The Tectonic Case Study: Fabricating Reality

BRUCE LONNMAN
American University of Sharjah

Introduction

Precedent research in design has a long history in studio teaching and is sometimes used as a first assignment to jump-start a design project and provide students with some basic knowledge and visual references pertaining to the problem. In the study of structure, precedent or case study research can be extended as a methodology encompassing a wide range of activities including structural behavior model studies, hypothetical transformations of structural assemblies, visual analyses of form, as well as the use of quantitative analysis to understand or verify structural design assumptions. In fact, the use of carefully selected, well-documented case studies can support the active-learning environment of the design studio in a number of useful ways that focus on building structure and its relationship to other design considerations.

Active Learning in Design Education

Active learning is a term that has come to describe the unique approach to design education that architecture schools have long embraced. The studio setting, which is key to this approach, is part lab, part classroom. Sometimes it simulates a design office, while at other times it is a place for tutorial exchange. More often it is akin to a workshop. It operates under a different premise than a typical classroom. It is a place where learning occurs in the context of problem solving and the making of things (or of the making of representations of things to be built). In Donald Schon's terminology, the studio "is a kind of practicum, a virtual world that represents the real world of practice but is relatively free of the pressures, distractions, and risks of the latter" (Schon, 17).

Mark Gelernter provides insight into the nature of studio-based education and how it differs from the conventional university model typified by the lecture hall and based on a positivist view of objective knowledge and the scientific method. Positivism viewed education as a passive activity, one in which the primary goal was transmitting to students the objective facts discovered through empirical research. Architectural education on the other hand has been shaped by alternative theories of learning (e.g. John Dewey and Jean Piaget) that emphasize the active role of the individual in constructing a "self knowledge" based on perceived usefulness (Gelernter, 284). The differences between these two forms of education is striking and helps to explain the difficulty students encounter adjusting between studio courses and the various non-studio classes that generally follow the positivist, lecture-based model of passive learning.

In a design studio, learning is instigated and directed by a problem, normally a building design project. Students are challenged to create a solution that addresses many separate and sometimes conflicting issues. Fundamental to this process is the generation of a hypothesis. A hypothesis in architecture is a design proposal, a three-dimensional form that is tested for its suitability in meeting the conditions of the problem. These conditions range from objective facts such as area requirements of the brief or conformance with the laws of gravity, to more subjective criteria related to expression and aesthetic character.

This aspect of the design process involves a kind of visual speculation that is guided by experience and knowledge. Obviously, with practice and the acquisition of knowledge one becomes better at generating workable design alternatives. The paradox for the design student, however, is that to learn how to design it must be attempted and generally the student lacks the requisite knowledge and skill needed to create an acceptable design proposal. This usually leads to frustration and immobility. To overcome this impasse a student needs to be coached through the process. The design critic fulfills this role either by example or through directed actions (e.g. "create a simple massing model of the major volumes"). A second form of design aid is through the introduction of specific knowledge that can provide resource material to serve as a point of departure. This might be in the form of a particular design precedent or a set of typological components (e.g. various long span structural systems) relevant to the problem.

Despite the advantage that knowledge or 'content' might seem to offer in assisting the design process, many studio critics resist this approach. Some maintain a traditional view that studio focus exclusively on the synthetic aspect of design and assume that relevant knowledge is obtained in non-studio courses. In this approach a student working on a design project and faced with the need to select and configure a structural system would rely on the knowledge gained in a separate course on structures or building technology. The timing of such a course as well as the relevance of the course content typically do not match the studio requirements. Objective knowledge or facts learned in a passive context and not applied to problem solving are quickly forgotten. Also the constant revision and shifting of curriculums as well as the migration of studio teachers between levels further erodes the possibility of establishing coordination and continuity.

On the other hand, a design curriculum that adopts the studio-based learning model exclusively must carefully outline the sequence and content of studios to insure that a minimum level of skill, knowledge, and conceptual understanding required for professional competency (e.g. the topics identified by NAAB) is provided to all students. Studio projects would need to be designed to meet learning objectives across the curriculum and sequenced accordingly. The difficulty of implementing such a scheme probably makes a total studio curriculum unachievable. On a limited scale, Ed Allen's description of a second and parallel studio for technical teaching is an experiment in incorporating technical content into a design studio setting (Allen). Despite the advantages of this approach, it is improbable that any program would devote the manpower resources required to convert large lecture class teaching to the relatively inefficient studio-based model. However the lessons pointed out in Allen's essay can be incorporated into large, non-studio classes with certain adjustments and compromises. The essential point is that a design problem creates the need for specific knowledge to develop and test a design, and that this interaction of knowledge acquisition and application enhances learning.

The Case Study: Content for Design Studio

A well chosen, carefully documented case study supports the design process by providing useful knowledge specific to the design problem at the time when it is most needed. If a case study is made by students in the context of a design problem they are working on, it takes on a role much different than a research assignment in a non-design oriented course. The value of knowledge gained in the exercise becomes clear as students make the connection between a hypothetical design project and an actual built design. Most important, the exercise of making the case study is a valuable teaching opportunity that provides the design instructor a chance to discuss the relevance and relationship of specific issues (e.g. building technology) to the design problem at hand. In addition, a rigorous examination of a built work will inform an understanding of the design process itself. learning.

A Tectonic Case Study: Structure / Envelope

The following is a description of a case study exercise used in a mid-level architectural design studio focused on building technology, specifically structure and envelope. Emphasis on exposed well-detailed structures, materials, and their expression led to the assignment being called the Tectonic Case Study. Although the technical aspects of the case study project are highlighted, documentation and analysis of the building design is not restricted to these issues.

In the first phase of the assignment students form teams and select a case study from a list of available choices. The list is composed of contemporary built works that have certain characteristics coinciding with topics explored in the studio design project.
These include:

- medium to long-span roof design.
- repetitive structural bay system.
- structural framing and assembly.
- natural lighting and/or passive environ- mental design features.

Additionally, for each case study considered, there must be documentation available that is detailed and revealing of the construction (wall sections, development drawings of key details, etc.). Books, journals and other publications containing information are located and placed on reserve. In some cases construction document sets are used. The last criterion is that the case study should be an exemplary building design. Typically the availability of documentation through monographs and high quality journals ensures that selected projects are recognized for their overall design excellence in addition to their tectonic attributes.

With resources at hand in the studio, the actual exploration of the case study begins. Precedent analysis requires certain skills that develop with practice and guidance. There are many techniques for investigating a precedent, yet perhaps the most valuable is asking the right questions. In studio, discussions between the team members and the instructor follow a format similar to a design critique. Verbal reasoning is supplemented by visual thinking in the form of freehand drawing and sketch models. At this stage it is important that the instructor actively participate in the process by demonstrating from experience how a designer uses drawing as a tool for exploration and discovery. It is worthwhile to emphasize that the same technique of analytical drawing is used in the design process to visualize, test, and explore potential design solutions whether at the scale of a parti or a construction detail. In either case freehand drawing should strive to be proportionally accurate and clearly legible.

During an interview recorded on camera the architect Santiago Calatrava provided a vivid demonstration of his drawing skill (Adda). At one point in the film, Calatrava visually explains the structural system of the soaring entrance hall of his Satolas TGV Station in a series of freehand sketches that accurately describe the curvature and proportions of the enclosure and structural armature. Throughout his career Calatrava has often revealed his skill in drawing. A study of his design drawings shows that the proportions and profiles of his preliminary structural design sketches are generally very close to those of the final engineered structures.

Throughout the first exploratory phase students are encouraged to create simple, diagrammatic models of a structural bay of the project. Extremely basic and reductive in detail, these quickly constructed sketch models are a necessary first step in visualizing the three-dimensional form of the structural system. Often they provide clues into the behavior of the system, especially with regard

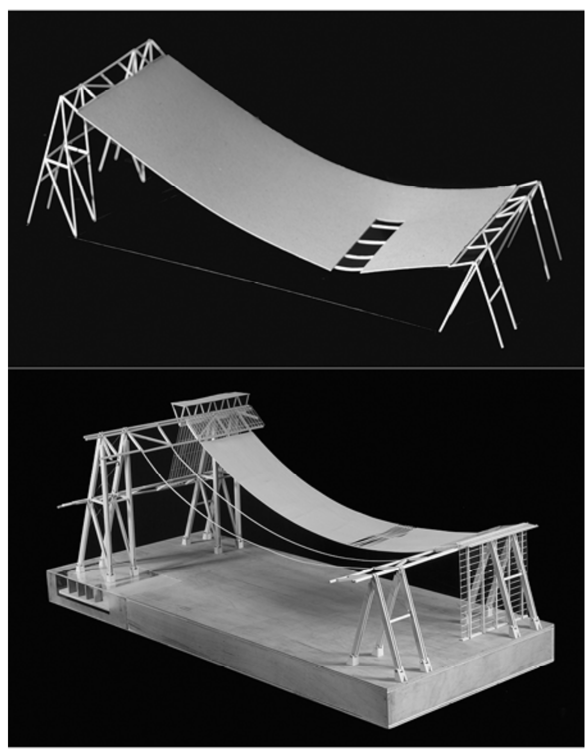

Fig. 1. Study model and Final Model (Hall 26, Hanover Expo, Thomas Herzog + Partner).

to stability. (Fig. 1) Complementing these physical models are three-dimensional drawings that articulate the structure and enclosure systems. These begin as freehand drawings and are then refined into layered computer-drafted digital models. (Fig. 2)

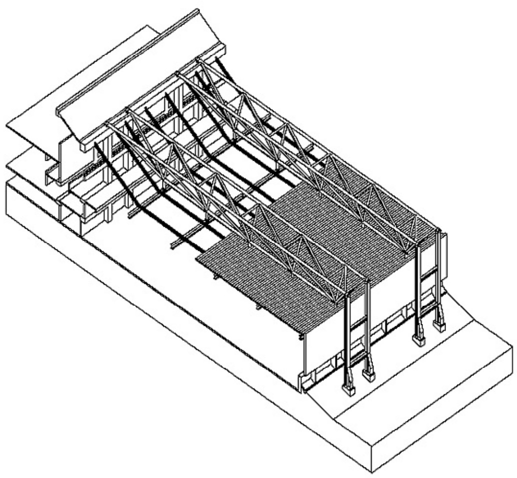

Fig. 2. Cutaway Axon (Exeter Academy Athletic Facilities, Kallman, McKinnell & Wood).

A period of about two weeks is needed to meet with all the case study groups twice and uncover most of the building's mysteries. Most of the basic structural issues such as framing, load path, means for ensuring lateral stability, and so forth are discussed and diagrammed. Likewise questions about the building envelope and other systems are addressed. What is the position of the envelope relative to the structure? What does it consist of and how is it assembled? How does the design control air temperature? Although conversations of this type tend to be lengthy (and not very time efficient), the dialog is one of the most effective ways to motivate students and connect building technology with design. Often students from other teams drop in and out of the discussion and pick up on comments that apply equally to their case study research.

At this stage each team begins the design and construction of a detailed physical model of a single structural bay depicting structure and envelope. In a real sense this becomes a design project as many details of the model, such as the depiction of connections or the fabrication of formally complex elements has to be studied and an appropriate strategy for making it needs to be explored. In some cases the fabrication of a component will require a specially designed secondary device either to support or guide the shaping of the piece. This is a concept we tend to stress; that something might have to be designed in order to make something else. (Fig. 3)

Generally the models are constructed of high-density particle board (MDF) in part due to the precision of cutting that is possible. In some cases soldered metal tubing, Plexiglas, and other materials are used. The connection to the woodshop and the introduction of hand tool and machine shop practices is a conscious decision to extend the means of exploration available to students and further emphasize the value of learning by making. (Fig. 4) The size of a model is determined by the scale, either 1:50 or 1:100 depending on the building's span. A typical project with a 90 m span will produce a model of about a meter in length at a scale of 1:100. Building a scale model of this size and using materials that require fabrication with small tolerances and proper joinery is analogous in many ways to a real construction project. Numerous issues confronted in the model design and its construction are not intrinsically different from those that are routinely encountered on the job site.

Fig. 3. Forming trusses. (Fuhlsbuttel Air Terminal, von Geran, Marg, & Partners)

Fig. 4. The woodshop as an extension of the design studio.

The Structural Transformation Diagram

The *structural transformation diagram* is a tool that helps students understand the concept of structural efficiency. Although most of the case studies have structural systems that are fairly legible, nearly all of the projects have some interesting innovation or sophisticated handling of the load path that can be seen as an improvement over a more conventional design. To begin a conversation about the design features that result in an efficient, highly refined structure, the student team attempts something like the equivalent of reverse engineering. The structural transformation diagram is an imagined process of enhancement beginning with the most basic form of the structural span and by stages, transforms it into the actual structure of the case study.

A typical example is the diagram created for the Exeter Academy Sports Facility, an elegant gymnasium center designed in the seventies by the firm of Kallmann Mckinnell and Woods. (Fig. 5) Beginning with a basic four column frame that defines the bay, successive structural improvements involve transformation to a subdivided framing system with deep edge beams, replacement of the deep beams with open web trusses, displacement of the trusses to the top side of the roof, transformation into 3-D trusses, and finally, transformation of the single column support into paired columns supporting each upper chord member of the truss. The number of “improvement” stages and the specific order is an aspect of the design of the diagram. Although the invented transformation does not intend to represent the original engineering design process, in some cases it may approximate it. The real value of the exercise develops out of the discussion regarding the structural logic of each successive design improvement.

Structural Behavior Performance Model

Another parallel activity in the case study assignment involves an exercise in verification of structural behavior. Termed the structural behavior performance model, each team of students identifies a structural behavior associated with their case study and designs a simple performance model that will visually demonstrate the assumed action. The choice of behavior can range from conditions of member stability to proving the efficiency of a member section.

To enhance the visualization of the behavior for demonstration purposes, soft flexible materials such as polystyrene foam and cardboard are used in the model. Joints are simulated by various means (pins, nuts and bolts, wire, etc.)

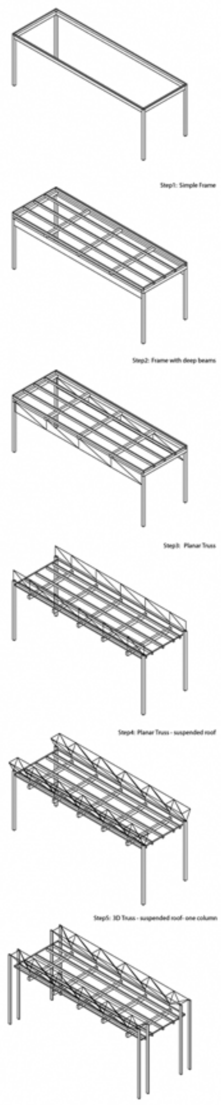

Fig. 5. Structural Transformation Diagram. (Exeter Academy Athletic Facilities)

and loads are placed or hung on the model. The use of polystyrene foam (PSF) enables large deflections to occur with small weights (Kellogg) It is also a material that has thickness and comes in large sheets (insulation), can be shaped easily with a hotwire, and is economical.

There is no real need to make the structural behavior model look like the structure of the case study that it represents. Only that it has the correct characteristics so that the behavior can be tested. In some cases several models are constructed so that one parameter can be modified to test the effect on the behavior. For example, three identical trusses except for the proportions of the panels can be made to test an assumption about how trusses resist shear force. Upon testing it becomes clear how panel proportions (and the inclination of the diagonal member) directly influence the shear capacity of the truss.

This type of active participation in designing the test, constructing the model and the test setup, and finally testing the structure in front of the class causes this assignment to be the most popular project of the semester. The testing requires good communication skills on the part of the instructor if the lessons about structure are to be absorbed by the class as a whole. Students generally become overly concerned with the breakage and need to be reminded of the structural principles that resulted in the failure. Outlining structural relationships on the screen, asking the class to make predictions, and taking measurements and plotting results are some of the ways to focus students' attention on the learning how structures behave. Including questions about the tests on a quiz is also effective!

Documentation of the Case Study

Following the completion of the wood "Tectonic Model", the major finished product of the assignment, each team prepares a set of posters (A2 or approximately 18in x 24in) summarizing the research on the case study. Documentation of the case study building includes views, selected published drawings as well as new drawings prepared by the team. New constructed drawings vary with each project but are created to dissect the building in three dimensions and describe the systems analytically using cutaway sections, transparent volumetrics, pulled apart axons, and layered digital models. Some rendered computer models are created to clarify systems. Representational renderings are discouraged unless they serve to illustrate the tectonic qualities of the design. Often the rendered view of a complex joint explains the logic of the design and the artistry of its production.

Perhaps even more important than the model, the documentation of each case study contributes to a digital precedent research document that is distributed to each member of the studio. This visual reference material provides specific examples with detailed analyses that are specific to the functional and formal characteristics of the new design project the studio will begin work on.

Conclusion

Case study or precedent research is a standard method for introducing knowledge or *content* into design studio education. The case study assignment provides a frame for creating a foundation of knowledge appropriate to the task at hand. The task may be a design problem with greater focus on a limited range of issues. In the example referred to here, an emphasis is placed on building technology, specifically structural span, envelope, and passive environmental controls. Consequently, the Tectonic Case Study targets these issues and identifies a broad selection of contemporary buildings notable as exemplary works that artfully address technical questions and provide innovative design solutions.

In conclusion it is observed that students develop a passionate attachment to an in-depth research project focused on an exemplary building of the student's choice. Whether the project is presented as a studio-based case study exercise or a term project in a structures lecture course has implications on the timing, schedule, and the form of teacher-student interaction. In either format, however, the commitment and intensity of interest on the part of the student confirms case study learning as an excellent pedagogical method for teaching structures.

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