"Intuition vs. Theory in Beginning Architectural Design"

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Abstract:

Beginning architecture and architectural engineering students at Oklahoma State University's School of Architecture are not exposed to structural theory design courses until the third year of their curriculum. This can be seen as a detriment to the design courses during the first two years, where students must rely on intuition when addressing structural issues. This paper will explore one possibility for introducing structural concepts in the initial semester of the student's career.

One project in the first semester 'Introduction to Architecture' course focuses on architectural engineering, and consists of student teams designing and building a model structure that is load tested. To test the effects of structural knowledge on the design process, three control groups of students were established for the project, with each given varying amounts of structural information for use in their design. The first group was provided no structural information and had to rely on intuition, the second group was given limited information, and the third group was given detailed information on structural concepts. The results of the study will be discussed, and recommendations will be given on providing beginning architectural engineering students with basic structural concepts for their use in early design courses.

Historically, the School of Architecture at Oklahoma State University has concentrated on architectural design basics during the first two years of a student's education, only exposing students to structural design after they are admitted to the professional school at the start of their third year. Because of this, first and second year architecture and architectural engineering students are lacking in the knowledge of how structures influence the design process, and how simple concepts applied can greatly enhance the structural stability of their design. These first two years of a student's curriculum without formal exposure to basic engineering concepts and theories prohibits the student from applying structural concepts to their work in the design studio courses, which can lead to misconceptions about structures in the upper level design courses. As educator Mario Salvadori states, "Even though the functional and structural components of architecture are most often distinct, structures has always had a decisive influence on design."[2] The issue of structures should be addressed by the student in these early design studios, so that a base of knowledge about structures can be established that can be built upon in subsequent courses. If this is not done, the results are third year students who cannot properly incorporate structural requirements into their designs. This past semester, a study was implemented to evaluate the effects of theory based information presented to students versus leaving the students to use their intuition with regards to structures. Helping the beginning design student better

understand basic structural concepts that can be incorporated into the design process should result in design that is structurally stable.

The question becomes how to measure the effectiveness of exposing students to structural concepts, and how to be efficient in presenting basic theory and concepts to the students. To exam these questions, a study was performed with first semester architectural and architectural engineering students in the two credit hour "Introduction to Architecture" course that is required for all students in the school of architecture. The basis of this course is to give the student an idea of what to expect as an architecture or architectural engineering student, enabling the student to experience the studio life without committing to a full semester, six credit hour studio design course.

Arch 1112 Project Two F 03
School of Architecture Oklahoma State University

Construct "A Tower"

The practice of Architecture is a complex integration of aesthetic and technical systems that typically requires a team of experts in related fields working together to solve a design problem. The primary role of the architect is to work with a client to establish a design direction – a concept – that is a direct result of the project goals, the needs of the user group, and the vision of the architects and architectural engineers. Architectural engineers play an integral role in the creation of architecture, as they are responsible for the design and analysis of the required technical systems.

Imagine that you own an architectural engineering consulting firm, and have just been contacted by the architect of a prestigious international firm. She has hired you to propose a structural concept for a new tower to be built in New York City. The tower will occupy a prominent site on "Times Square", and will support the load of several billboards advertising various events in the city. Site constraints suggest that a high area to one side of the structure will be the most visible location for these advertisements.

The tower may be no taller than forty feet (20" in scale) and no shorter than thirty feet (15" in scale), but it will have to support a load that is cantilevered eight feet (4") outwards from the center of the main structure. The cantilevered load will be located near the upper reaches of the structure, at least thirty feet off the ground. The footprint of the structure must stay within a ten foot (5") diameter area, and pedestrians must be allowed to pass through the base of the tower at the ground level.

In the next hour, you and your teammates must propose an innovative structural concept to present to the architect. You will do so in model form, at ½"=1'-0" scale. All proposals will be evaluated for aesthetics, strength and durability. Structural soundness will be tested by Professors Steve O'Hara and John Phillips, both faculty of the Architectural Engineering program at OSU. Good Luck!

Project Due:	**Structural Testing begins in one hour.... GO!**
Reading Assignment:	**"A Museum of Substance"**
Next Week:	**Class meets at 9:30am on Friday, Nov 21.....**

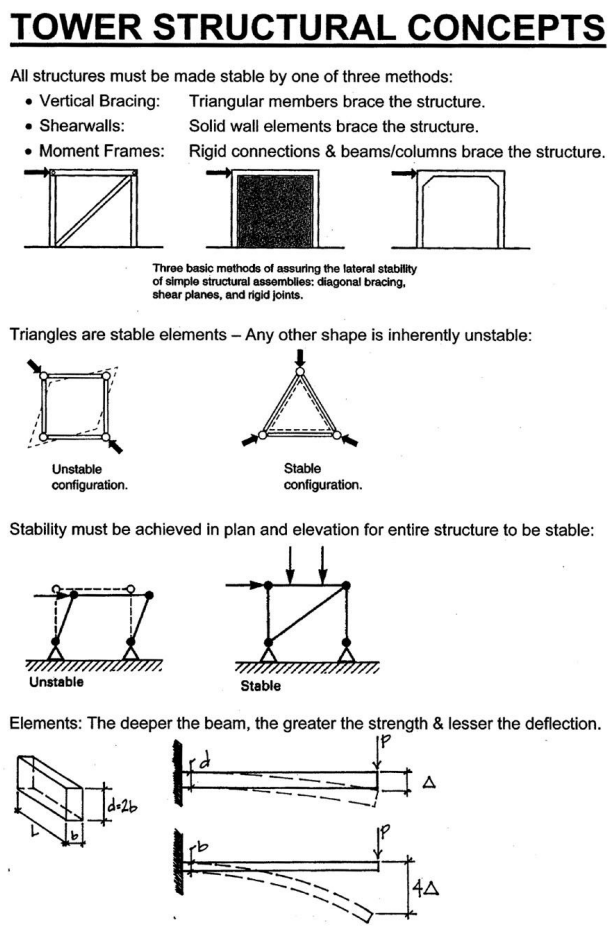
Tower project program

Tower construction materials

One of the projects during the semester, titled "Construct A Tower"[2], gives the class insight into architectural engineering. The project is a team project, with groups of four students designing and building a structural tower within 90 minutes from a limited supply of materials. The tower is to be between 15 to 20 inches in height and is to be attached to a base within a 5 inch diameter circle. Additionally, an extension from the tower must be built near the top of the tower, and must extend out from the edge of the 5 inch diameter base an extra 2 inches. The materials for use by the students include a controlled number of plastic straws, wood dowels, card stock, and hot glue. Once designed and constructed, a series of weights are attached to the tower extension to determine the structural strength and stability of the towers. This project gives the students a practical experience in dealing with structural engineering. The students interact as a team and must make quick decisions in designing and constructing their tower. Architectural engineering professors are present in the class during this project, acting as guest critics and answering questions about structural design.

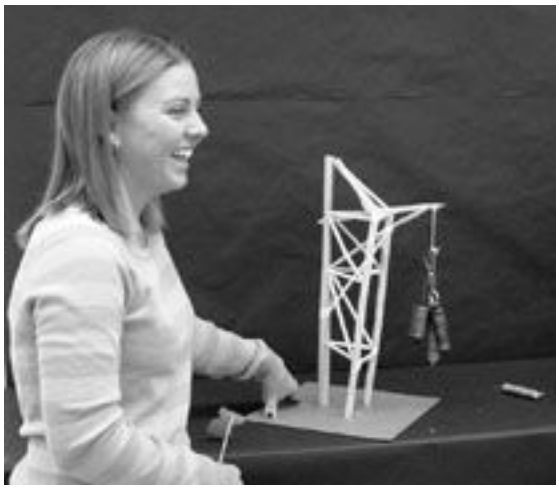
Upon completion, the towers are tested to determine the amount of weight that can be supported from the extension of the tower. To test intuition versus theory based knowledge, the class was

broken into three groups, each meeting on a separate day. For each of the three groups, varying amounts of structural theory and concepts were presented. Group 1 was given no information on structural design, and had to rely on their intuition when designing and constructing their tower. Group 2 was shown images of tower types and basic structural concepts, but given no lecture on structural theory. These images consisted of basic structural concepts, and images of existing structural towers that utilize the three basic methods of stability: Vertical bracing, Shearwall, or Rigid Frame construction. Group 3 was shown an enhanced version of the images of towers and concepts, as well as given a handout and short lecture on structural theory and concepts, and how these could be incorporated into the tower design to produce an end product that is structurally stable. Each group was given equal amounts of time and materials to construct the towers.



Informational handout[3]

Team approach to design



Successful load test

At the end of the 90 minute time period, the student teams present their designs to the class, describing the structural concepts implemented in their design. The student teams are also asked to give an opinion on how their tower will perform under the applied loading. Weights are then hung from the tower extension in one pound increments, with the students determining when to stop loading the tower. They are not required to load until failure, but often the competitive nature of the student teams result in collapse in an effort to be the tower that supports the largest load. When the towers do not perform as the students anticipated, the engineering professors

discuss structural concepts that could be incorporated into the designs that may lead to stronger and more stable structures.

Explaining structural concepts

Successfully loaded tower

At the completion of this study, the results were reviewed to determine if one of the groups performed better than the others. It was the findings of this study that determined there was no clear cut deciding factor on which group constructed the strongest and most stable towers. It was initially thought that the group provided no structural theory or concepts would perform the least successful of the three groups, but this was not the case. One reason that there was no dominant group may have been due to failures of connections in the towers, which prevented many of the towers from being loaded to full member capacity. There were towers from each of the three days that performed outstanding under load testing and were thought of as highly successful towers, but there were also some spectacular failures. Each of these presented the opportunity for the engineering faculty to discuss the positive aspects of the successful designs, and what might be designed differently on those that did not fair as well to make them structurally stable.

Each of the three days had approximately 8 student teams, and for this initial year of the study the average load supported by the towers from each of the three groups was one measure used to evaluate the success of the project. Overall results of the towers tested for the project resulted in an average supported load, prior to failure of the towers of 2.13 lbs for Group 1(a low of 1.0 lb and a high of 5.0 lbs), 2.00 lbs for Group 2(a low of 1.0 lb and a high of 3.0 lbs), and 2.50 lbs for Group 3(a low of 1.0 lb and a high of 4.0 lbs). The tower that supported the greatest load overall occurred in group 1, with a supporting load of 5.00 lbs, and the structure did not fail under this load. If a supported loading of 3.0 lbs is set as a benchmark for a successful tower design, then group 3 would be the most successful of the groups. The number of towers that supported 3.0 lbs or more for each group was: one for Group 1, two for Group 2, and four for Group 3, suggesting that the enhanced presentation of structural theories and concepts in addition to the tower images aided the students in their design.

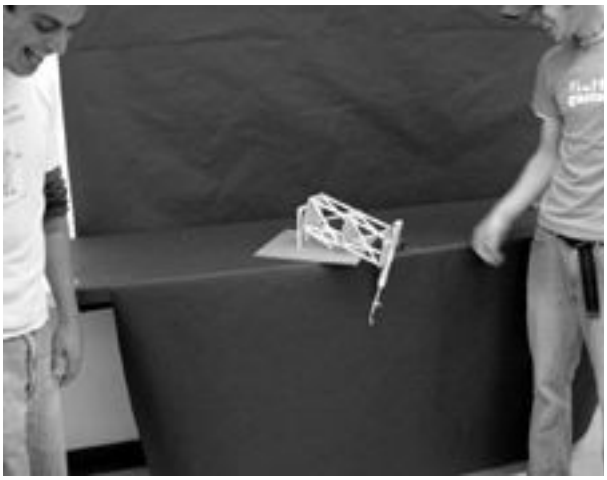
The towers from Groups 2 and 3, being those groups provided information on structural theory and concepts, were thought of as more structurally feasible overall than those produced in

Group 1. Their use of the information provided appeared to influence the tower designs such that they were overall structurally stable a greater amount of the time than those in Group 1.

Initial load = 1.0 lb

Loading = 2.0 lb

Loading = 3.0 lb



Loading = 4.0 lb = Collapse

Towers are loaded by the students, with some teams choosing to load to failure.

This study is in its first year, and should continue over the next few years to establish a baseline of data that can be used to evaluate the results of the program. The outcome of this initial trial run of the study have been encouraging, with an enthusiastic interest from the students in the aspect of structural engineering and its influence on design. Discussions with the students were insightful and the students seemed to react positively to the interaction with the engineering professors. It is our intention that the students continue to interact with the engineering professors during the initial two years of the curriculum so that they can be better prepared for incorporating structures into their designs, and so they will not hesitate to consult us on engineering questions throughout their academic career.

Though the study has been thought of as a success, some recommendations on improvements to the study can be made. These include a method to streamline the information provided to the students. In particular, the third group was given a large amount of information, and it appears

that this may have inundated the students to a point that much of the information was disregarded. Condensed information as a quick reference may help the students utilize the

Preparing for load test

Learning from our mistakes

structural concepts more efficiently, without overwhelming them. In addition, a prevalent condition encountered during the testing process was that a large number of the towers failed not because of structural instabilities, but due to inadequate connection of the tower members. This may be a result of the limited time and materials given to the students for construction of the towers. It is our opinion that this project is not the setting to introduce the complex nature of connections to students, so a review of the construction materials used will be made to determine if a change could help reduce the number of connection failures during testing. Additionally, suggestions could be made to the students on construction methods that may provide stronger connections.

With formal exposure to structural engineering courses not occurring in a student's education until the third year of the curriculum, it is imperative that structural theory and concepts continue to be introduced in the beginning design studios. These concepts and theories will enable the student to account for the influence that structure has on architectural design, and enable the student to better understand the requirements necessary to design a stable structure. Through continued formal and informal discussions with beginning architecture and architectural engineering students, we at Oklahoma State University will strive to enhance the student's knowledge of structures and how it can influence the design process.

1. Salvadori, Mario: "Why Buildings Stand Up – The Strength of Architecture", W.W. Norton & Company, Inc., 1980.
2. Bilbeisi, Suzanne: "Construct A Tower", School of Architecture, Oklahoma State University.
3. Schodek, Daniel L.: "Structures", Prentice Hall, 2001, 4th ed.

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John Phillips, an assistant professor of architectural engineering, was a volunteer instructor in the first semester "Construct A Tower" project. He also teaches Analysis I, Foundations, Structures: Timber Steel & Concrete, Steel II, and Steel III courses, as well as being a contributing faculty member to the comprehensive design studio. Professor Phillips is a registered engineer in the state of Texas, and a structural consultant for Brown Engineering in Stillwater, Oklahoma.