TECHNOLOGY AND THE STUDIO

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The Influence of Ecological Sensitivity on Architectural Structures: an assignment for Structures I students-design of a warehouse

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Abstract

The focus of this assignment is to emphasize the strong link between architectural structures and the ecological response of a building. This project is assigned to Structures I students, typically third year undergraduates and first year students in our three and a half year graduate program. Students design a small warehouse using waste and/or recycled materials for the structural frame and enclosure systems. They are challenged to treat this project as an advertisement of their design skills and their ability to create a building sophisticated in architectural structures and creativity, while at the same time being responsive to waste and material management. They present the design and related structural decision as if they are making a formal presentation to a client who needs to be convinced of the value of their technical creativity.

The students are sensitized to the fact that in the U.S., having only 5% of the world population uses nearly 40% of the world resources. As future architects, can they design a simple building type that uses ecologically responsive structural materials? It is expected that this building should use over 90% recycled materials or reuse abandoned construction products, while the scale model of the building should use 100% used products. The students, in their reports and presentations, must identify the extent of reused and recycled materials, the embodied energy content, and their reasons for selecting the building materials they used in their design. This project evokes a great deal of interest in the class and the students enjoy the research and are challenged by the assignment. Typically in architecture schools we tend to develop sustainability concepts in environmental control systems courses, seldom in structures courses. I am developing course materials to integrate sustainability into the three sequential structures we offer now. This is the first step toward that effort.

Intention

Intention behind this assignment is to research and explore the interdisciplinary background information on waste and sustainable structures to develop design opportunities in simple architectural problems.

Waste is unsustainable

Engineering and architecture evolved over 5000 years, from piled stones to soaring steel skyscrapers, serving humanity worldwide. Scientific advances and new urban and commercial requirements have caused extremely quick developments in construction processes and materials since 1700s. Until then, wood and masonry were the only materials of construction.(1) Now, new construction methods and materials make it possible to build structures of immense size and complexity to serve the contemporary world, to withstand nature's mighty forces - gravity, storms, earthquakes and floods. We have used up enormous quantities of our natural resources such as, timber, iron ore, coal, bauxite, etc., and have reached a juncture where we must ask questions about the continued availability of these resources for our common future.

If sustainability is defined as the employment of resources to ensure the present standards of living for the future generations, how can architectural structures participate in this effort? The profession of architecture influences nearly 40% of the resource exploitation of the world and the structural component occupies a large part of architecture. An efficient and appropriate use of structure therefore enhances the sustainability of our buildings. When we waste materials we deny opportunities for people to work, which creates loss of dignity and value for people. We should remember that a society that wastes its resources wastes its people and vice versa. And both kinds of waste are expensive.(2)

Background

Recent history helps us to appreciate the need for awareness and suitable action regarding resources. After the oil embargo in 1973, this country embarked upon a campaign for energy efficiency. In the nearly three decades that followed, the U.S. has learned a lot about improving energy performance of buildings and other energy-

using products and equipments. Yet, architecture students are surprised to learn that in the U.S. we use 40% of the world resources with about only 5% of the world population. They have much to learn and understand about the natural resource situation in this country and worldwide.

In the class lectures and videos illustrating case studies, students are exposed to the extent of waste that is generated in the world and the efforts by architects to deal with the problem in this country. For example, the Fresh Kills Landfill is a repository for 26 million pounds of daily garbage from New York City. Garbage deposits in the last 50 years occupied 2200 acres, rising more than 225 feet and holding nearly 300 billion cubic feet of trash at this one site. This site was closed in March 2001. Waste management is a serious social and technical problem for the City of New York. Imagine how much waste we produce across the whole country! A summary estimate of total annual waste in the US exceeds 50 trillion pounds a year. In *Natural Capitalism*, the authors estimate that, it would take the entire lifetime of 24,000 people to count up to 50 trillion, counting at one number per second. This is an enormous number! If other countries copied our rate of waste generation in the United States, the world would waste away a tremendous amount of our natural resources very quickly. The World cannot ignore this. The architects who are responsible for a significant use of natural resources should do their part, by employing more efficient and appropriate use of these resources.(2)

Midrashic story

The warehouse project is designed to sharpen awareness and to create interest in sustainable structures in "Structures I" students. These students are exposed to this subject for the first time, therefore, I believe it is appropriate to introduce the concept that we are all responsible for our environment and ecology. Prior to assigning this exercise, they are told an important Midrashic story, as narrated by Elie Wiesel, winner of Nobel Peace Prize in 1986.(3)

"A man is on a boat. He is not alone, but acts as if he were. One night, he begins to cut a hole under his seat. His neighbors shriek: 'Have you gone mad? Do you want to sink us all?' Calmly, he answers them, 'What I'm doing is none of your business. I paid my way. I'm only cutting a hole under my own seat.' What the man will not accept, what you and I cannot forget, is that all of us are in the same boat"

The environmental and waste management problems associated with ecology affect all of us. Particularly, architectural students should become aware of the negative consequences of design that does not provide for prudent and appropriate use of materials. They need to understand the problems caused by wasteful use of materials by many contemporary designers.

Structures lesson from spiders

Animals, insects and trees fascinate us with their elegant structural forms and structural efficiency. This class is encouraged to ponder fundamental structural questions. For example, how is it that spiders make silk, stronger than Kevlar, by ingesting crickets and other insects and without chemicals and high-temperature extruders? It is quite extraordinary to see how a garden spider builds its web and to study a web's structure.(4) Students have an opportunity to review several natural structures in Animal Architecture by Karl Von Frisch, Nobel Prize Winner for Ethology in 1973. Students are encouraged to explore the wisdom of putting a couple of people, with a total weight of about 300 pounds, in an automobile that weighs 2000 pounds to 4000 pounds to haul them. How smart is it? Can we do something about it? We, in the class, have discussions on such issues and also review buildings such as 'eco-house' designed and built by architects like Eddy Jones for Arizona Public Service, with ecological and structural awareness, and apply the information to the current design project. Unless we think in radical and original ways, we will be chasing an impossible dream in the area of waste and resource efficiency.

It becomes clear that the students entering the field of architecture and built environment should

- become aware that natural resources are depleting at an alarming rate,
- understand poor management of waste is a major problem in this country,

- realize their future as citizens of the world depends on how well they manage their resources,
- become knowledgeable about what is being done by architects who care about environmental problems,
- learn about buildings that are designed without a concern for efficient use of energy and other natural resources,
- know that the building structure lends itself to critical evaluation of the effects of using recycled and waste products, and
- appreciate that in a consumer society such as the U.S., with all the pressures to use more and more, it is really very difficult to effect prudent use of materials.

Embodied energy

Students are made aware of the concept of embodied energy in structural systems, as yet another measure of material efficiency that they may employ in designing their warehouse. By understanding the definition of embodied energy - the energy consumed by all of the processes associated with the production of a structural material, from the collection of natural resources to final product delivery, including mining, manufacturing and equipment, transport, and other functions - students explore the energy content of their structural materials. They also learn, for example, that concrete uses 2 GJ/ton while aluminum uses 100 GJ/ton and also the embodied energy content of various other building materials. This gives them an intuitive sense of building materials such as rammed earth, straw bales, etc.(5)

They learn to appreciate that reusing common structural building materials saves up to 95% of the embodied energy which would otherwise be wasted. The savings by recycling for reuse varies considerably, with savings of up to 95% for aluminum but only up to 20% for glass. The students are expected to research these issues for their building and structural designs. Reuse of a structural material without too much remanufacture is encouraged in order to minimize additional energy input.

Concept of adaptive reuse

According to the authors of Natural Capitalism, it is not the supplies of oil or other metals that are beginning to limit our development. It is the living systems which are the source of our desired materials such as wood, fish or food and that are far more important to our continued prosperity than nonrenewable resources. This brings us to the question, "How can we extend the existence of living systems?" The answer implied in this question is that we should use appropriately all our resources and design structures to minimize waste and maximize life. Many contemporary designers are creating structures that process their own wastewater, reuse brown water, produce energy from the sun, use daylight, provide habitat for wildlife and material and spiritual wealth for the community. Adaptive reuse of a building structure for a different function or relocate the structure in a different location for another use was also considered as an alternative way to respond to sustainability.(6) While the concept of adaptive reuse is interesting the class did not pursue this concept much further due to lack of time.

Warehouse project

All the above ideas are discussed in the class prior to students embarking upon their search for available sustainable resources to design their warehouse. Although the focus is on structural design, (7) the assignment is to design a sustainable warehouse of 4000 square feet using only reusable or recycled materials. The scale model representing the building should also use materials discarded by others as waste. The goal is to use over 90% recycled structural materials in the building design while the scale model should use 100% recycled products. Students visit waste yards of department stores and supermarkets as well as tire discard yards and automobile wrecking yards. They also search websites for information about recycled items.

Key Structural issues

- Students should justify the structural choice based on the architectural configuration of the building.
- The framing plan and the structure proposed should be compatible with the materials selected.
- Structural proportion and architecture of the building should be aesthetically sensible.
- The building design and materials must respond to the region.

Key skills addressed

- Clear understanding of the appropriateness and the nature of the materials selected.
- Beams, trusses and cables must have compatible span vs depth ratios.
- Vertical load carrying members should be appropriate in size and shape for the chosen design.

Outcomes

It is gratifying to note that a majority of students in this class invested a great deal of time researching and thoughtfully dealing with the assignment. They met with the instructor during their design process several times to ensure they are on the right track. They confirmed to their amazement that less than 2% of the total waste stream is recycled in the form of glass, steel aluminum, and paper products, in this country. Most students also indicated, in their reports that over consumption and waste are major problems facing the U.S. and the world.

The list of recycled building products researched and used as structural buildings materials in their projects include the following diverse items:

* Bamboo and papercrete
* Earthberm and tire-wall
* Translucent concrete
* RASTRA and recycled steel
* Cardboard tubes
* Recycled cardboard and telephone poles
* Recycled rubber, plastic and steel
* Straw bale and recycled aluminum
* Rammed earth
* Fly ash
* Discarded cables from electric companies
* Corrugated board wall and recycled wood.

After four weeks of exploration and study, 75 undergraduates and 25 graduate students, in 2001 and 2002, presented to the class their final projects addressing the following evaluation criteria:

* Appropriate architectural and structural design
* echnical competence in the reuse of waste and recycled products
* ntegration of building program and site
* Research quality (web pages and references)
* Quality and clarity of presentation.

Following are selected nine sample projects from the 2001 and 2002 classes. These student projects were selected for their research quality, thoughtfulness, clarity and response to the evaluation criteria.

Lessons learned

1. Evaluation of projects is qualitative and general. It would be useful to develop a quantitative evaluation of this type of assignment. For example, the energy content of the structure as a whole or the weight of the structure per square foot of the built space could be another measure of efficiency.
2. A "tight" problem definition limits the time on peripheral issues and focuses effort on the primary intention - in this case the integration of sustainable structural building materials.
3. Establishing high expectations early in the semester - and not let them creep downward proved very useful.

Observations

1. A significant percentage of students believe that they have the responsibility to learn about the resource conditions of the world.
2. They are willing to research, explore, question, and develop solutions to this problem.
3. They make creative efforts to apply the knowledge gained in this assignment to their design projects.
4. They believe that the amount of time allocated for this project is too short and competes with the other design studio projects.
5. They understand how structural appropriateness and efficiency can be an integral part of the architectural design process.

I wonder how I can make my students sustain interest in this topic throughout their professional life. Can they make an impact on this society, which craves more and more material things and exports

this dream to the entire world? And most developing countries want to be like the U.S.! (8)

References

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5 Richard J. Vitullo, 2000: AIA Environmental Resource Guide - embodied energy of building materials.

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8 The State of the World 2000, 2000: The World Watch Institute, W.W.Norton & Company, Inc.