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Teaching Structural Design in Construction Management Programs: The Challenge of Motivating Students to Learn

Dr. Souhail Elhouar, P.E., Bradley University

Dr. Elhouar is a Professor of Civil Engineering and Construction at Bradley University. He holds a M.Sc. and a Ph.D. in structural engineering and a BSc in Building Engineering and Construction. He is a licensed professional engineer and specializes in the design and construction of steel structures and teaches related courses in civil engineering and construction management programs.

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Abstract

"We are not going to be engineers; Why are we learning this?" is a question that probably every professor teaching a structural design course to Construction Management (CM) students must have had to answer at least on one occasion. When taken at face value, this question may seem to have some merit to it as one may also ask: how does learning how to evaluate the lateral-torsional buckling capacity of a steel beam benefit a future construction manager? But when the issue is examined more carefully, it becomes very evident that the coverage of structural design concepts is essential for developing a solid understanding of structural behavior, which is a must-have for construction professionals. In this paper, the author enumerates the benefits of covering structural behavior concepts in CM programs, investigates the levels of coverage of these concepts in select programs based on published information, and identifies some of the challenges that may come in the way of CM students gaining an adequate understanding of structural behavior. Some learning and instructional techniques for overcoming these challenges are also presented. The author also conducted a survey among a number of students to assess their learning expectations from a structural behavior and design related course and the adequacy of some of the instructional methods that were used. The results of the survey are presented throughout the paper and a list of topics for the adequate coverage of structural concepts to construction management students is proposed.

Keywords: structural, design, concepts, teaching, construction, management

Introduction and review of literature

Construction Management is a multidisciplinary profession that requires its adherents to possess competences in a variety of subjects. The American Council for Construction Education (ACCE) stipulates in its most recent accreditation standard [1] that, by the time they graduate, students seeking a construction management degree must attain the seventeen Student Learning Outcomes (SLO's) shown in Table 1, which are being shown in their totality here to provide a comprehensive presentation of the ACCE learning outcome requirements for the benefit of the reader. These learning outcomes were obtained by collecting proposals from construction professionals around the country, consolidating the input, and then holding series of discussions between practitioners and academics to select the learning outcomes with the most relevance to the industry while keeping their number to a manageable level. The ACCE Student Learning Outcomes are classified according to Bloom's Taxonomy [2] action verbs with five being at the create level, two at the analyze level, and two at the apply level. The remaining eight are at the understand level, of which SLO 16, which requires that students attain an understanding of the basic principles of structural behavior by the time they graduate. This necessitates the inclusion of structural analysis and design topics into the curriculum and the subsequent assessment of the students' understanding of the basic concepts of structural behavior in each accredited Construction Management program. These programs must therefore develop and implement an assessment plan to measure their students' attainment of the ACCE SLO's and devise and

implement corrective actions where needed. Keeping the number of required learning outcomes to a reasonable level that sets minimum standards ensures that assessment serves its intended purpose of improving quality without becoming a heavy burden on programs.

Table 1. Required ACCE [1] student learning outcomes for bachelor degree programs

1.	Create written communications appropriate to the construction discipline.
2.	Create oral presentations appropriate to the construction discipline.
3.	Create a construction project safety plan.
4.	Create construction project cost estimates.
5.	Create construction project schedules.
6.	Analyze professional decisions based on ethical principles.
7.	Analyze methods, materials, and equipment used to construct projects.
8.	Apply electronic-based technology to manage the construction process.
9.	Apply basic surveying techniques for construction layout and control.
10.	Understand different methods of project delivery and the roles and responsibilities of all constituencies involved in the design and construction process.
11.	Understand construction accounting and cost control.
12.	Understand construction quality assurance and control.
13.	Understand construction project control processes.
14.	Understand the legal implications of contract, common, and regulatory law to manage a construction project.
15.	Understand the basic principles of sustainable construction.
16.	**Understand the basic principles of structural behavior.**
17.	Understand the basic principles of HVAC, electrical and plumbing systems.

The purpose of this study is to shed some light on what it means to have an understanding of the basic principles of structural behavior and provide some ideas for how to best introduce the related topics and concepts to construction management students. Generally, these students do not relate well to seemingly purely engineering topics, and this attitude interferes with their ability to adequately learn the material. This obviously places an added burden on the faculty who must exert an effort to motivate the students, in addition to teaching the material to them. A search by the author for publications dealing with structural design instruction in CM programs did not produce any relevant publications, but there seems to have been an effort to address the issue of integrating the instruction of structural design in architectural curricula, where it seems much easier to motivate architectural students to learn about structural design concepts. This is because famous architects, such as Frank Lloyd Wright, Louis Kahn, and others, who are also role models for these students, used "sophisticated structural concepts along with innovative material applications to design buildings that engage engineering and structures as a decisive form of expression," as was reported by Wetzel [3], for example.

Through this paper, the author also aims at initiating a discussion to possibly define the minimum components of an adequate understanding of the basic concepts of structural behavior. In the first section, the author makes the case for why understanding these basic concepts is important for construction managers to have. The second section is used to review the extent of the coverage of structural behavior and design concepts in ACCE accredited CM programs and

the most commonly used textbooks. The review was done to gage the range of coverage of structural concepts within these programs with the intent to develop a common minimum threshold for what constitutes an adequate understanding of the basic concepts of structural behavior. The third and fourth sections examine the students' perception of what they think is important for them to learn in terms of structural behavior and evaluate some of the instructional methods used in a structural design course to introduce and reinforce learned concepts. This was done by anonymously surveying twenty students at the introduction and then at the conclusion of the course. It was obvious from the surveys that going through the course did help convince the students of the need for them to have an adequate understanding of the basic concepts of structural behavior.

In conclusion, the author is proposing that providing an adequate understanding of the basic concepts of structural behavior can be achieved by exposing students to eleven specific topics, ranging from the basic concepts of mechanics to concepts of load path and the behavior of structural systems and components. The author is hoping that this will initiate a discussion that might eventually lead to the development of a commonly adopted structural behavior curriculum component in construction management programs.

Importance of understanding the basic principles of structural behavior in construction

The first thing a construction manager is typically confronted with in a project is erecting structural components from the foundation to the framing system. Standard practice states that the Engineer Of Record (EOR) is responsible for the safety and integrity of the structure in its completed state, as can be clearly seen in the Code of Standard Practice (CSP) [4] of the American Institute of Steel Construction (AISC), as an example. The CSP states that "the erector shall be responsible for the means, methods and safety of erection of the structural steel frame." It further states that "The structural engineer of record shall be responsible for the structural adequacy of the design of the structure in the completed project. The structural engineer of record shall not be responsible for the means, methods and safety of erection of the structural steel frame." This clearly places the burden of the safety of the structural components and systems during construction on the contractors. Project managers must often make decision with respect to the necessity of providing adequate temporary bracing or the ability of certain structural elements to support some load during construction. For example, the fact of placing a pallet of steel deck at the wrong location on an erected beam that has not been laterally braced yet may cause damage and possibly injury; an incident that can easily be avoided by having the proper understanding of the behavior of unbraced beams. Moreover, construction project managers must ensure that structural components and details are executed as specified, and sometimes not understanding the concept behind a detail can lead to a missed opportunity for identifying and correcting a potentially dangerous or costly construction error, such as a misplaced or poorly placed rebar in a reinforced concrete beam or wall. It is not surprising that construction related errors have led to many failures and collapses in the past. Zhang et al. [5] studied the causes and statistical characteristics of bridge failures, mostly in China and the USA, by examining ten summaries of investigations of such failures. Construction mistakes were listed as leading causes of failure, at varying proportions, in eight of those investigations, and the authors identified construction mistakes as one of the top five leading causes of failure in the investigated bridges. Having a good grasp on the basic tenets of structural behavior is definitely

a necessary proficiency to have for construction professionals to make sure they have an adequate ability to communicate with engineers and to execute safe and economical structural systems.

Structural behavior and related coverage in accredited construction programs

To the knowledge of this author, there is no formal academic definition of what constitutes an adequate understanding of structural behavior, and this is further demonstrated by the variability in the coverage of the material in the different construction management programs. Aa a matter of fact, a perusal of the requirements of ACCE accredited construction programs revealed that these programs typically require their students to take two or three structural analysis and design courses, with a few exceptions that either would only require one mechanics course or a total of four courses. Coverage in these courses, at a minimum, includes the topics of statics and mechanics of materials, with most programs additionally requiring any combination of design concepts in steel, concrete, wood, masonry, and temporary structures. This wide variation in coverage of structural concepts either indicates that the meaning of "understanding the basic principles of structural behavior" varies considerably from one program to another, or some programs are going way beyond what is required for accreditation, or a combination of both.

Considering the lack of consistency in the coverage of structural topics by the different programs, and the lack of information in the literature of an established standard description of what constitutes an adequate understanding of the basic concepts of structural behavior or what those basic concepts might be, it may be helpful to consider another source of information, such as structural design textbooks that are primarily written to benefit students in the architectural and construction fields. There are not too many of these textbooks but the author identified and reviewed four of them for the purpose of this study. Two of them [6, 7] covered the basic topics of mechanics, i.e. statics and mechanics of materials, while introducing some design concepts as they apply to load path, beams, columns, and trusses. The third textbook [8] proposes an extensive coverage of concepts in structural engineering but at a mostly introductory level. The textbook is divided into five major parts addressing the fundamental functions of structures, wood construction, steel construction, concrete construction, and an overview of structural systems for buildings with three building case studies. The fourth textbook [9] is similar to the third one as it provides a concise yet comprehensive overview of the design of structural elements of various materials, including columns, beams, and tension members and their connections. Clearly textbook offerings in the area do meet the needs of the various programs from the ones that limit their coverage to the most basic concepts of structural behavior and design to the ones that include a substantial coverage of the design of structural systems for construction.

Students' perspective

To have a better grasp of the perception of students of the need for them to have an adequate understanding of the basic concepts of structural behavior and their expectations in terms of achieving it, a class of twenty students taking a steel and concrete design course for construction majors were polled, at the introduction of the course, and asked to identify topics that they were

hoping to learn in the course. The students identified the following topics, listed in alphabetical order:

1. Advantages of using structural steel as a construction material
2. Characteristics of steel and concrete materials
3. Concrete reinforcement (rebar placement and spacing, …)
4. Detailing of steel and concrete members
5. Different applications of reinforced concrete
6. Different applications of structural steel
7. Different types of steel shapes and their uses
8. Estimating of steel structures
9. How steel and concrete work together
10. Load transfer
11. Precast concrete
12. Real life applications for project managers
13. Reinforced concrete construction
14. Renovation of structural steel buildings
15. Steel erection process
16. Structural inspection
17. Structural loads and how they affect design
18. Structural steel fabrication process
19. Structural steel welding
20. The basics of structural behavior
21. The basics of the structural design process

One of the advantages of having the students go through this exercise was to motivate them to think about the possible benefits to them from the course, which in turn will potentially motivate them to learn. Moreover, what is interesting is that the list of topics the students came up with is very telling as it identified all of the structural topics that may not be well covered in other courses within the program. This indicates that they already have an adequate understanding of what they need to know to be successful in their profession. The students were also asked to rate what their understanding was before taking this course of the need for construction managers to have knowledge of the basic concepts of structural behavior. A summary of the answers to this question is shown in Figure 1. Two out of the twenty students (10%) believed that having an understanding of the material was not needed while 14 (70%) believed it was somewhat needed and four (20%) believed it was important. None of the students, however, thought that understanding the basic concepts of structural behavior was critical to their career.

Rate your understanding, before taking this course, of the need for construction managers to have knowledge of the basic concepts of structural behavior	**Respondents**	**Percent**
I believed it was not needed	2	10%
I believed it was somewaht needed	14	70%
I believed it was important	4	20%
I believed it was critical	0	0%

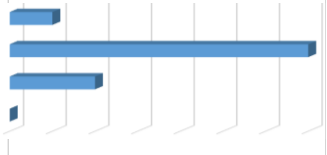

Fig. 1. Students' perception of their need to develop an understanding of the basic concepts of structural behavior before taking a structural design course

Challenges and possible pedagogical approaches

There is no argument that the understanding of the basic principles of structural behavior is an important competency for construction managers to have, and the fact that it made it on the list of required student learning outcomes for the purpose of accreditation is the best testimony for that fact. However, the fact that many, if not most, construction management students consider topics dealing with the understanding of structural behavior as engineering topics that do not concern them makes it challenging for them to learn the material as the burden of learning first and foremost falls on the students themselves. Students who do not see the need for learning a subject will lack the needed motivation and may not put in the necessary effort to learn it. On the other hand, faculty can help by examining, along with their students, realistic situations where a less than adequate understanding of the behavior of a structural system caused a disaster during construction.

Faculty can also increase students' interest in learning about structures by motivating them to think about the topics that they perceive as important for them to know, and figure out a way to incorporate most or at least some those topics into the course, even to a small degree, if they are not already part of the curriculum. It was mentioned earlier that the students in a steel and concrete design courses were asked to identify topics that they were hoping to learn in the course. The same students were polled again at the end of the semester and were asked to select all the topics that they felt were covered adequately and that they thought they had a good grasp on. The results of the survey are shown in Figure 3, and they indicate that all but one of the identified topics were covered, with at least half of the students believing they had a good grasp on 12 out of the 21 identified topics.

At the beginning of the semester, you each identified the topics that you were hoping to learn in this course. Please refer to the list below and select all the topics that you feel were covered adequately and now you have a good grasp on.	**Respondents**	**Percent**
Steel erection process	14	70%
The basics of the structural design process	14	70%
Advantages of using structural steel as a construction material	12	60%
Different types of steel shapes and their uses	12	60%
The basics of structural behavior	12	60%
Different applications of structural steel	11	55%
Structural steel fabrication process	11	55%
Structural steel welding	11	55%
Concrete reinforcement (rebar placement and spacing, …)	10	50%
How steel and concrete work together	10	50%
Real life applications for project managers	10	50%
Structural loads and how they affect design	10	50%
Characteristics of steel and concrete materials	9	45%
Estimating of steel structures	9	45%
Reinforced concrete construction	9	45%
Detailing of steel and concrete members	8	40%
Load transfer	8	40%
Precast concrete	8	40%
Different applications of reinforced concrete	7	35%
Structural inspection	4	20%
Renovation of structural steel buildings	0	0%

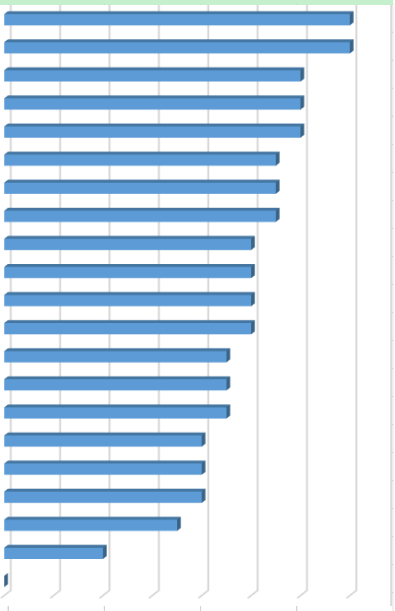

Fig. 2. Students' perception of the adequacy of coverage of topics of interest to them based on a survey taken at the end of the semester

In terms of pedagogy and learning tools, the students were polled towards the end of the semester with respect to which of the following instructional methods were most effective in their opinion:

1. PowerPoint Slides
2. Face-to-face class lectures
3. Worked out examples
4. YouTube videos
5. Homework assignments
6. Homework quizzes
7. Invited Speakers

The results of the survey are shown in Figure 3, and they indicate that, by far, worked out examples are the most effective way for the students to learn, which is not surprising for an engineering design course. The students also equally appreciated having access to PowerPoint slides and YouTube videos and having their lectures delivered face to face.

In your opinion, which of the following learning tools were the most effective?	Respondents	Percent
PowerPoint Slides	9	45%
Face-to-face class lectures	9	45%
Worked out examples	18	90%
YouTube videos	9	45%
Homework assignments	8	40%
Homework quizzes	4	20%
Invited Speakers	7	35%

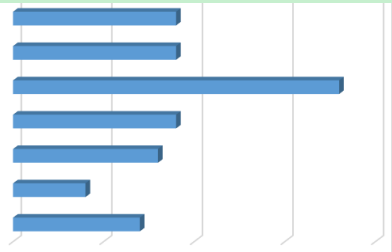

Fig. 3. Students' perception of the adequacy of instructional methods used during the course

The students were also asked to assess their perception of their understanding of structural behavior after having taken the course. The results of the survey are shown in Figure 4, and they indicate that most of the students (90%) rate their understanding as average or above average. Only two of the students ranked their understanding as below average, a number that is surprisingly the same as the number of students who did not think they needed to learn the material. It is important to emphasize here that the purpose of this question was not to assess the learning outcome related to the understanding of the basic concepts of structural behavior, but rather to assess the students' own perception of their achievement of the learning outcome.

Please assess your overall understanding of structural behavior and construction after taking this course	Respondents	Percent
Close to nothing	0	0%
Below average	2	10%
Average	14	70%
Above average	4	20%
Excellent	0	0%

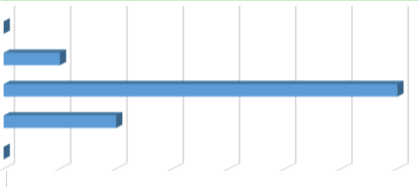

Fig. 4. Students' perception of their understanding of structural behavior at end of course

Finally, the students were asked again to rate what their understanding was after taking the course of the need for construction managers to have knowledge of the basic concepts of structural behavior. Here again there were two students that still believed that it was not needed, but interestingly, half of the students who originally thought the understanding was somewhat needed upgraded their assessment to 'it is important', and two of the students upgraded their assessment to 'it is critical', while none of the students believed that at the beginning of the course. The results are shown below in Figure 5.

Now that you have completed this course, rate your understanding of the need for construction managers to have knowledge of the basic concepts of structural behavior.	Respondents	Percent
I believed it is not needed	2	10%
I believed it is somewaht needed	7	35%
I believed it is important	9	45%
I believed it is critical	2	10%

Fig. 5. Students' perception of their need to develop an understanding of the basic concepts of structural behavior after taking a structural design course

Conclusion

The safety of a structural system during construction and when in service does not only depend on the quality and adequacy of the structural design effort but it is also contingent on the proper execution of the intended design during fabrication and construction. For this reason, construction professionals must have a solid basic understanding of structural components and systems and their behaviors to be able to safely manage the construction process. Although the understanding of the basic concepts of structural behavior is an accreditation requirement according to the American Council for Construction Education (ACCE), there is not a clear academic standard to define what the basic concepts are and what understanding them means.

The examination of the coverage of structural engineering and design topics by a number of ACCE accredited construction management programs revealed a wide variation in the extent of the coverage of the material, but there are commonalities that can help identify a minimum level of understanding of structural systems and their behaviors that students should achieve before entering the workforce. In the absence of a set standard, it is being proposed that construction management students should be exposed to the following topics and concepts before they graduate:

1. Structural failures during construction and why they occur.
2. The basic concepts of mechanics, including equilibrium, internal forces, and stresses.
3. Design codes and codes of standard practice.
4. Types and sources of loads.
5. Structural materials (concrete, masonry, steel, and wood) and their properties and behavior.
6. Concepts of structural stability with an emphasis on the susceptibility of structural components and systems to loss of stability and buckling during construction.
7. Load path (also referred to as load tracing).
8. Gravity load resisting systems and their components, including prefabricated, cast or built in place, pre-stressed, post-tensioned, and their connections.

9. Lateral load resisting systems and their components, including shear walls, braced and unbraced frames, and diaphragms.
10. Basic concepts in the design of steel and wood members.
11. Concepts in the design of temporary structures and supports.

These topics can easily be covered in two regular semester courses of three credit hours each, and the inclusion of case studies of structural failures during construction will allow the students to better grasp the value of what they are learning and be more motivated to learn. And this study showed that when motivated, construction management students can appreciate the opportunity to learn about structural design and construction so they can be better prepared to participate in building a safe infrastructure.

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