Group Projects

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Abstract

Accreditation boards and industry are telling educators that the ability to work together in groups or teams is an important skill for engineering and construction graduates to have. As a result we are trying to integrate this more fully into our classes. This paper presents several group projects that have been tried in structural engineering classes over the last two years in the Architectural Engineering and Construction Science programs here at Kansas State University. Positive results and areas of concern will be discussed and examples of student work and feedback will be included.

Introduction

There is much talk these days about incorporating group work into undergraduate classes. Employer surveys indicate the people who are employing our engineering and construction science graduates believe the ability to work effectively in teams and to communicate with peers, consultants, and clients are very important to being successful on the job. Accreditation boards are starting to recognize this and have made the development of students' teamwork skills a desired outcome. In addition, those involved in education theory and learning styles have concluded most students will perform better and learn more when collaborating with classmates. In light of the above information, we have been integrating more team-based projects into the structural design and construction classes here at Kansas State University. This has been a learning experience for faculty and students alike, with some successes along with a lot of room for improvement.

Decisions to include certain group projects in structural classes were based on relevance and perceived benefit to the students. We tried to pick projects that represented the types of things graduates might be expected to do on the job, encouraged deeper thought and life-long learning, and/or were too complex for individual work.

Projects

The structural faculty in the Architectural Engineering and Construction Science and Management department here at Kansas State University have been purposely integrating group projects into Timber Structures, Steel Theory/Design, Concrete Theory/Design, Masonry Structures, and Steel Construction classes over the last two years. The types of projects used in these classes have included analysis, design, evaluation and research. Each project was developed with learning objectives and enhancement of the student's experience in the class in mind. The projects presented in this paper are from the structural classes taught by the author, Professor Charles Bissey and Professor Craig Baltimore.

Analysis projects are used to help students begin to look at the overall structural system, types of stresses in members, load path and erection sequences. These types of projects have been used in Steel Theory/Design, Timber Structures and Steel Construction Classes. The students work in assigned teams to analyze an assigned or group-chosen approved structure and then communicate their conclusions in written and graphic form.

Design projects generally focus on putting together and applying the pieces learned in class. These projects tend to be fairly open-ended with room for individual interpretation, assumptions, and engineering judgment. In the Steel Theory/Design, Masonry Structures and Timber Structures classes the design projects have required team efforts to design and document a small building structure in lieu of a comprehensive final exam. The students work in assigned teams to perform a preliminary design based on material they have learned in class. The teams generally all work on one building with minor variations. Each team is required to turn in calculations, plans, sketches and individual journals. The class professor serves as "senior engineer", providing guidance during the design process and assessing the final project for accuracy and clarity. Smaller design projects have also been used in the Concrete Theory/Design classes.

Evaluation projects have been used in the Steel Theory/Design classes to reinforce the structural fundamentals of load path and material behavior. These projects generally involved analysis of a structural failure, with results presented in written and oral form. Formal presentation of projects to the class provides practice using oral communication skills and allows the class to see a number of different failures in addition to the one they have researched in detail.

Research projects are generally done on a project of the team's choice within a broad topic area. These projects are meant to spark student's interest in structural engineering and construction topics and encourage life-long learning while reinforcing important structural principles. Projects are usually presented in written and oral form. These projects have been used in all the structural classes mentioned.

Project Examples

Analysis Projects:
Load path analysis has been done on various structures, including the Mamba roller coaster at Worlds of Fun in Kansas City, the Environmental Education Center in Massachusetts, the Reno Gateway Bridge, the Kansas State University Stadium expansion, the Cockrell Butterfly Center in Houston, the Artsgarden in Indianapolis, and many more.

Examples from student group projects describing the load path through structures chosen by each group are shown in Figure 1, Figure 2 and Figure 3. Students did not always get the path exactly right, but the project forced them to start thinking about how loads travel through a structure and about how to communicate it to someone else.

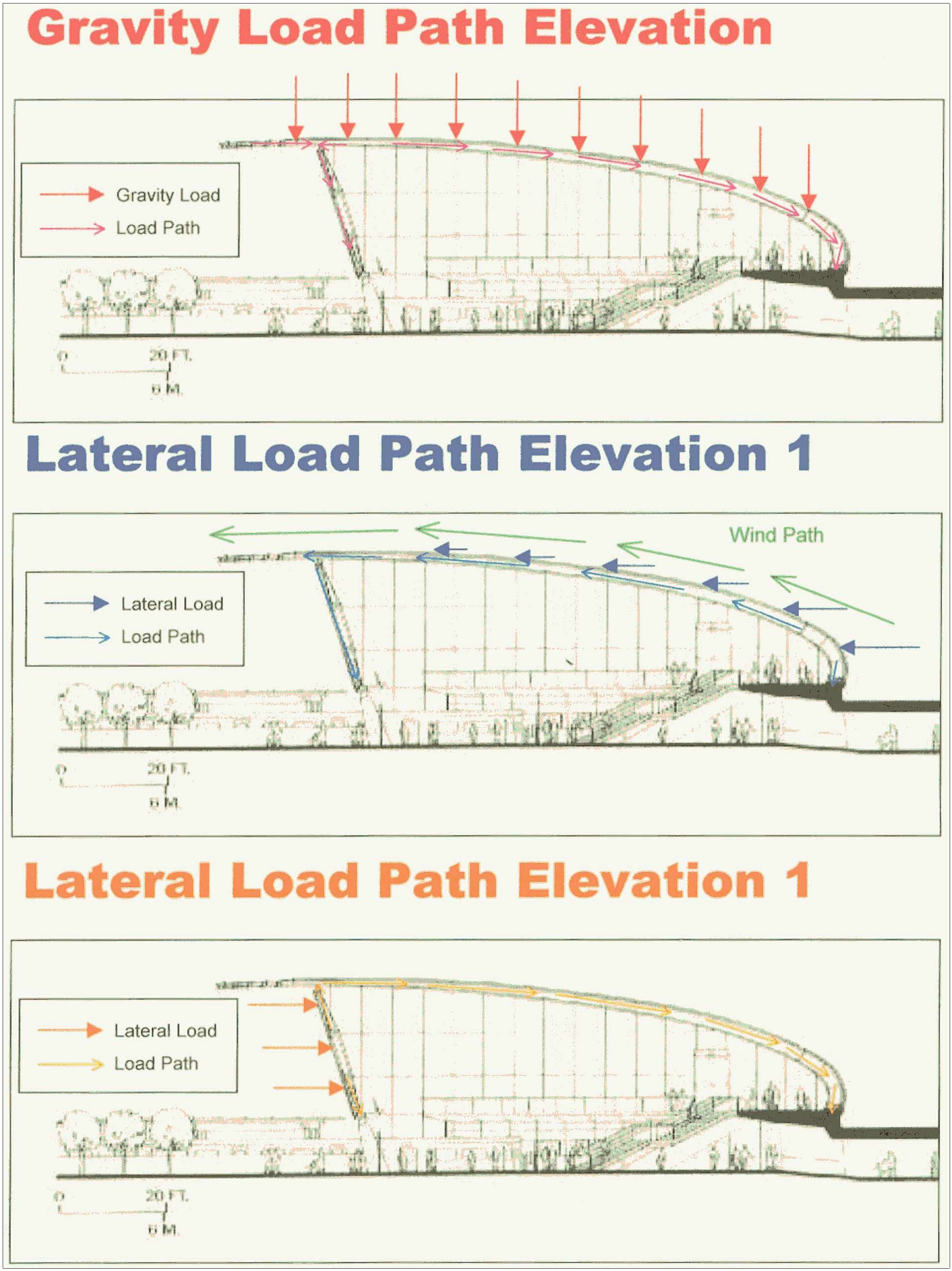

Figure 1: Load Path Diagrams for London Underground's Jubilee Line Terminal Station[1]

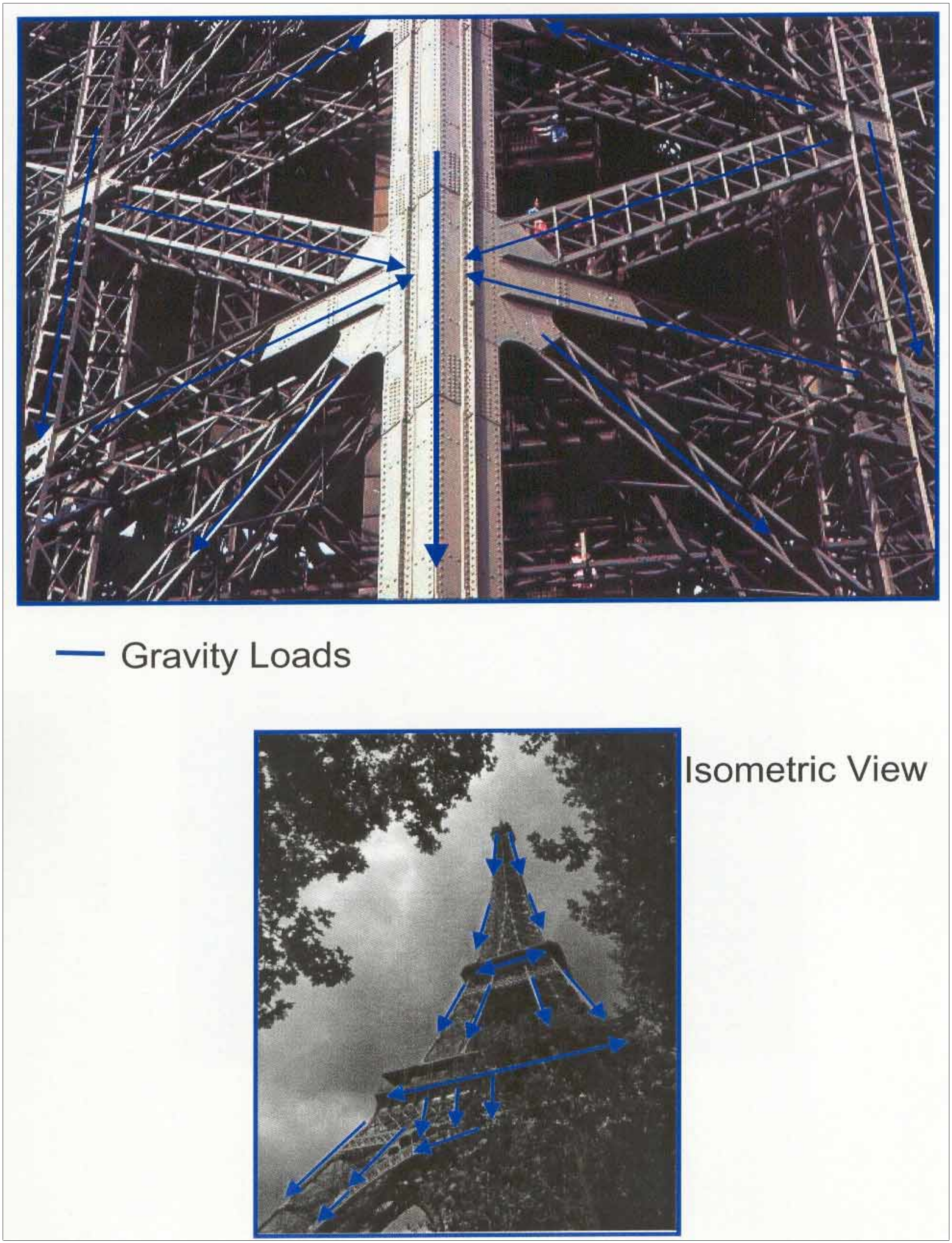

Figure 2: Gravity Load Path for Eiffel Tower[2]

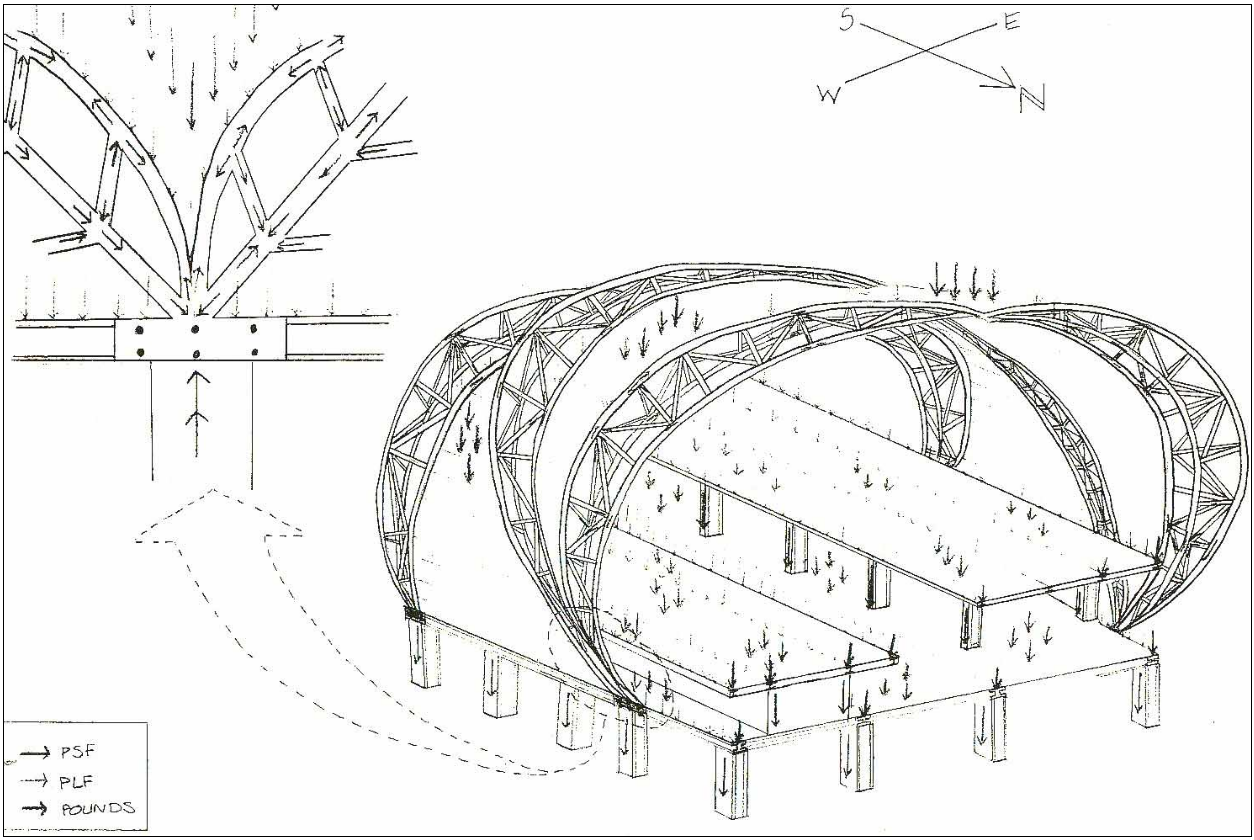

Figure 3: Gravity Load Path for the Bangkok Airport[3]

Design Projects:
Steel design projects are handed out with a set of architectural plans for the selected building, project location and material strength information and a problem statement. An example problem statement follows:

> "Steel Building Design
> Students shall work in assigned teams to design specified members and connections for an assigned steel building. Design shall be performed according to the AISC LRFD Specification, Second Edition and the Uniform Building Code, 1994 Edition. Design calculations and sketches shall be presented in a final notebook and on a presentation board to be handed in Tuesday, December 14 at 11:50 a.m. Each team member will be responsible for understanding all the calculations and should be prepared to answer questions about the design during the final examination period. All team members shall fill out and hand in detailed time sheets and journals for the project.
>
> Each team member shall keep a weekly journal and a daily time sheet for the project. Journals should summarize how the team has worked together, giving specific illustrative examples of strengths and weaknesses. Each team member should evaluate her/his performance and the performances of other team members. Address whether or not each team member is meeting your expectations and how well the team is communicating as a whole. Time sheets shall list

specific tasks and the amount of time spent on each task.

There will be 3 submittals before the final project is turned in. Each submittal will be graded and comments and corrections should be incorporated into the final project. Submittals will be as follows:

✓ **Submittal 1**, September 24, 1999
- Tabulated service loads to be used in design
- Load diagram for each unique member in the structure
  - Do not use any live load reductions or snow load reductions
- Journals and time sheets

✓ **Submittal 2**, October 15, 1999
- Preliminary member sizes (hand calculations)
- Risa 3D computer model complete (provide disc and 3-D plot)
- Preliminary framing plans
- Journals and time sheets

✓ **Submittal 3**, November 12, 1999
- Framing plans with member sizes
- Reaction forces on members
- Hand calculations checking computer output, including a comparison and evaluation of differences between hand calculations and computer calculations
- Journals and time sheets

✓ **Final Submittal**, December 14, 1999
- Project notebook including:
  - Description of structural system
  - Design calculations and relevant computer output
  - Detail sketches (done by hand)
  - Previous submittal mark-ups
- Structural framing plans (done by hand)
- Summary of design on presentation board (include a 3-D representation)
- Journal pages
- Time sheets"[4]

The students had to determine loads and the framing layout for the building's structural system and then design all of the major components. Finally, they presented their design in a project notebook and on presentation boards On the following page, two examples of the final presentation board submittal for the project outlined are shown in Figure 4 and Figure 5. Figure 4 shows a layered isometric that allows the viewer to look at the structure from the bottom floor up by layering each successive floor on a clear overlay. Figure 5 shows one team's design solution, including plans, isometric, connection details and a description of the structural framing system..

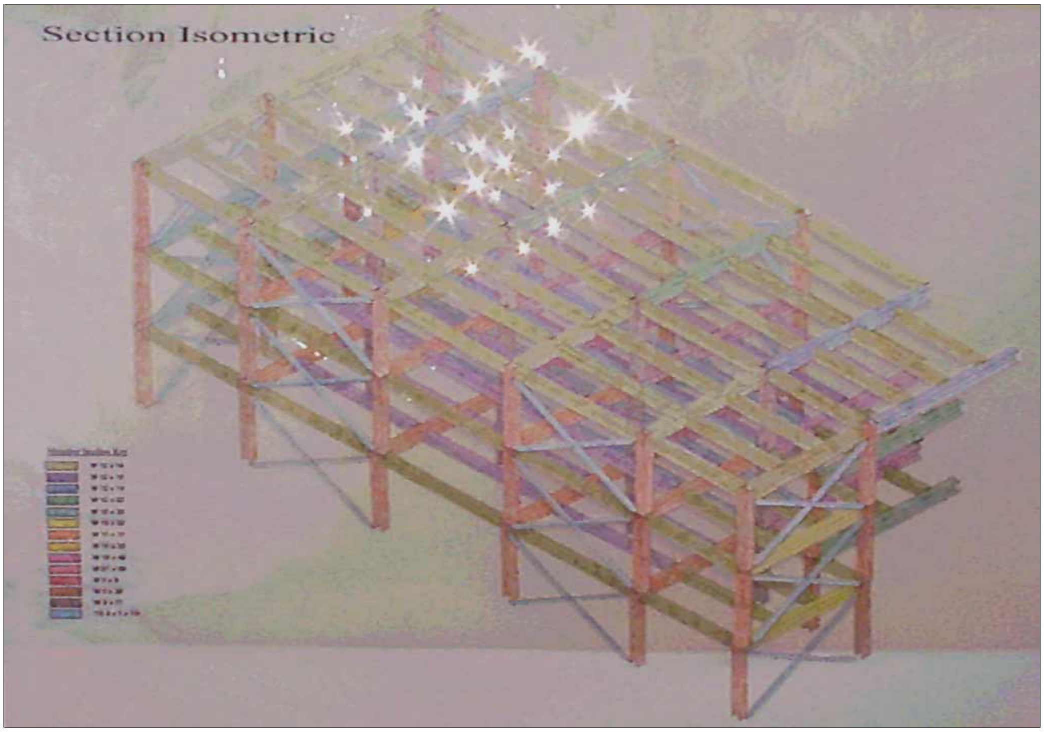

Figure 4: Steel Design Project[5]

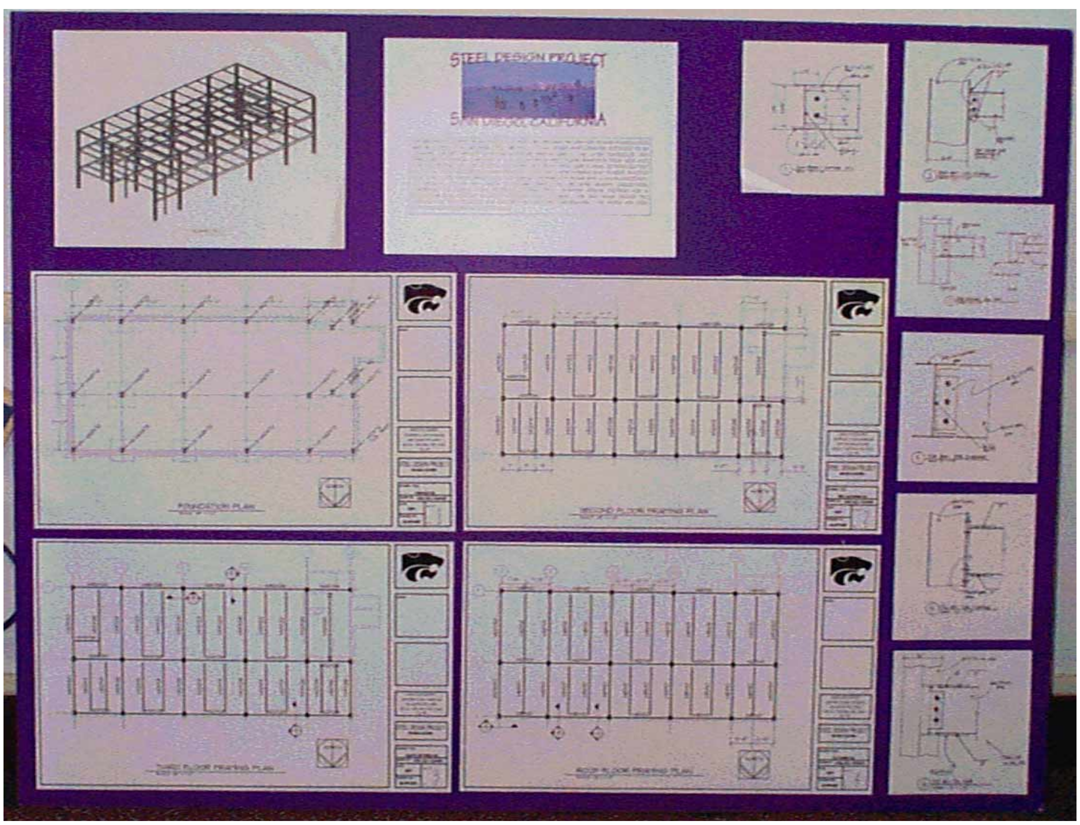

Figure 5: Steel Design Project[6]

Masonry Design projects were assigned as group projects for the masonry class. A student group description of the project follows:

> "The objective of this project was to design the masonry building assigned to the class. We designed the building as a bearing wall system with shear walls. As a group we felt it would be easier to design the building with pilasters at 16 feet on center, with bond beams spanning the top of the north and south to take the load form the roof trusses.
>
> Our first objective was to design the walls for bending due to the wind loads. We took a tributary width of 24 inches (3 courses) and a span of 16 feet (the distance between pilasters). We found this was adequate and designed the wall accordingly. Since the pilasters around the perimeter of the building are all 16 feet on center, the flexural steel in the walls is the same for the entire perimeter.
>
> Our next task was to design the pilasters. We first decided to use 16"x16" pilasters, but we ran the numbers and found the pilasters were too small to hold the moment being applied by the wind loads. Our next thought was to use a stronger block, but that would have violated the specifications of the project. We then made the pilaster 16"x24" and this turned out to be an adequate size for the applied loads.
>
> Next we designed the bond beam. We started with a depth of 48 inches and fund that the beam was greatly over-sized. Then we reduced the depth to 32 inches and used d=28". Our numbers showed that this beam was under-sized for the loading by about 3 percent, so we increased our d to 28.5 inches. This made the beam design adequate. This bond beam was used on the north and south sides of the structure to transfer the roof joist loads to the pilasters.
>
> The last phase of the design was the designing of the shear walls. We decided to make a string of shear walls located between the pilasters, each 16 feet long. After calculating the base shears due to seismic and wind loading, the seismic loading was controlling. We performed a rigid and flexible diaphragm analysis on the structure and made the following conclusions: for the walls spanning east and west the loads distributed by the rigid and flexible diaphragms were identical. For the walls spanning north and south we found the most severe loading was due to the center panel on the west end. This was due to the fact this wall had more load per foot because of the opening. The center panel had more of a flexural load due to its height. For ease of construction and to cause less confusion we decided to use this worst-case scenario to design the shear panels on the east and west ends of the building" [7]

The description above is not that well-written, but it does describe the design and thought process this particular group went through in some detail. It is apparent that some higher-level thinking and decision-making is occurring throughout the course of the project.

Evaluation Projects:
A particularly successful evaluation project required research and evaluation of a structural failure. The failures investigated were picked by the teams and included: The Million Dollar Bridge in Alaska,

the Point Pleasant Bridge in West Virginia, the Kemper Arena roof collapse in Kansas City, the Hartford Civic Center collapse in Connecticut and the Rainbow Bridge in China. Figure 6 is an excerpt from a group report on the Point Pleasant Bridge collapse.

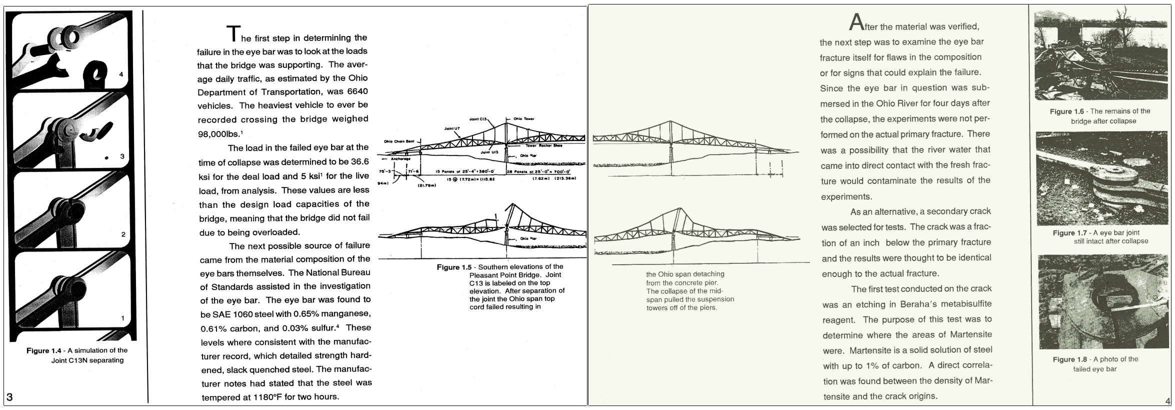

Figure 1.4 - A simulation of the Joint C13N separating

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The first step in determining the failure in the eye bar was to look at the loads that the bridge was supporting. The average daily traffic, as estimated by the Ohio Department of Transportation, was 6640 vehicles. The heaviest vehicle to ever be recorded crossing the bridge weighed 98,000lbs.[1]

The load in the failed eye bar at the time of collapse was determined to be 36.6 ksi for the deal load and 5 ksi[1] for the live load, from analysis. These values are less than the design load capacities of the bridge, meaning that the bridge did not fail due to being overloaded.

The next possible source of failure came from the material composition of the eye bars themselves. The National Bureau of Standards assisted in the investigation of the eye bar. The eye bar was found to be SAE 1060 steel with 0.65% manganese, 0.61% carbon, and 0.03% sulfur.[4] These levels where consistent with the manufacturer record, which detailed strength hardened, slack quenched steel. The manufacturer notes had stated that the steel was tempered at 1180°F for two hours.

Figure 1.5 - Southern elevations of the Pleasant Point Bridge. Joint C13 is labeled on the top elevation. After separation of the joint the Ohio span top cord failed resulting in the Ohio span detaching from the concrete pier. The collapse of the mid-span pulled the suspension towers off of the piers.

After the material was verified, the next step was to examine the eye bar fracture itself for flaws in the composition or for signs that could explain the failure. Since the eye bar in question was submersed in the Ohio River for four days after the collapse, the experiments were not performed on the actual primary fracture. There was a possibility that the river water that came into direct contact with the fresh fracture would contaminate the results of the experiments.

As an alternative, a secondary crack was selected for tests. The crack was a fraction of an inch below the primary fracture and the results were thought to be identical enough to the actual fracture.

The first test conducted on the crack was an etching in Beraha's metabisulfite reagent. The purpose of this test was to determine where the areas of Martensite were. Martensite is a solid solution of steel with up to 1% of carbon. A direct correlation was found between the density of Martensite and the crack origins.

Figure 1.6 - The remains of the bridge after collapse

Figure 1.7 - A eye bar joint still intact after collapse

Figure 1.8 - A photo of the failed eye bar

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Figure 6: Failure of Point Pleasant Bridge[8]

These projects required research of material behavior and reinforced the importance of understanding the load path through the structure.

Research Projects:
Research projects have included investigation of materials, the AISC Code of Standard Practice erection provisions, Connection Design, Log Buildings, Seismic Design, Performance of Wood Framed Structures in Hurricanes, and Engineered Structural Wood.

A problem involving the AISC Code of Standard Practice was assigned to the steel construction class. The problem statement for the project follows:

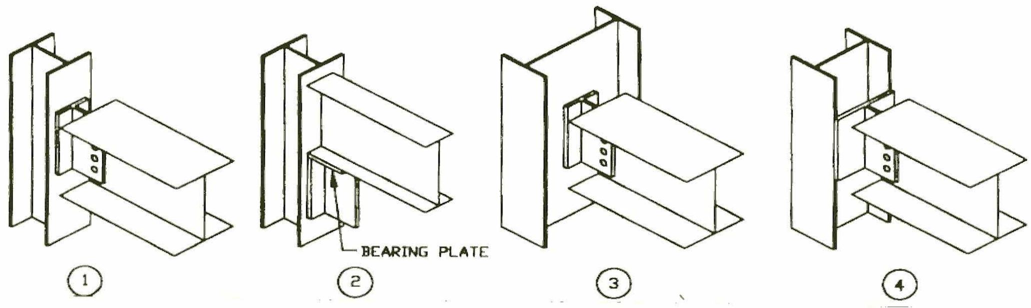
> "The AISC Code of Standard Practice for Steel Buildings and Bridges outlines the sequence and time allocations that the contractor is to follow beginning with the bidding process for a project.
>
> For this problem,
>
> > Project: Three story, approximately 30,000 square foot, commercial building designed with a steel frame, wide flange sections for beams and columns, floors and roof uses steel bar joists with steel deck.
> >
> > Project Architect/Engineers published request for bids on Monday, February 4, 1997. Notices were also sent to all local area general building contractors.
> >
> > Bids due on February 28, 1997. Assume contract is signed with the general contractor on March 5, 1997.
>
> Prepare a traditional schedule for the structural steel for this project following the Code of

Standard Practice. Use a bar graph as part of your solution along with an outline of all of the activities you will need to include."[9]

Figure 7 shows an excerpt from a report on steel connections involving structural tees. The students were to research and report on a specific type of steel connection. The final report included a description of the connection, discussion about its use, and an example design problem. The students generated all of their own diagrams for this report. Each group presented their report orally to the rest of the class.

Tee Connections

Tee connections are any connections that are made with structural tees. These structural tees are connected to beams, girders, or columns by either welds or bolts. Structural tees are typically used to connect a beam to a column. The figure below illustrates four ways this connection can be made.



The first two drawings of the figure show the structural tee connected to the flange of the column. The difference between the first and second drawing, is that a bearing plate is attached to the top of the structural tee, which provides the bearing area for the beam. Attaching the structural tee to the flange induces a moment along the strong axis of the column. The third drawing shows the structural tee connected to the web of the column. This connection causes bending about the weak axis. The fourth drawing also induces a moment about the weak axis, but the difference is that the structural tee is too wide to fit in-between the flanges, so it is welded to the edge of the flanges.

Methods of Failure

The connection can fail in several different ways. The figure below shows failure due to prying, shear, and local failure.

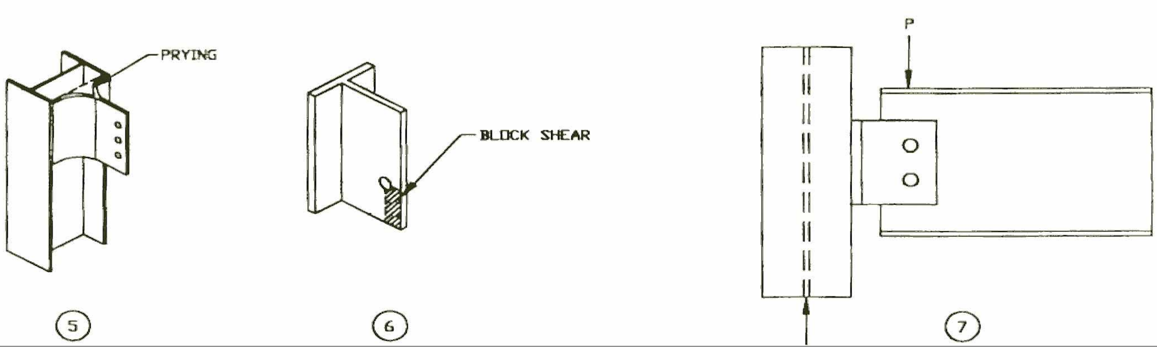


Figure 7: Connection Research Project[10]

Results

The overall experience has been a good one for both the students and the professors. The projects have generated more interest in class work and seem to help many students understand the class material and its overall relevance to engineering and construction better. Several projects have allowed students to research information on class material and then present it to the class instead of the professor. The projects have provided opportunities for students to improve communication and thinking skills as well as enhance technical understanding of the subject. The projects encouraged students to seek out information from faculty, practitioners, the library, professional organizations, and the internet, giving them opportunities to make professional contacts and to get to get to know the faculty better. The variety the projects add to the class helps to keep the class fresh and interesting for the students and the professor.

The general quality of submitted projects, with few exceptions, has been good to excellent. All the students involved to date appeared to have benefited from the group projects in the structural classes, though there is a range in how much students benefit individually.

One major ongoing concern about the group projects is evaluating individual participation and responsibility. Acknowledging that there will always be those willing to hitchhike and let their team members do most of the work, we have tried several methods to encourage and assess individual accountability. Project time sheets, individual journals, individual exams, formal evaluation from team members, and individual scores for group participation and responsibility have all been used in various combinations to prevent free rides. The most effective method or combination of methods varies somewhat from group to group and we have not yet determined the best method to address this. It is and will continue to be one of the most challenging parts of facilitating group projects.

Another minor problem with projects performed in assigned teams is scheduling. The students at this level generally have very busy and varied schedules and have cited conflicting schedules of group members as an important issue in completing projects. Though there is definite benefit in assigning teams and forcing students to work with classmates they may not know, students have also been allowed to select their own teams for some projects.

There have been a few cases where groups have conflicts among themselves. These are usually due to lack of communication between group members that then fester into resentment. There have been occasions when the professor has had to step in as arbitrator to resolve disputes among group members. Fortunately, this is not a frequent occurrence.

Other than the scheduling complaints and a few complaints about lack of effort from team members and an occasional personality conflict, most of the student feedback about the group projects has been relatively positive. There is often some initial frustration with the open-ended nature of these projects, as students seem to be used to being told exactly what to do. In some cases the professor may have to overcome the students' perception that the professor is the enemy trying to trip them up rather trying to help them think and learn. The benefits and frustrations of doing group projects in the structural classes are reflected in the following journal excerpts:

> "I was also very pleased that M's and W's level of craftsmanship and professionalism was high"

> "I feel this project not only helped me increase my knowledge in load paths, but taught me the value of teamwork as well as communication."
> "When discussing the project, everyone shared their opinions and worked together to arrive at the solution."
> "Working on this project in a group was an interesting experience, especially since the groups were randomly assigned instead of picked by us as students."
> "The project gave me a great deal of insight on how the connection works."
> "I had fun with the project."
> "Interviewing B was very informative."
> "This project was a good idea because it taught me a lot about our particular type of connection. When group presentations take place, I am sure that I will know a lot about each of the different connections."
> "I wish we could change our groups for each project."
> "In general , this project was not easy because of the lack of information in both libraries."
> "I learned a lot from this project...I don't feel sorry for the time I struggled and spent for this project."
> "This project was very hard to coordinate due to everyone's busy schedule."
> "We were a bit overwhelmed by the information that was at our fingertips and so the entire group established the scope of our project"
> "Our group functioned well with the exception of C. He completely missed two meetings and was 45 minutes late to another."
> "One of our members has been unable to attend our meetings."
> "Team projects are a good chance to create a project that is better than any of the group members could have produced on their own."
> "I learned a lot about the stadium and its components and how lateral forces are serious factors in design."
> "I had a real good time with this project and this group."[ºº]

This is only a small sampling of the comments received in journal pages. There have been a significant number of written and verbal comments about how a particular project helped the student understand some aspect of the class, engineering or construction better or how it helped tie things together for them. These projects do require additional work outside of class, yet few students complain about this. Many of the students appreciate the opportunity to be creative with their class work.

Conclusions

Our experience over the past two years indicates that using group projects in structures classes is challenging, but beneficial to students and professors. The projects give students opportunities to practice a wide range of skills and allow them to help each other learn. The projects have fostered relationships between faculty and students, have provided variety in classes, have helped make the classes more interesting and caused students to invest more in the class. The students learn to take the initiative and gain confidence in their own abilities. The biggest challenge in administering group projects is making students individually accountable as well as accountable as a group. We have concluded that the benefits of using group projects in structural classes definitely outweigh the challenges and concerns.

References:

1. ARE 524 Theory II student work Spring 2000, team of 2.
2. ARE 524 Theory II student work Spring 2000, team of 3.
3. ARE 524 Theory II student work Spring 1999, team of 3.
4. ARE 524 Theory II assignment sheet, Fall 1999.
5. ARE 524 Theory II student work Fall 1999, team of 3.
6. ARE 524 Theory II student work Fall 1999, team of 3.
7. ARE 760 Masonry Structures Design student work Fall 1999, team of 3.
8. ARE 524 Theory II student work Spring 1999, team of 3.
9. CNS 524 Steel Construction assignment sheet, Spring 1997.
10. ARE 524 Theory II student work Fall 1998, team of 5.
11. ARE 524 Theory II student journals from Fall 1998-Spring 2000.

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