Project-Based Steel Design Course

Mousa Tabatabai-Gargari

University of Cincinnati

Abstract

This paper presents an alternative method to teach an undergraduate course in steel design. This method has been experimented for two quarters at the University Of Cincinnati College Of Applied Science. The idea is centered on a project where the structural elements are designed following the flow of gravity forces from the deck to the ground, while paying close attention to the way loads transfer from one member to another. The focus is on the interaction of the elements as well as the role of each element in the entire structural system. This is a three credit undergraduate course in a quarter system. The role of the professor has been more like consulting as opposed to lecturing. Design of the projects required about the same amount of time that would be spent for designing example problems for individual members in a traditional lecture. Adoption of this method did not increase the workload of the professor. The course evaluations by the students confirm that this method has been effective in facilitating and enhancing their learning process, as well as creating interest and participation.

Introduction

A typical undergraduate steel design course normally covers fundamentals such as failure modes and design criteria of tension members, compression members, flexural members, as well as connections, packaged in various chapters of a textbook. Usually each chapter is taught as a separate entity, thus few students get the idea of interaction between structural elements and the purpose of analysis and design of individual structural members. It is not uncommon to hear some students question the purpose and necessity of having to learn such topics. The traditional method of lecture does not present the students with the big picture, where the role of each structural member is clearly identified in conjunction with the entire system.

To address this shrotcoming some programs offer a structural systems course that follows the steel design course, here the interaction between structural elements is introduced. Although the structural systems course serves the purpose of explaining the role of each member in conjunction with the other members, however it takes place too late in the program, and thus does not serve the purpose of efficiently describing the function of the structure as a system.

Alternatively, the steel design course can be taught based on a project where the students get involved in design of a *system*, and subsequently learn about the elements in the context of the whole structure.

An alternative teaching method as opposed to the traditional lecture has been experimented to verify if any improvement in student learning can be achieved. To this end, steel structures, a course in pre-junior year was taught based on a design project during summer and autumn quarters of 2003. The students were assigned a project, and were required to find out what kind of knowledge was needed in order for them to analyze and design the entire project. Based on the list of needs put forward by the students, the syllabus of the course was prepared. The syllabus addressed theories, technical information, and relevant codes for designing deck, beams, girders, columns, base plates, tension members, and connections. The syllabus also included the time schedule for each topic so that the design process can follow a logical sequence.

Using this alternative method the students immediately understood the purpose and objective of the course. Their task then was to identify different elements of the structure and to understand the failure mode and design criteria for each element. Finally preparing the bill of material enabled them to further their awareness of the geometry of the structure, and the precision to which the members shall be manufactured.

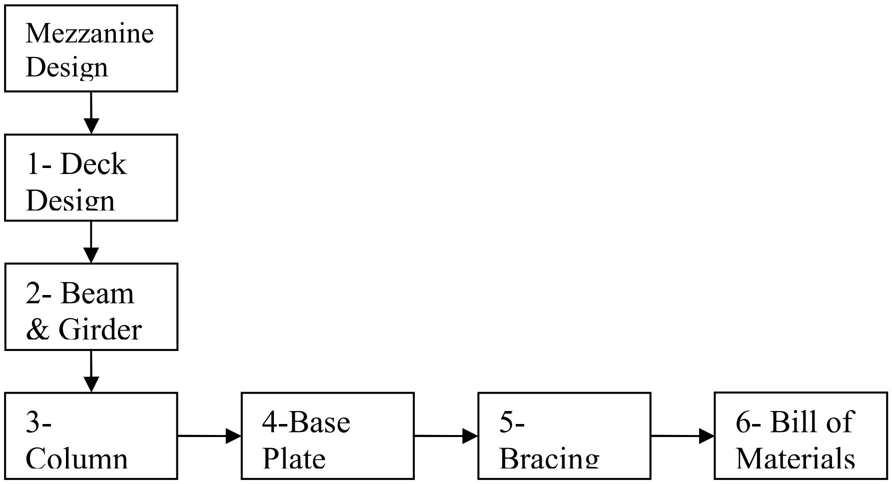
The project was a single story steel mezzanine with planks of plywood tek screwed to the corrugated metal deck. The preliminary dimensions as well as minimum design live load required by the code were given. After selection of the deck elements the beams were designed. Then the girders were designed to support the beams. After completing the design of girders the columns were designed, followed by base plates. Finally connections and knee bracing were designed. At the end the detail drawings as well as bill of materials were prepared.

The course evaluation by the students showed an improvement in student satisfaction over the previous quarters taught by the same professor. At the time being it is difficult to quantify the improvement in student learning, however, the comments by the students stating that the project helped them learn the techniques and theories of steel design are encouraging. "We knew what we were doing and why we were doing it," commented one student.

The key difference between the project based teaching and the traditional method of lecture is the manner of presentation of the theory of design, as well as the format of presentation. With the new method each topic was delivered when the students asked for it. The role of the professor was consulting rather than lecturing. This role made a huge difference in the way the students perceived the course; information was made available to them when they needed it rather than being lectured as isolated theories and techniques.

The professor's workload was about the same as in the traditional method. The extra work for preparing the project was almost equivalent to preparing example problems when the traditional method was used. However, the satisfaction of observing the enthusiasm demonstrated by the students was an added bonus.

System Design Flowchart



Project Description

Mezzanines are used for creating added storage space, office, or work platform, inside an existing building such as warehouse or production shop. Mezzanine space benefits from the existing utilities such as heating, cooling, electrical, and mechanical utilities, but structurally it must be self-supporting; it must be able to support all the vertical and horizontal loads based on the intended use as well as the code requirements for minimum design loads. There are several manufacturers who specialize in fabrication of mezzanines, and produce their proprietary systems. All the manufactures fabricate structural components of their system in a production shop. Immediately after production, the elements are cleaned, painted, labeled, packaged, and shipped to the sites. The site work involves merely the assembly of the system by bolting the appropriate elements.

The plan view, as well as, the elevations of the single story mezzanine is shown in Figures 1, 2 and 3. The details are shown in Figures 4, 5 and 6.The structural system includes HSS square columns, and channel beams and girders made of A572-50 steel. Teams of 4 to 5 students are responsible for design and documentation of the project according to AISC LRFD Specifications[1]. For a design live load[2] of 125 psf and dead load of 25 psf. The students were required to perform the following tasks:

1. Verify proposed outer beams hot rolled grade 50 steel channels, C12x20.7 for flexural strength, and shear strength. The deflection due to the service live load is limited to span/180.
2. Verify proposed interior beams hot rolled grade 50 steel channels, C15x33.9 for flexural strength, and shear strength. The deflection due to the service live load is limited to span/180.
3. Verify proposed girders hot rolled grade 50 steel channels, C15x33.9 for flexural strength, and shear strength. The deflection due to the service live load is limited to span/240.
4. Verify proposed column HSS 4"x4"x1/4", F_y=46 ksi. Assume pin-pin end condition.
5. Design the connection between the girder and the column using a rectangular A36 steel gusset plate fillet welded to the column using E70 electrode, and bolted to the girder using A325 high strength bolts with threads included in the shear surface.
6. Design the connection of beam to girder using a single angle A36 steel, to be bolted to both girder and beam. The bolts will be high strength A325 threads included in the shear surface.
7. Design the knee-braces using A36 steel angle for a lateral load equivalent to 10% of the gravity load.
8. Design the base plate and anchor bolts.
9. The report must include the following documents:
   - A cover sheet containing the title of the document, date, and the names of the team members in alphabetical order.
   - Table of contents.
   - Brief description of the project in one page.
   - Calculation sheets either typed or neatly printed on engineering paper.
   - Detail AutoCAD drawings 8.5"x11" sheet showing necessary views of each connection as shop drawing.
   - Bill of materials.

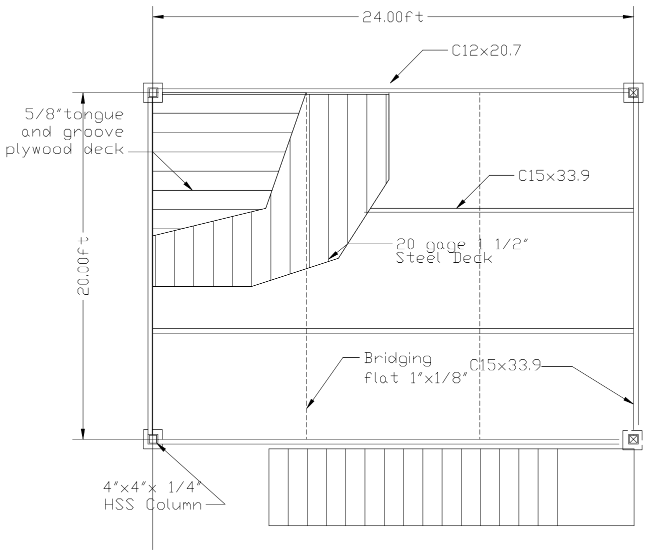


Fig. 1, PLAN VIEW

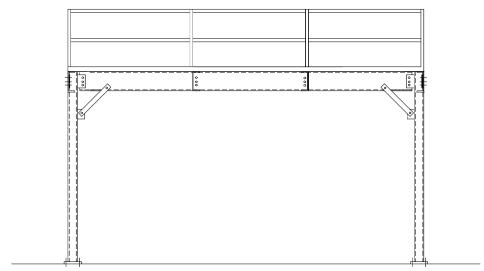


Fig. 2, SIDE ELEVATION

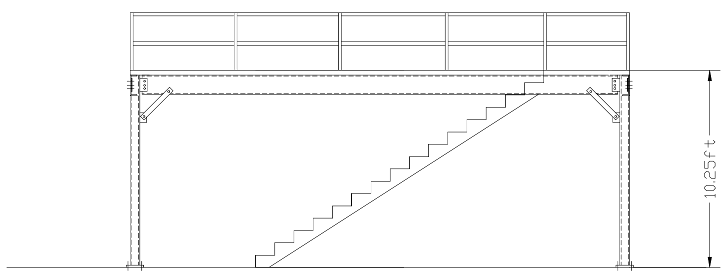


Fig. 3, FRONT ELEVATION

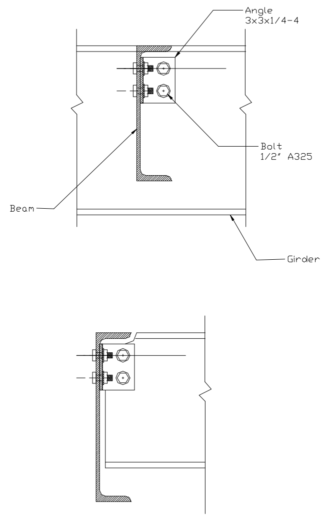


Fig. 4
Beam to Girder
Connection

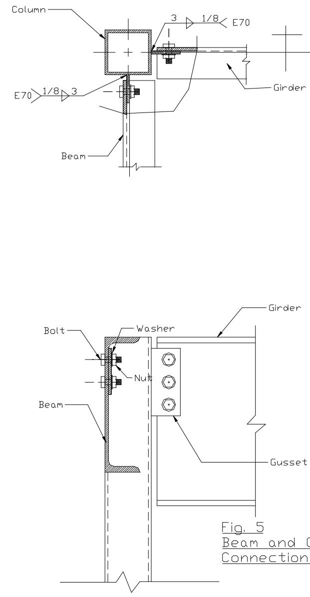


Fig. 5
Beam and Girder
Connection to Column

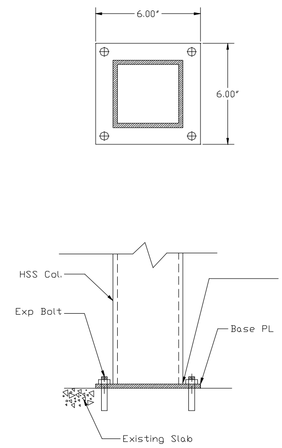
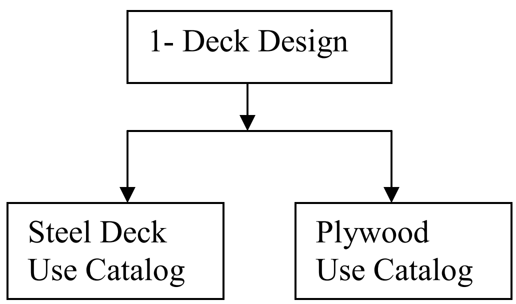
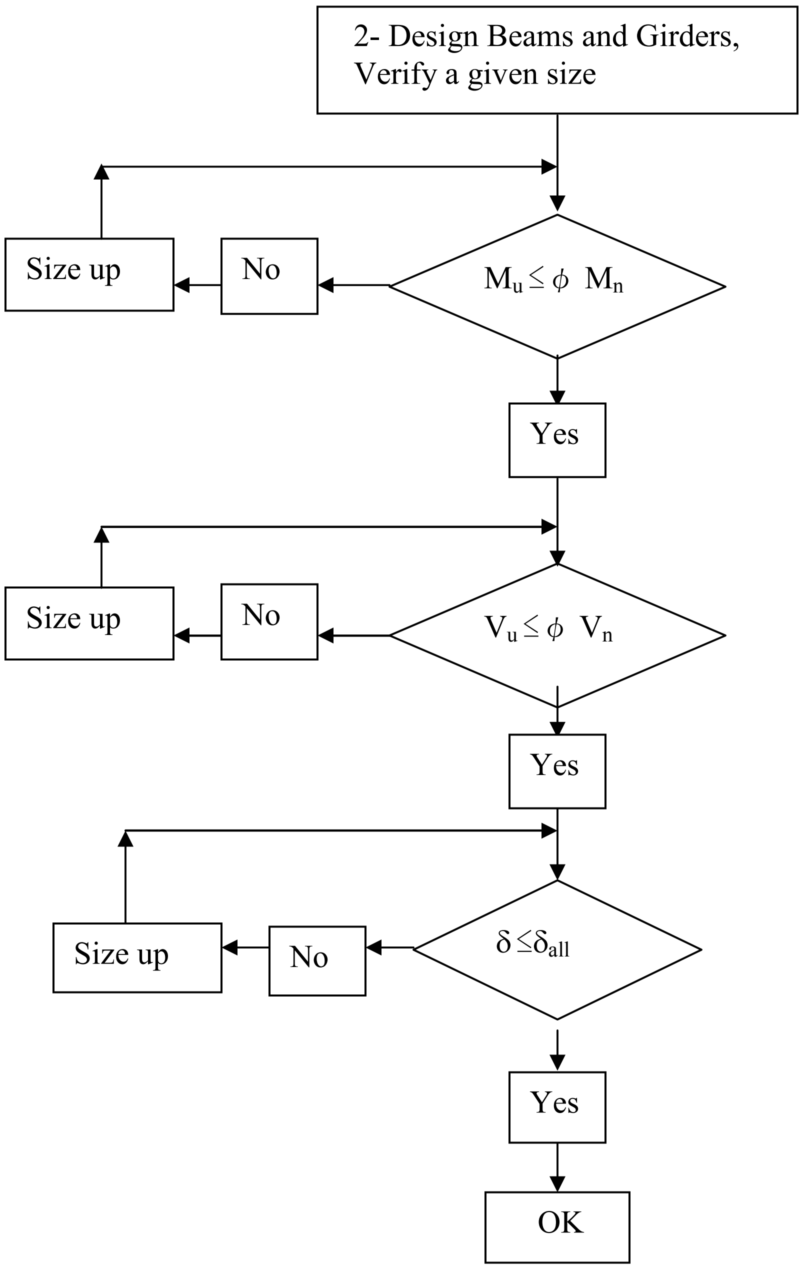
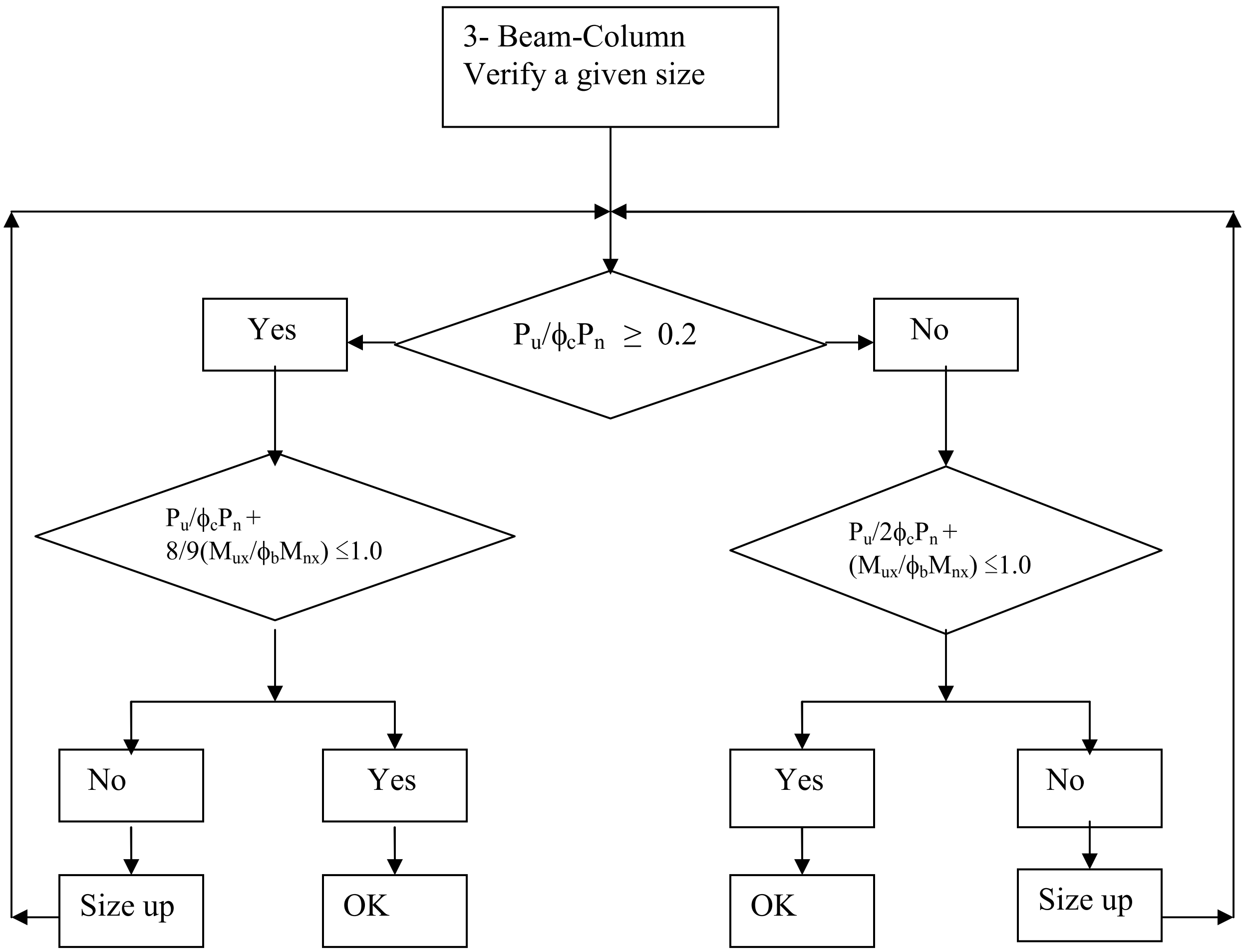


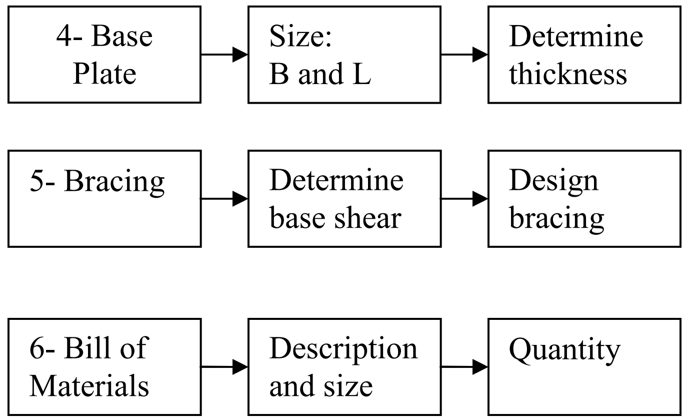
Fig. 6
Base Plate

Member Design Flowcharts




2- Design Beams and Girders, Verify a given size
Size up
No
$M_u \leq \phi\ M_n$
Yes
Size up
No
$V_u \leq \phi\ V_n$
Yes
Size up
No
$\delta \leq \delta_{all}$
Yes
OK


3- Beam-Column
Verify a given size
$P_u/\phi_c P_n \geq 0.2$
Yes
No
$P_u/\phi_c P_n + 8/9(M_{ux}/\phi_b M_{nx}) \leq 1.0$
$P_u/2\phi_c P_n + (M_{ux}/\phi_b M_{nx}) \leq 1.0$
No
Yes
Yes
No
Size up
OK
OK
Size up



Conclusion

An alternative method for teaching an undergraduate steel design course has been demonstrated. This method was based on designing a single story mezzanine inside a warehouse. The students were required to design or analyze the structural elements in the context of the entire system. This method provides the students with an overall idea of the way the whole system works as opposed to synthesizing the individual elements that constitute the system. The course evaluation by the students has been encouraging; several students have commented that the project helped them better understand the theory in an objective manner.

The key difference between the project based teaching and the traditional method of lecture is the manner of presentation of the theory of design, as well as the format of presentation. Each topic was delivered when the student teams asked for it. The role of the professor was consulting rather than lecturing. This role made a huge difference in the way the students perceived the course; information was made available to them when they needed it rather than certain isolated facts being lectured. “Why do we need to learn this topic”, a question frequently asked with traditional lecture was not brought up anymore. The students already knew what they needed and why they needed certain theories and information.

The amount of work needed to prepare project based course material by the professor was about the same as the traditional way of preparing for lecture. The extra work for preparing the project was pretty much equivalent to preparing example problems and homework assignments. The alternative method did not demand any extra time and effort. To be mentioned that it was very encouraging to observe the excitement and enthusiasm the students show as the project went ahead.

Bibliographic Information

1- Manual of Steel Construction, Load and Resistance Factor Design, Third Edition, American Institute of Steel Construction Inc., Chicago, Illinois, November 2001.
2- Minimum Design Loads for Buildings and other Structures, American Society of Civil Engineers, New York, New York, 1996.

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Biographical Information

Dr. Mousa Tabatabai Gargari received his bachelor's degree in Civil Engineering from University of Tabriz, Iran in 1967, and his Master's degree in Structures from University of Illinois, Urbana, Illinois in 1976. After twenty years of engineering career in construction and design of heavy industrial projects he pursued his education towards a Ph.D. in Building Engineering "Behavior Modification of Space Trusses" in Concordia University, Montreal Canada. Dr. Gargari is a registered professional Engineer in Ohio and Quebec, specializing in design and consulting in material handling structures; racks and mezzanines as well as computer aided structural design. Dr. Gargari is an associate professor in College of Applied Science, University of Cincinnati, Construction Science Department. He teaches structures, and civil engineering courses.