Hi Jim,
> Macomber Builders wants to donate 12 tons of Boston Blue Clay to the rammed earth project at N51. The material
comes about from an excavation about 60 feet deep for a new dormitory at Emerson College at Boyleston and Tremont
Street. I have cleared the delivery of the material, which is about 3/4 of one dump truck, with Chris Dewart at
the woodshop, as well as Nic Rader, who will be working for Larry Sass at the N51 courtyard over the summer. The
plan is to store it in the north-western corner of the courtyard.
> Macomber wants to make sure that MIT facilities is ok with the plan to drop off the material in the next week or so
for liability reasons. The trucking company doing the haulking will be AA Will out of Stoughton MA.
> Do you forsee any problem with the delivery of the material? Would you mind if I pass along your contact info to
Macomber so they can get in touch with you?
> Anxious to take care of this in the next day or so if possible, as the excavation will not last much longer.
> Thanks very much,
> Joe
>
5/24/2005 12:02 PM
Hi, Joe, this reuse of local fill sounds like a home run for the project. MIT Grounds disclaims responsibility for the
courtyard so the only person I can think to ask about this is the local maintenance zone coach. I will also cc our
contact in MIT Facilities Design and Construction.
If no one objects, we can give Macomber permission to drop the material off, but no one obviously can give them
permission to do anything negligent during the delivery. They need to rely on their own insurance to cover any
injuries or damage caused by their truck. If they are worried about our coming back at them asking them to remove
the material some day, then you need to assure everyone that the disposition of the material after it is left on MIT
property is 100% assumed by the your project and its budget.
You need to plan for site clean up after the material is incorporated into the wall and to make sure that you have use
for every bit of clay that is delivered. No one at MIT wants to get a phone call telling them that we have a useless
gigantic wet lump of clay that we need to get rid of somehow. You do have tarps to cover the clay before use, don't
you?
Good luck,
jim

Jim Harrington, AIA
Facilities Manager
M.I.T. School of Architecture & Planning
77 Massachusetts Avenue Room 3-311
Cambridge, MA 02139 USA
617.258.6061 voice
617.236.9111 pager

617.253.9407 fax
> -----Original Message-----
> From: Joe Dahmen [mailto:jdahmen@MIT.EDU]
> Sent: Tuesday, May 24, 2005 12:20 PM
> To: Jim Harrington
> Cc: rhaskell@PLANT.MIT.EDU; tharp@PLANT.MIT.EDU

courtyard. Although I had approval from various sectors, the whole thing seemed a bit tenuous. I didn't dare hold a single meeting at which everyone would be present, for fear that something would come up that prevented the project from taking place.

I had secured an OK from the Dean of the School of Architecture and Planning, who agreed that the Dean's Office would to fund a part of the project. The manager of facilities in the department of Architecture had a background was in geology, so he was in favor of the project. I had contacted the city of Cambridge planning and traffic offices, who came out to look at the site. The consensus was that no permits were required if I kept the height under six feet. I had tested the soil that I intended to use and it seemed like it would work.

So I hired an excavator named Ed Robichaud, who agreed to dig a trench for the foundation with a backhoe, four feet deep and seventy feet long. We really only needed 12 holes of that depth, but Ed was adamant that it would be less work to simply dig a trench, place the tubes, and fill it back in. Then, after we had cast concrete in the tubes, he would come back to place asphalt around the bases of the piers. The whole thing would cost $2,300. It seemed worth it to not have to do all of that digging.

A number of people showed up for the groundbreaking. My parents were there, in addition to a few students as well as Charlie, who ran the metalshop during the school year and was working on the project full time with me over the summer. As the backhoe bucket bit out its first piece of soil, I was elated. On the second bite, the bucket hit something very solid and scraped along it for about three feet, making a horrible grinding sound: an old concrete foundation long since paved over and forgotten. The loser in the deal was Ed's hired man


Doug, who was tasked with breaking out enough of the old foundation with an electric jackhammer to make room for the post that we had to set atop it. So Doug spent four hours in a hole in the ground, breaking up what he could with a jackhammer. By the end of the day we had a very large pile of soil alongside a trench that was 7 feet deep in several places, the result of Ed looking for a change in color in the soil to indicate stable clay. Everything above that was filled land: we were building on what at one time was a tidal swamp of the Charles River.

## Foundation

The rammed earth wall is supported on a pier and beam foundation of reinforced concrete. This method differs from the typical spread footing characteristic of most rammed earth construction, which results in the use of a considerable amount of concrete and steel below grade given the thickness of rammed earth wall sections. In contrast to the continuous footing, we designed twelve-inch diameter posts of reinforced concrete approximately six feet apart directly under the wall. The posts have flared bottoms to distribute the weight of the wall and rest on undisturbed soil below the frost line. These posts are connected with a 9-inch thick continuous beam of reinforced concrete, the bottom of which is elevated several inches above the grade, to eliminate the danger of heaving due to frost. This approach saved over eighty percent of the concrete that would be used in a conventional spread footing. The layers of earth would then be rammed on top of the continuous beam. We cut and bent the rebar ourselves in the metalshop, finishing the last pieces as the readymix truck pulled up to place the concrete in the tubes. After the tubes were cast we built formwork for the pile cap in the metalshop, and carted in out in four long sections. Into this we tied another round of rebar, and then the readymix truck came back and poured the connecting beam formwork full. The foundation, from start to finish, had taken three of us one week.

Just as we finished the concrete grade beam, I convinced an excavation contractor to donate


twelve tons of clay for the project free of charge from the construction site of a new building at Harvard University. I found a dump truck driver from Roxbury, Al Courtney, who was willing to bring the twelve tons of clay from Harvard to MIT for $200. We met on Oxford Street at the building site just outside of Harvard Square at 7:30 am on Thursday morning in July. By 7:45 the truck was in position under the clamshell bucket. The engineer in an orange vest in charge of the loading turned to me and shouted over the roar of the crane "one scoop or two?" All of the volume calculations that I had done over the preceding weeks came down to this. I looked at the clamshell bucket and said "two", figuring that it was better to wind up with some extra clay than to come up short. So much for detailed calculations. At 8:15 Al had dumped the clay in the courtyard at N51, which shook the ground when it hit the pavement.

## Formwork

Following completion of the foundation beam, we constructed formwork from plywood and dimensional lumber, connecting it to the concrete beam below. The formwork was further reinforced using pipe clamps and horizontal walers to contain the outward forces of compaction. This method is in keeping with widely-available literature on rammed earth construction and approximates the form-ties used in site-cast concrete. For larger projects, the use of modular formwork manufactured for use in site-cast concrete would represent considerable savings in time and material, but for a modest-sized project building it from lumber was the most sensible approach. As the wall was built in two sections, separated by a gate at the center, we formed one side first and reused the formwork on the second side after the first was rammed. This approach allowed us to apply lessons learned in the first side to the second, and resulted in some material savings. However, using new lumber for the formwork was one of the least satisfying aspects of the project. It was like we were building two walls, and throwing one away at the end of the project. I justified the use of the lumber for the formwork at the time by the


DANGER
FLAMMABLE GAS


fact that perhaps the test wall would lead to a lot more people using rammed earth, and therefor less concrete, which was a trade off that I deemed worthwhile. I did not want to use slip forms to make the wall, because I did not trust myself to make a perfect wall that way, and it seemed to me then as now that if the wall were not perfectly plumb and straight, observers would think that this was a characteristic of rammed earth, rather than an error by the builder. This is true, but it seems like these compromises of materials in exchange for expediency are just the sort of thing that lead builders to justify the use crappy materials in place of more environmentally responsible approaches, especially when the latter are more time consuming.

## Mixing

Mixing the clay, delivered to the site in a plastic state, with sand and aggregates to final consistency proved to be the most challenging aspect of building the wall. During the laboratory phase we managed the soil creation with an industrial bread mixer, which was very effective for small quantities but not appropriate to full-scale fabrication. Our solution involved modifications to the revolving paddles of a gasoline powered plaster mixer. This produced a machine capable of mixing reasonably-sized batches of the engineered soil, which were then deposited in formwork and compacted.
A variety of mixtures were incorporated in the wall for research purposes, each marked by an embedded steel plaque identifying it. The mixing method limited the size of aggregate used in construction; crushed stone larger than three-quarters of an inch caused problems for the machine.

## Compaction

In order to gain an understanding of the factors influencing proper compaction, we placed and compacted the first side of the wall by hand. This approach permitted comparison of the efficiencies of hand- versus-mechanical placement and

compaction. The first half of the wall was thus placed with five-gallon-buckets in an assembly-line fashion, and compacted with hand tampers, a tool made from a steel plate mounted at the end of a wooden handle. The soil is placed in the formwork in layers eight inches deep, which are compacted to approximately five inches. This phase of the project taught us a great deal about managing material flow, the feeling of solid compaction, and the value of perseverance. In order to get the first side finished on time, we had several rammed earth parties, in which we were able to get a great deal compacted in exchange for barbecue and beer.  Charlie ran the barbecue and I supervised the ramming. Most people seemed happy to get out of their offices and laboratories for an afternoon and participate in physical labor,. The beer part was a little tricky to pull off, as there are many regulations governing consumption of alcohol on the MIT campus, but I got the beer anyway. All that compacting makes people thirsty.

After the first half of the wall was complete we removed the formwork. This was a great relief, as we had been compacting for around a week and a half and had not en what the finish would be, apart from the section blocks at the end of each section. When we pulled the first section nobody on the crew could stop touching the wall. The surface was beautiful! It was far smoother than I had hoped. Even the holes where the clamps had gone through were perfectly formed. We removed the rest of the formwork and took the rest of the afternoon off.

We compacted the second half of the wall using a pneumatic backfill tamper that I had ordered through the internet. In addition, we placed the soil with a hydraulic skidsteer loader, which we rented for a week along with a large, tow-behind air compressor to run the backfill tamper.

The man delivering the equipment showed up around 10 in the morning and  asked if I would like him to drive the machine off the truck. I agreed that would be best. I had ordered the equipment over the phone and was a little taken aback by the size of it. I had never driven a loader before. The man climbed in through the front and pulled down a glass hatch. The machine was brand new and it

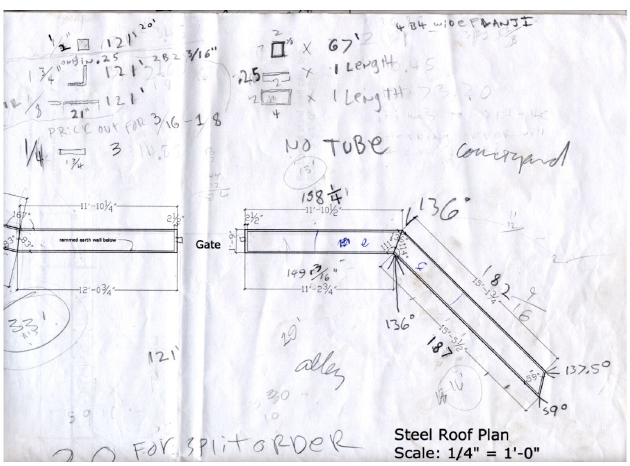
looked very futuristic. He started the engine and backed it down the ramp at the back of the flatbed trailer. Then he shut it off and climbed out through the front of the thing, the same way that he had gotten in. Luckily, he asked if I was familiar with the particular model, so I said no. Could he show me where the key was? He ran me through the basic procedures for the Bobcat as well as the diesel air compressor, then got in his truck and drove away. After half an hour I managed to get the loader started, and turned a few circles around the site. It seemed like it would be pretty easy to accidently knock over a large section of the wall that we had just built. Shuji, who had agreed to stay on for the second half of the construction only if I would let him drive the loader, wanted nothing to do with it when he saw the size of the thing. Eventually, though, he became very good at driving it around. We practiced by removing one of the galvanized steel post tops that we had cut off an inch above the pavement of steel. It was nerve wracking to drive the machine around on such a constricted site. On the other hand, one bucket at the front of the loader was worth almost 100 of the five gallon buckets that we had been using to move the soil before.

The second half went considerably faster, construction taking approximately one quarter of the time of the first half. Some of this gain in time can be attributed to our increase in understanding of the task at hand, but the use of a hydraulic loader to place the soil and a pneumatic backfill tamper to compact undoubtedly resulted in considerable savings in labor. Some of this savings must be applied toward the environmental and economic cost of running and maintaining the various machines, but it would seem that this approach would make the most sense in a region such as New England, where labor cost is high relative to other regions of the United States. Indeed, every contemporary rammed earth project site visited during the first stage of the research utilized mechanical methods of placement and compaction.

When we were finished compacting the second half of the wall, I called the equipment yard that


had rented us the loader, mixer, and compressor. I had Charlie and Adam take apart the mixer and clean it thoroughly. Over the course of the month that we had it, we had sheared off the mixing paddles twice. Luckily, Charlie was a welder, so when this happened he would clean the machine and weld them back in place. The rubber wipers that made contact between the paddles and the drum were entirely worn away, so we bought a new set and installed them. Then I borrowed Ramage's truck again, which luckily had a pintle hitch, and hitched the mixer to the back and returned it myself to avoid paying an additional $100 fee for pickup.

When I returned the machines to the rental yard I had to call the Building Technology group at MIT to get them to authorize payment for the equipment. The rental was well over $1,000 dollars, which required the approval of the MIT procurement office. The administrator in BT handling the case called me back to say that procurement was unwilling to let me rent the equipment that I was asking for. At this point I asked for the number of the official in the Procurement office so I could speak to him directly, sensing some confusion. Sitting in the cab of Ramage's truck in the parking lot United Rentals, I listened patiently to him for twenty minutes as he explained all of the reasons that I would not be able to rent the equipment. Most of the reasons centered around the liability that MIT would incur should anything go wrong while using it on MIT property, which seemed reasonable enough. As he was talking, my mind drifted. Somewhere I must have sensed that it could not be entirely within MIT policy to be using the equipment at N51. But why didn't the official from Environmental Health and Safety who stopped by regularly to say hello and check on our progress say anything? For that matter, it must have been against MIT policy to allow Ed Robichaud, an independent contractor, to dig up the yard for the foundation with his backhoe. After 20 minutes or so, the official from procurement had talked himself out. I played back to him as best I could remember what he had said about why it was that I would not be allowed to


rent the equipment. He agreed that I understood it all correctly. I said that all sounded very reasonable. He agreed, and mentioned that he was sorry but that it was MIT policy and he was in no position to change it. Then, as gently as I could, I let him know that I was not at the yard trying to *rent* the equipment, but was trying to *return* it. There was a long silence at the other end of the line. I waited. He authorized payment, but he made me agree that I would never do that sort of thing again.

## Steel Cap

When compaction of the earth was complete, we removed the forms and built a temporary cap out of plywoood from the formwork, then tarped the whole thing while we waited for the money to come through for the steel cap. After the debacle with procurement, I was determined to arrange the rest of the payments according to official procedure. When we had a steel order form filled out I took it down to the Building Technology office. Because it was over $1000 of metal, according to MIT policy the administrator had to check to see whether core ten was listed as a precious metal. Core ten was not listed as a precious metal, but it was not on the list of non-precious metals either, so we had to wait while another administrator verified that it was an acceptable use of a departmental credit card. In addition, we had to set up a purchase order, which the steel company resisted because as the order was hardly large enough to be worth the trouble. Approximately a month later the various administrator were satisfied, and the steel was shipped. The cap was

fabricated of core ten steel by Matt Stone, a welder who had gone through art school with Charlie.

In the mean time, fall classes had begun again. Between classes I dealt with various unresolved issues at the site. Every time it rained I had trouble sleeping, wondering whether the tarps had been blown off the wall. In fact, after the tarps had been on for a month, they started to rot from the ultraviolet radiation, and develop holes at the corners. In addition to worrying about the state of the tarps, Ed had to replace some faulty asphalt

that he had laid on uncompacted soil, which sank after the first few rainstorms. I had to be around to supervise that. I was still trying to raise the money necessary to finish the wall. I contacted facilities to see whether I could get them to pay for the steel cap. I was getting tired of the hoops that I had to jump through every time I needed to get a construction expense reimbursed.

When I contacted the head of Facilities, he sent me back an email mentioning that they had never heard of the rammed earth wall, and that any construction on he MIT campus had to be cleared with them first. Could I please come into their office and explain what the project that I was proposing? The following week I sent Facilities a document with a full explanation of the project: plans, sections, maintenance requirements, the works, then scheduled a meeting the highest administrator that I could get to. After the meeting I emailed the head of Facilities again, and told him that I was sorry for the misunderstanding, and that I needed a forklift to install the steel cap on the wall. He emailed me back twenty minutes later with

# TechTalk

SERVING THE MIT COMMUNITY

## ference tackles depression

related to learning and memory, sought to improve the diagnosis, prevention and treatment of depression. The disease is now believed to cause not only mental anguish but also early death from medical conditions as diverse as stroke and cancer.

Moderated by Dr. Peter D. Kramer of Brown University, author of "Listening to Prozac" and "Against Depression," the event's wide-ranging presentations touched on the latest findings in basic neuroscience, insurance issues, behavioral studies, current and potential treatments, depression in the workplace and depression among artists and writers.

Robert Pinsky, former U.S. poet laureate, read poems by Yeats to support his idea that depression is a necessary part of human evolutionary adaptation, a craving for perfection that results in frustration and feelings of worthlessness. Psychiatrists Dr. Charles Nemeroff of Emory University and Dr. Ned H. Kalin of the University of Wisconsin related the results of studies on certain gene combinations that seem to make people resistant or prone to depression. Garry Giannone, vice president at Prudential Financial, used a case study about a divorced single mother whose depression almost cost her her job as an example of how intervention in the workplace is needed to seek out and help undiagnosed and untreated employees.

Panelist Paul H. Stypulkowski of Medtronic Neurological described how a treatment of last resort — deep brain stimulation, in which electrical leads are implanted in the brain —has successfully treated symptoms of Parkinson's disease and epilepsy and may be applied to depression.

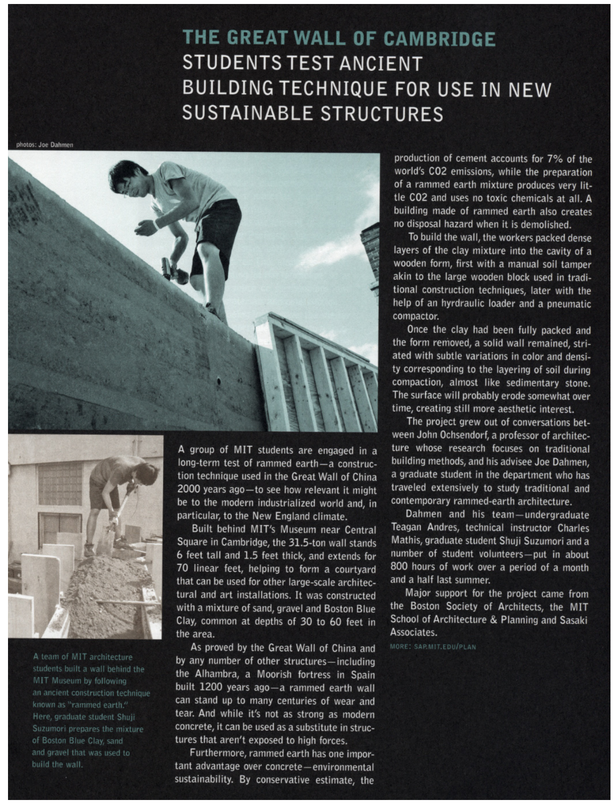
The conference's goal, said co-organizer Mark Bear, Picower Professor of Neuroscience at the Picower Institute, was to allow a diverse group of professionals to explore how fundamental insights in neuroscience can be applied to problems of great societal importance. The Open Mind Series, said Keith Dixon, president of CIGNA Behavioral Health, is a demonstration of CIGNA's "commitment to understanding more about the complex relationship between the mind and body and to learn what else we can do to help people

See BRAIN
Page 4

PHOTO / DONNA COVENEY

**Working from the ground up**

Graduate student Shuji Suzumori helps to build a wall behind the MIT Museum late last month. He was among a team of architecture students who built the wall to test an ancient construction technique called 'rammed earth.' Suzumori is pouring blue clay and gravel into a compactor to mix and crush the material before it's used. **Story, additional photo on Page 5.**



## THE GREAT WALL OF CAMBRIDGE

STUDENTS TEST ANCIENT BUILDING TECHNIQUE FOR USE IN NEW SUSTAINABLE STRUCTURES

photos: Joe Dahmen

A group of MIT students are engaged in a long-term test of rammed earth—a construction technique used in the Great Wall of China 2000 years ago—to see how relevant it might be to the modern industrialized world and, in particular, to the New England climate.

Built behind MIT's Museum near Central Square in Cambridge, the 31.5-ton wall stands 6 feet tall and 1.5 feet thick, and extends for 70 linear feet, helping to form a courtyard that can be used for other large-scale architectural and art installations. It was constructed with a mixture of sand, gravel and Boston Blue Clay, common at depths of 30 to 60 feet in the area.

As proved by the Great Wall of China and by any number of other structures—including the Alhambra, a Moorish fortress in Spain built 1200 years ago—a rammed earth wall can stand up to many centuries of wear and tear. And while it's not as strong as modern concrete, it can be used as a substitute in structures that aren't exposed to high forces.

Furthermore, rammed earth has one important advantage over concrete—environmental sustainability. By conservative estimate, the production of cement accounts for 7% of the world's CO2 emissions, while the preparation of a rammed earth mixture produces very little CO2 and uses no toxic chemicals at all. A building made of rammed earth also creates no disposal hazard when it is demolished.

To build the wall, the workers packed dense layers of the clay mixture into the cavity of a wooden form, first with a manual soil tamper akin to the large wooden block used in traditional construction techniques, later with the help of an hyrdraulic loader and a pneumatic compactor.

Once the clay had been fully packed and the form removed, a solid wall remained, striated with subtle variations in color and density corresponding to the layering of soil during compaction, almost like sedimentary stone. The surface will probably erode somewhat over time, creating still more aesthetic interest.

The project grew out of conversations between John Ochsendorf, a professor of architecture whose research focuses on traditional building methods, and his advisee Joe Dahmen, a graduate student in the department who has traveled extensively to study traditional and contemporary rammed-earth architecture.

Dahmen and his team—undergraduate Teagan Andres, technical instructor Charles Mathis, graduate student Shuji Suzumori and a number of student volunteers—put in about 800 hours of work over a period of a month and a half last summer.

Major support for the project came from the Boston Society of Architects, the MIT School of Architecture & Planning and Sasaki Associates.

MORE: SAP.MIT.EDU/PLAN

A team of MIT architecture students built a wall behind the MIT Museum by following an ancient construction technique known as "rammed earth." Here, graduate student Shuji Suzumori prepares the mixture of Boston Blue Clay, sand and gravel that was used to build the wall.

the phone number of the guy that would make the arrangements for a forklift and two operators whenever I was ready for them.

We installed the continuous cap of weathering steel in sections using the forklift a week later. I had to skip class in the midst of the installation, but otherwise everything went well. The operators were very professional and skilled at driving the forklift. The cap rests on the top of the wall, overhanging several inches on each side to keep direct precipitation from the wall. The presence of an impervious cap overhanging both sides of a rammed earth wall should be considered mandatory for all applications in New England.  It is as important to keep rammed earth dry from above as protecting it from rising damp below. Matt and I stayed on the site well past dark, grinding the last of the welds by the light of a halogen light set up in the alley.

## Summary

Building the rammed earth wall at MIT has demonstrated that the method can be done in New England. The principal question remaining to be answered is what soil to use in construction. The technique of soil processing employed in the construction of the demonstration wall is located between two existing methods observed in the first stage of research. The first method, a traditional approach, utilizes soil as it occurs naturally on or near the building site. This method is the most advantageous environmentally, but can require testing for each particular project as soils vary widely and sometimes unpredictably. In the second method, most often followed by rammed earth builders in the Southwest United States, builders mix engineered road building soils with a small amount of portland cement. While this approach offers predictable performance, it requires the use of cement, whose environmental costs have been outlined above, and often employs soils transported far from their initial location, raising the environmental cost. While both of these methods

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The Great Wall of MIT

Friday, December 30, 2005

By Heather Whipps

LiveScience

PHOTOS

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When it comes to scientific progress, sometimes you have to look back in order to move forward.

Parts of the Great Wall of China, still standing after more than 2,000 years, were built using a construction technique called rammed earth.

Now a group of architecture students at the Massachusetts Institute of Technology have imitated the technique in an experiment aiming to confirm the usability of the ancient building method in the modern world.

Led by graduate student Joe Dahmen, the MIT team began work in September, using twelve tons of local Boston blue clay mixed with two

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NEWS

La grande muraglia del MIT

24 Gennaio 2006

Parti della Grande Muraglia cinese, ancora erette dopo più di 2,000 anni, sono state costruite usando una tecnica di costruzione chiamata "terra compattata".

Ora un gruppo di studiosi del Massachusetts Institute of Technolgy (MIT) ha riprodotto la tecnica in un esperimento finalizzato a confermare l'utilizzabilità dell'antico metodo di costruzione nel mondo moderno.

Guidato da Joe Dahmen, il team del MIT ha iniziato la sua ricerca nel mese di settembre usando 12 tonnellate di argilla di Boston, unita a due parti di sabbia e ghiaia. La mistura è stata modellata, a mano e con l'aiuto di un compattatore pneumatico, in un guscio di legno rimosso ogni volta che la sezione era completa e asciutta.

Due mesi dopo...

Il muro così concluso misura 70 piedi di lunghezza e 6 di altezza. Secondo Dahmen, si comporta piuttosto bene a due mesi di distanza. "La nostra muraglia regge bene" ha dichiarato. "Sono stati osservati leggeri cambiamenti sulla superficie in qualche area,

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have been employed successfully in a range of projects, either might be considered a compromise.

The use of marine clay, a consistent material source abundant in the region, mixed with commercially-available, locally produced aggregates represents a third course, positioned between the two outlined above. This third method can be standardized without the addition of Portland cement due to the consistency of the clay. The method contains great promise because it offers predictable performance without the use of environmentally damaging materials. Nevertheless, a continuous-feed soil mixing and placement machine must be developed before building with engineered soil blends containing blue clay is practically and economically feasible.

These thoughts about the design and fabrication of a combination soil mixing and placing apparatus form the next hypothesis investigated in the thesis. In addition, I will look at the possibility of deploying rammed earth in a large scale, infrastructural capacity, to maximize the environmental advantages over the building techniques it supplants. Specifically, I will propose a rammed earth sound barrier for use along a stretch of limited access highway in Dorchester.

## Rammed Earth N51: Credits

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My advisor during the project was John Ochsendorf, MIT Assistant Professor of Building Technology, with whom I had been working for the previous two years and whose advice, support, and positive outlook were as valuable as his technical assistance in this project. In addition, Ike Colbert, the dean for Graduate Students at MIT, was very supportive and offered a great deal of advice necessary to complete the project.