Introducing Undergraduates to Load Calculations: A Course Designed Around ASCE-7

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Abstract – More often than not, undergraduate students in structural engineering programs are only briefly exposed to ASCE-7 (Minimum Design Loads for Buildings and Other Structures), usually in the introduction of concrete or steel design courses. In junior-level design courses, the loads on a structure are usually presented as a "Given" to the students, but the importance of understanding how to determine design loads on a structure is seldom emphasized. To be most effective, students need to be introduced to design load calculations prior to their senior-level courses when some level of competence is needed to apply these concepts and methods in design projects and capstone courses.

Graduate-level courses on this topic are offered at some universities, and allow the instructor to provide more in-depth information and more extensive discussions on advanced topics such as seismic loads. These graduate courses may provide some insight into the design of a course for undergraduates. While some of the higher level information would need to be omitted in order to make the course more manageable and suitable for the level of undergraduate students, some of the fundamental content could be combined with other practical information such as specification of pre-engineered components, plan reading, and site visits.

This paper provides an overview of a new course designed to introduce undergraduate students to load calculations, designed around ASCE-7. A description of the course structure along with course topics and course project are provided.

Keywords: Civil engineering, engineering design, load calculations

INTRODUCTION

Many structural engineering undergraduate students have very limited experience with determining loads on a structure, being only briefly introduced to ASCE-7 in design courses, and sometimes in a capstone design class. ASCE-7, sub-titled "Minimum Design Loads For Buildings and Other Structures" [1], is a design code produced by the American Society of Civil Engineers (ASCE) and is an integral part of the International Building Code, which is the dominant building design code in the United States.

When the students enter the workforce, they often have very limited knowledge of ASCE-7, and almost no experience specifying commonly used items such as engineered wood products, open-web steel joists, metal roof/floor deck, hanger brackets and anchors. A course has been developed,

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titled “Structural Loads and Systems”, that will be offered at the junior level to students who have completed their introductory structural analysis course. The intent is to provide the students with background information on topics that many structural engineers use on a day-to-day basis, but very little instruction time is provided on at the undergraduate level. The details of this course are the basis for this paper.

This course is based on a graduate course by the same title that was offered at Clemson University in the Fall of 2006 and Fall of 2007 by Dr. Patrick Fortney [2]. The graduate level version of this course was presented as a lecture, with regular homework assignments, two midterm exams, a final exam, and a final project. The lecture portion of the course also devoted a portion of class time to discussion between the instructor and students as well as amongst the students. The redesigned course will follow the same general format, but with some changes in course content to make the course more manageable for undergraduate students.

COURSE TOPICS

Specifying loads is one of the most important factors in designing a structure, yet very little time is spent explaining to students how the loads are determined. In many undergraduate design courses, the loads are presented as a “Given”, with little to no information provided as to where the value came from. The primary objective of this course is to provide familiarize students with ASCE-7, so that they are able to correctly interpret the code and apply it in situations outside those explicitly covered in the code. A sample course syllabus is shown in Appendix A.

The topics that will be covered in order to meet this first objective will be ASCE load combinations, dead loads, live loads, snow and ice loads, wind loads, and earthquake loads. To make the class more manageable for the students, some of the more complex topics have been omitted. For example, the Simplified Method for wind load calculation will be taught, however the more complex Analytical Procedure will be omitted. Similarly, for seismic loads, the Equivalent Lateral Force procedure will be included in the course, but not the more complex Modal Analysis Method or any Finite Element Modeling. While the methods that are included in the course are not always the most precise, they are commonly used in industry, and provide the students with the basic tools to perform more complex analyses later.

A secondary objective of the course is to provide the students with practical knowledge they will apply regularly in both future courses and in their career as a structural engineer. Skills like plan reading, preparing specifications, and construction terminology are topics the students may have learned prior to the course, but having the students to practice these skills will allow them to be more comfortable when using them later. All assignments will be presented with professional drawings, and specifications and requirements will be presented in a format consistent with what the students will encounter in a professional environment. The students will be expected to produce clear sketches and drawings for the homework assignments as well as the final project, and present them in an organized fashion.

The third objective of the course is to provide the students with some guidance in specifying so-called “pre-engineered” components, such as metal roof/floor deck, open-web steel joists, engineered wood products, and anchors and hangers. These items are commonly used in structural engineering applications, but rarely is any instruction given at the collegiate level on the use of them. Making the students aware of how to specify these products, and also the differences from manufacturer to manufacturer provides the students with a level of comfort with the components, and the ability to specify the correct component for the correct application. Additionally, the opportunity exists for guest speakers from manufacturers to join the class and present their design process to the students. This also serves as a networking opportunity for the students, allowing them to make industry contacts.

COURSE STRUCTURE

It was the goal of the authors in the redesign of this course to use a learner-centered approach. The material in this new course easily lends itself to discussion, and the instructor would be encouraged to have several talking points ready each class to promote discussion. There will also be opportunities for the students to work together in class on small problem sets. In addition to these in-class activities, there will be daily quizzes. The quizzes will be short (3-5 questions), and will be based on the lecture topic for the day. The quizzes will be handed out at the beginning of class, and will cover the main topics for that day's lecture. The students will then submit the quiz at the end of the lecture. The purpose of these quizzes is to ascertain whether or not the students understood the lecture material. Based on the overall results of these quizzes, the instructor can adjust future lectures to cover concepts that were poorly understood by the class.

The homework will be calculation-based, allowing students to practice concepts learned for each specific topic. The final project will incorporate all the topics learned during the course of the semester, and in small teams, the students will produce a set of calculations and drawings and present them in a professional manner. The aim of this is to have the students produce a set of calculations akin to what they will be required to produce as practicing structural engineers.

Younger students especially find it difficult to use "engineering judgment", due to the simple fact that they have very little engineering experience. One tool that will hopefully take some of the "mystery" out of applying engineering judgment is the use of the engineering design process. It is the intent of the authors to have the students incorporate the engineering design process into their assignments. The outline of the process the students will be expected to follow is:

1. Define the problem
2. Conduct research
3. Analyze criteria
4. Find solutions
5. Analyze solutions
6. Make a decision
7. Present the solution

Problem definition will be provided to the students, and for smaller homework assignments the students will not be expected to conduct in-depth research or analyses. The homeworks are intended to be an opportunity to informally apply the engineering design process, while the final project will provide a chance for the students to incorporate a more formal design approach by providing them with an open-ended problem. The students also will be introduced to tools such as a Pugh's Decision Matrix; Strengths, Weaknesses, Opportunities, and Threats (SWOT) analyses; and the House of Quality [3] to aid in decision making.

COURSE PROJECT

The course project will provide the students the opportunity to apply all the skills acquired over the course of the semester. The project will be presented as an open-ended design problem, allowing the students to apply the engineering design process to the project. The project will require the students to determine all the design loads (dead, live, snow/ice/rain, seismic, and wind) on a given structure, and specification of pre-engineered components such as metal decking, support joists, and anchor bolts for some component of the structure. To determine the type of material the students will design with, they will be required to use the engineering design process to select a material that suits their needs. The students will work with the instructor throughout the process, using tools such as a Pugh Design Matrix or any other concept selection tools they may be familiar with. The results will be presented in both a written report with sketches, and the students will be required to give a short (approximately 10-15 minutes) presentation on their work and any problems they encountered or other items of interest. The students will be expected to explicitly state what they did to address each step of the engineering design process, and justify any assumptions or other design choices they made. The projects will be varied from team to team, which slight changes such as the geographical location of the structure or the intended use of the building. An example of the course project can be found in Appendix B.

CONCLUSIONS

The application of a learner-centered approach in this course will enhance the students' level of understanding of the course material. This course will provide students with skills that will be useful in their later design and capstone courses, as well as when they are practicing engineers. While some of the more complex technical elements of the graduate level course have been omitted, the students will have a basic foundation that will allow them to understand these methods. Giving the students the chance to familiarize themselves with the ASCE-7 code will provide a smooth transition to applying the code when they are practicing engineers. Additionally, having the students implement the engineering design process and design tools will allow them to explore the design process from a practical standpoint, and to see which types of decision making tools best suit their needs. A possible text book for the course is the second edition "Structural Load Determinations under 2009 IBC and ASCE/SEI 7-05" to assist in the proper determination of structural loads in accordance with the 2009 International Building Code and ASCE/SEI 7-05, including dead load, occupancy live load, roof live load and environmental loads such as rain, snow, wind and seismic loads. The AISC has developed a similar course on building loads and examples from the AISC Steel Building Example CD might also be used as teaching aids for the course discussed in this paper.

REFERENCES

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APPENDIX A

CEE XXX – Structural Loads and Systems

Course Syllabus

Grading: Exams #1 & #2: 15% each; Final Exam: 25%; Homework: 20%; Final Project: 20%; Quizzes: 5%

Week	Date	Topics
1	x/xx - x/xx	Introduction
2	x/xx - x/xx	The Engineering Design Process
3	x/xx - x/xx	Types of Buildings, Systems, and Components
4	x/xx - x/xx	Types of Loads and Load Paths – **HW 1**
5	x/xx - x/xx	Gravity Loads – Paths and Distribution
6	x/xx - x/xx	Snow and Ice Loads – **HW 2**
7	x/xx - x/xx	Snow and Ice Loads (cont.)
		Wind Loads
		EXAM #1
8	x/xx - x/xx	Wind Loads (cont.) – **HW3**
9	x/xx - x/xx	Earthquake Loads
10	x/xx - x/xx	Earthquake Loads (cont.) – **HW4**
11	x/xx - x/xx	Specifying Open-Web Steel Joists – **HW5**
12	x/xx - x/xx	Specifying Engineered Wood Products
13	x/xx - x/xx	Specifying Metal Roof and Floor deck – **HW6**
14	x/xx - x/xx	Design of Anchors and Hangers
		EXAM #2
15	x/xx - x/xx	Design of Bracing Systems
16	x/xx - x/xx	Project Presentations

Final Exam: As scheduled by University

APPENDIX B

CEE XXX – Final Project

The framing plans and building section shown in the figure below show limited details of a warehouse facility to be constructed. The building envelop consists of 10" CMU block that sits on a mat foundation/slab. The primary use of the building is for the storage and eventual distribution of heavy paper products.

Each design team (consisting of 3-4 members) will perform the following general tasks:

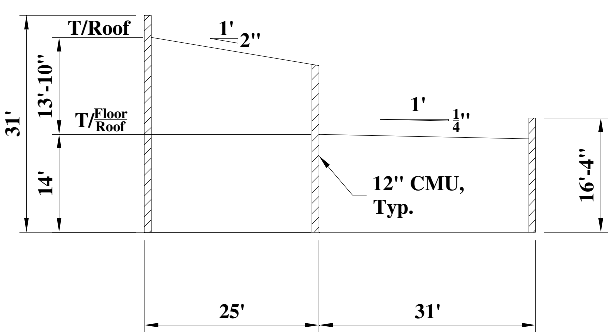
1. Calculate the gravity loads on the building
2. Calculate the wind loads on the building using the simplified procedure
3. Calculate the snow loads on the building

4. Calculate the seismic loads on the building using the ELF procedure
5. Choose construction material with approval of professor
6. Design and detail the upper roof system and connections to the CMU walls
7. Design and detail the lower roof system and connections to the CMU walls
8. Team presentation at end of semester

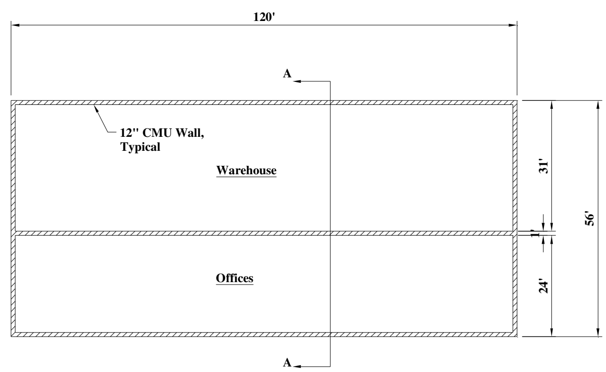
In all cases, complete calculations must be submitted with the final project submittal. Additionally, details of the final framing plans must be submitted including section cuts and details as required for communicating the design of the roof and floor systems and the connections.

Each group will design the systems using various building products (e.g., open-web steel joists, engineered wood products, steel deck/concrete composite systems). Groups will be formed during the first week of class, and each group will determine their construction material of choice by using engineering design tools such as a House of Quality or Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis. The instructor will meet with each team to finalize a material selection.

The building is located in Cape May, New Jersey. The zip code of the building is 08204. All design loading must be in compliance with the requirements of ASCE 7-05, and all designs must be in compliance with the IBC building code, and in the case of proprietary materials, must satisfy proprietary design capacities and assumptions.



SECTION A-A



FIRST FLOOR PLAN