Active Learning in a Reinforced Concrete Design Class

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Teaching structural design to construction management students usually means finding a balance point between an adequate coverage of the design concepts and too much coverage of the engineering details. Too much detail and the students become confused or lost in a process used to train engineers, but too little coverage of the design concepts and students' ability to interact with design professionals suffer. A reinforced concrete class was conducted using an active-learning approach. For the first portion of the semester, the class members took on roles in a construction company building a scale model concrete building. Once the model was complete, the class returned to a traditional lecture format where the completed structure was used to facilitate discussion of load tracing to determine moments and shears for components of a structure. Students seemed more willing to concentrate on the design issues.

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Introduction

The idea was simple. If undergraduate construction management students were more interested and excited about learning in design classes then learning would be enhanced. Comments by students frequently include remarks like, "I am not going to be an engineer or an architect. I don't see why we are doing this." In fact, the purpose of design classes for construction management students is to teach broad concepts to enhance the ability to work with design professionals such as engineers and architects. The accreditation standards of the American Council for Construction Education (ACCE), state "The Constructor must have an understanding of the contribution of the design disciplines' processes. The Constructor must be able to communicate with the design professionals, and should be capable of participating during the planning phase of design-build projects." (ACCE, 2006). Graduate students in construction have benefited from active learning in the classroom (O'Brien, Soibelman, & Elvin, 2003). Construction management students are often action and results oriented. Gier showed that the active learning model caused students to remain physically and mentally active through group activities, reflection, and drawing analogies to construction management (Gier, 2004). Arumala used student-centered activities – such as measuring deflection and strain in a steel beam – to help students grasp material in a structures class. Results indicated that students' active participation improved classroom performance (Arumala, 2002). Within a structures curriculum, research has shown that "student motivation level and degree of enthusiasm can be noticeably improved" by the construction of an actual structure which will allow the student to have a practical context for understanding the principles introduced (Hein & Williams, 1990).

A New Approach is Needed

Determining the balance point between adequate coverage of design concepts and too much detail is difficult. Manipulation of complex mathematical formulas or use of arcane design tables does little to illuminate broad concepts to future construction managers. Students become hopelessly confused or lost in a process used to teach engineers. Most construction management students (appropriately) are not exposed to methods of advanced structural analysis. In the education of a structural engineer, a great deal of course work is devoted to methods of structural analysis and load tracing apart from design of steel, timber and concrete structures. Design courses focus on selection of members or design of connections to meet design codes. Use of the engineering approach has been unsatisfying for construction management students and frustrating for construction management teachers.

A partial list of relevant and useful structural design concepts that should be presented to construction management students might include developing the ability of the student to observe a structure – whether completed or under construction – or structural drawings and make intuitive observations about the distribution of loads (load tracing), location of major axial, bending and shear stresses and likely deflections. More specific concepts can be identified as well.

Method

The students in the concrete class had completed a statics course as a prerequisite to the course. The first portion of the semester was consumed by the construction of model buildings. The final portion of the semester was used to conduct load tracing through the elements of the structure and to analyze design of beams, columns and footings. The first trial was in the fall semester of 2004. The process was repeated in the fall semesters of 2005 and 2006. In each successive class, incremental changes were made based on previous experience. In the fall 2006 semester, the class introduction and model preconstruction took the first 4 class meetings. The model construction phase took the next 12 class meetings. The final phase was classroom instruction which took the final 13 class meetings.

One of the major changes in 2006 involved team size and organization. In 2004 and 2005, the class was divided into teams of six to eight people working on one building per team. So each year, multiple buildings were constructed. The method of construction, e.g., tying rebar, varied between groups depending on the actual experiences of the team members. In 2006, in the interest of achieving better quality, the instructor decided to build only one building. Concentrating on one building eliminated competition between the teams, but enhanced quality by focusing students on a particular area. The work was performed in an environment similar to what students would face at work. The environment involved different aspects of construction management, beginning with signing the construction contract and ending with topping out of the structure.

Project Management

In the fall 2006 semester, the course had 36 construction management students. The instructor selected a student to serve as project manager and a student to serve as the owner's agent or inspector. The selection process was aided by a brief questionnaire all students answered at the first class meeting. The data indicated the construction experience of each student and the students' perceived strengths and skills. Students had an opportunity to request a specific job such as project manager, owner's representative, field engineer or superintendent. After the instructor selected the owner's representative and project manager, the project manager was allowed to select a team consisting of a field engineer, superintendent, ironworker foreman, concrete foreman and form crew foreman. The three foremen selected crews from the remainder of the class, accounting for all the students. For the construction phase of the class, authority was delegated according to an organizational chart submitted by the project manager.

Preconstruction Phase

The head of the construction management was recruited to act as the owner of the project. The project manager, acting as the contractor, was required to sign a contract in a formal meeting with the head of the construction program. The custom contract had a completion date, a termination clause, and brief general conditions written just for the project. Several submittals were required prior to receiving a "Notice to Proceed". The project manager was required to submit an organization chart, a safety plan, a bar chart schedule, and a schedule of values. A completion date was specified. Upon approval of the submittals, a "Notice to Proceed" was issued and construction began.

Construction Phase

During the construction phase, class meetings were brief. The instructor staged "project meetings" with the owner's representative, project manager, field engineer and superintendent while the rest of the class observed. Minutes were kept. The instructor's concerns were expressed and questions were answered. Questions for the owner were written on the top of a two-part form. Answers were returned on the lower half. The general conditions required the contractor to maintain an office in the laboratory where the model building was constructed and to furnish space for the owner's representative. Both the contractor and the owner's representative were required to maintain files of all drawings and correspondence. The instructor required the owner's representative to maintain a daily log.

The basic plans for the scale model building were presented to the students as a series of engineer's sketches. Figure 1 shows the footing layout. The models were constructed in wooden frames filled with compacted soil. The frames were constructed with 2x4 walls and a plywood bottom. Figure 2 shows a section of a footing and the wood frame. The scale of the model is one inch equals one foot. The overall footprint of the model is almost four feet square by three feet in height. The model building consists of two floors supported by six columns on spread footings. The basic idea for the model came from a basic text. (Shaeffer, 1992) Figure 3 shows a footing section. Fifteen sketches showing all the design details were supplied to the students. The concrete mix was adapted from a sand mix used in a building construction class at Auburn University. (Hein, 1997)

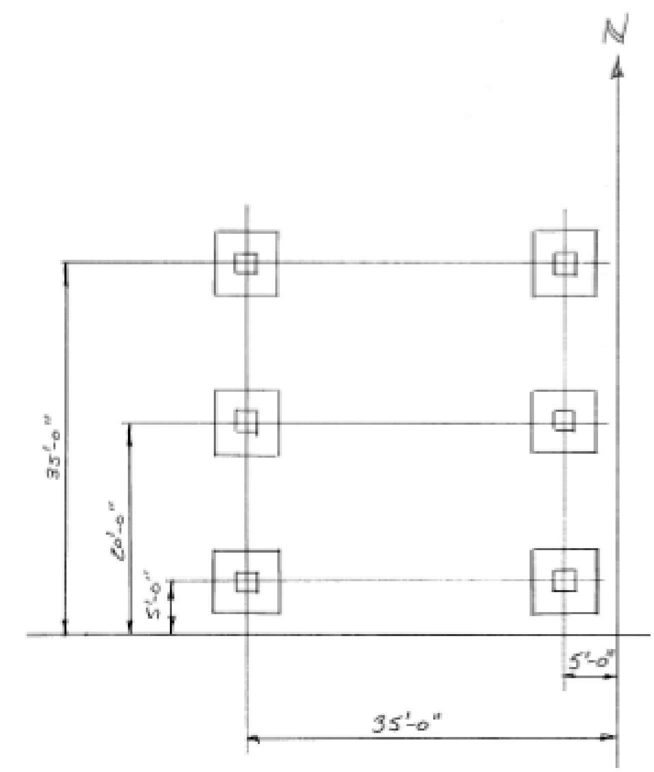

Figure 1: Footing Layout Sketch

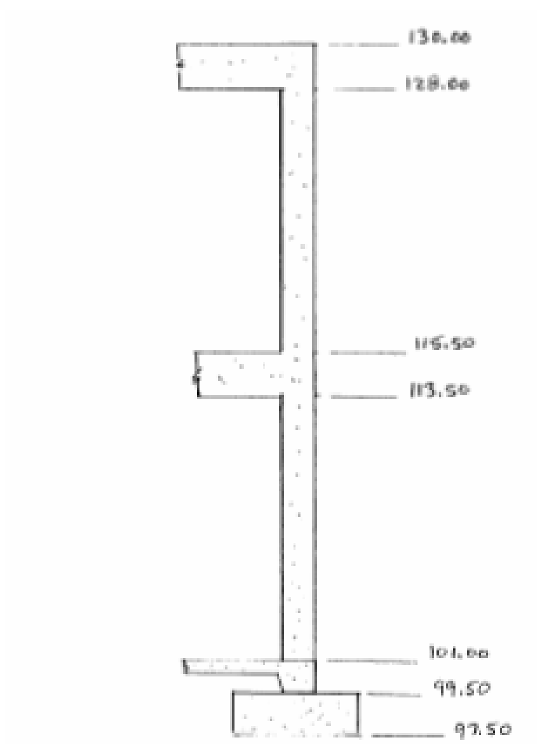

Figure 2: Building Section Sketch

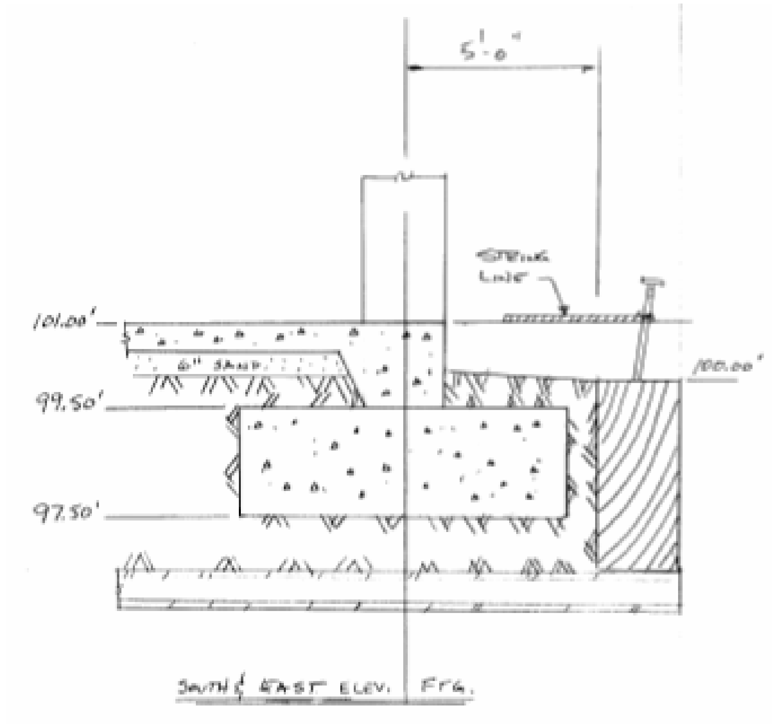

Figure 3: Footing Section Sketch

Progress was recorded by a stationary camera positioned above the construction site. Students maintained a project website with a webcam and the project documents. The slab on grade included fibermesh in the concrete. Figure 4 shows placement of the slab on grade. The second floor and roof were designed as joist construction with pans. The "pans" were formed by 2x4 blocks with a ¼" taper on all sides. 12 gauge suspended ceiling tie wires were used for all beam and column reinforcement. 19 gauge electric fence wire was used for ties and stirrups. ½" hardware cloth was used where the engineer's sketch called for #4 bars both ways with 6" spacing in footings and slabs. Figure 5 shows placement of the second floor. Figure 6 shows stripping of the second floor forms. Figure 7 shows placement of the roof. Figure 8 shows the students using an alignment jig for construction of forms. The jig provided vertical and horizontal control. Figure 9 shows the structure prior to topping out of the roof.

Figure 4: Placing the Slab On Grade

Figure 5: Placing the Second Floor

Figure 6: Stripping Second Floor Forms

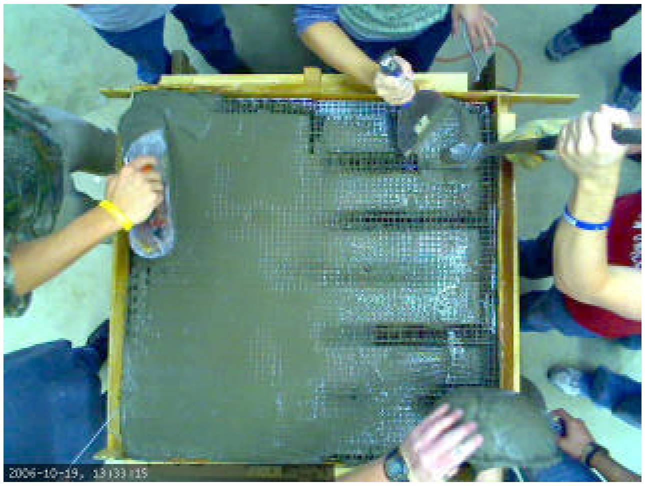

Figure 7: Placing the Roof

Figure 8: Aligning the Forms

Figure 9: Near Completion

Post Construction Phase

After the construction phase, the contract was "complete" and the class returned to a traditional lecture format. The majority of the lecture portion was load tracing using the American Concrete

Institute (ACI) coefficients to determine moments and shears for major components of the structure. In-class exams required students to trace given live and dead loads on slabs through the structure. Spreadsheets were used to analyze beams, columns and footings in the structure.

Students wrote a paper summarizing the results of the analysis. Students were also required to write about a problem that arose during the construction phase and a proposed solution. Samples of student comments include:

- "Being able to put my hands on this project helped me to understand the way we traced the load."
- "The majority of people today learn the most quickly and easily through hands on work and by personally experiencing situations."
- "…this would help visual learners such as myself to further understand the load tracing and how changes in the spreadsheet actually affect the concrete structure's strength and load carrying ability."

Grading

Grades for the class included peer grading for the construction phase, exams and a written paper. The point breakdown is shown in Table1.

Table 1

Point Distribution

Item	Points
Model Construction	
Milestone 1	100
Milestone 2	100
Topping out	100
Exams	300
Load tracing	
Paper	100
Concrete problems	
Design spreadsheets	
Total	700

A schedule of values served as the peer grading device. The schedule of values was a matrix matching every student with the peers giving the grade. Peer grading required a description of the duties of each job. The contractor was required to submit this schedule of values to the owner's representative three times; 1) after completion of the slab on grade, 2) after completion of the second floor slab, and 3) after topping out and final removal of forms. Each grade was for 100 points. The owner's representative completed the matrix on a spreadsheet for submittal to the instructor. The weights given to each student by different sources are shown in Table 2. The owner's representative contributed 60% to most students' grades. The owner's representative's initial grade assignment was reviewed by the instructor. The large portion of the grade assigned by the owner's representative (and by default, the instructor) reflected the instructor's caution in a first effort at peer grading.

Table 2

Peer Grading Weights

Student	**Source of Grade**
Project Manager	20%-field engineer 20%-superintendent 60%-owner's representative
Field Engineer	30%-project manager 10%-superintendent 60%-owner's representative
Superintendent	20%-project manager 5%-field engineer 15%-crew foremen 60%-owner's representative
Crew Foremen Ironworker Concrete Forms	20%-project manager 10%-field engineer 10%-crew 60%-owner's representative
Crew Members	20%-crew foreman 20%-other crew members 60%-owner's representative
Owner's Representative	20%-project manager 10%- field engineer 10%-superintendent 60%-instructor

Conclusions

Students enjoyed the opportunity to do a hands-on project. Students seemed more willing to concentrate on design issues when presented in a construction management context. A hands-on experience in a structures class can enhance the learning experience for construction management students. Peer grading increases student interest in the project, but must be carefully designed to encourage real evaluation by students. After this experience, the instructor felt more comfortable assigning a larger portion of the peer grading to student control. Focusing student attention on a single type of work on the project, such as tying rebar, is effective as well. The instructor considered presenting the structural theory as each element of the model was constructed "from the ground up." However, the instructor has always taught structures "from the top down" and was not able to devise a practical way to teach "from the ground up," since loads would not be known. The instructor found that the model building process greatly enhanced the students' ability to visualize the structure and was a great aid in teaching load tracing.

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