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## COMPARATIVE STUDY OF UNIVERSITY COURSES ON CONSTRUCTION SAFETY AT UNDERGRADUATE LEVEL

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**Abstract:** Worker safety is a critical success factor in today's construction projects. Workplace safety plays an important role in the on-time delivery of projects, and it also translates into whether the project participants will earn a profit on investment. More often than not, the majority of today's construction projects encounter events that compromise workers' safety. A key to creating and maintaining a safe workplace is providing effective safety education or training to workers including to those who are responsible for making decisions on a project such as safety managers, construction managers, and supervisors. Despite the emphasis on safety education of workers, safety performance in the construction industry is far from satisfactory. Therefore, there is a need to analyze the content of the safety courses to evaluate their relevance to the major safety challenges faced by the construction industry. In determining what recommendations might be reasonable in establishing construction safety course contents, one area to be examined is what construction safety content is being taught in universities. In this examination, the authors approached the question in two ways. First, they analyze construction safety syllabi from universities in the United States. Second, they set the baseline using the most frequently cited serious violations data over the period of five years as well as Focus Four hazards in construction. Then the content of the safety courses was compared with baseline data. While examining construction safety courses offered at the undergraduate level in construction programs, we found that the contents of the courses were inconsistent. In light of these differences, a growing need has emerged for guidelines for construction safety education, a common foundation from which construction safety education syllabi is enriched. Data obtained from the study provided a basis for recommendations to academia about potential changes which would bridge the gap between construction education and construction safety challenges.

**Keywords:** Most frequently cited serious violations, Focus Four, Safety Education

### 1 Introduction

Construction safety is a critical success factor in today's construction projects. Safety is important to deliver projects on-time that translates into return on investments (Alzahrani and Emsley 2013; Joseph Anthony 1999). Unsafe events are more common in the construction industry than other industries (Park and Kim 2013). According to the United States Bureau of Labor Statistics, construction workers sustained 937 fatal injuries (BLS 2016a) and 79,890 non-fatal injuries and illnesses involving days away from work in 2015 (BLS 2016b). Additionally, private construction had the highest count of fatal injuries in 2015 (BLS 2015). Events that cause either fatal or nonfatal injuries to workers affect the original execution plan and profitability of projects (Chan and Chan 2004, Coble et al. 1999). Therefore, the need for improving the safety performance of the construction industry is evident.

Occupational Safety and Health Administration (OSHA), the USA's health and safety regulator, is recognized as the leading institution setting and enforcing safety standards on workplaces. OSHA inspectors conduct inspections of construction job sites to "assure compliance with OSHA requirements and help employers and workers reduce on-the-job hazards and prevent injuries, illnesses, and deaths in the workplace" (OSHA 2016). When an inspector finds violations of OSHA standards or serious hazards, OSHA may issue citations and fines (OSHA 2016). OSHA releases inspection and citation data every year. For example, in 2015 nearly 11,000 inspections of construction sites resulted in nearly 28,000 citations and fines for violations of OSHA standards. From the data, the most frequently cited serious violations indicate the weakest areas of safety. Conversely, the "Focus Four" hazards are the hazards that were responsible for more than half (64.2%) of the construction worker deaths in 2015 (OSHA 2017). Eliminating the Focus Four hazards would save 602 workers' lives in America every year (OSHA 2017). This study attempts to identify the safety-related problems that are commonly occurring in the construction industry. The first step towards prevention of injuries and fatalities is to recognize the size of the problem (Kartam and Bouz 1998). Identifying those problems may help educators in developing and revising construction safety courses with the appropriate level of detail to understand the nature of the problems, the causes of fatal and non-fatal injuries, and ultimately forecasting possible injuries (Kartam and Bouz 1998). Hence, a revised course based on this research finding will emphasize on critical areas of safety derived from OSHA's most cited violations and Focus Four and will also enable students to analyze the fundamental causes of injuries and fatalities.

Construction firms hire thousands of university graduates who hold an academic qualification in construction management, construction engineering, civil engineering, or other related fields (Gambatese 2003). These fresh graduates who are joining the industry are expected to have the essential awareness related to construction safety. Most institutions offer safety courses to undergraduate students, especially in construction programs. However, depths and breadths of the safety topics vary in different institutions (Gambatese 2003). In light of these differences, standards in construction safety education may help in dissemination of the right best practices; providing a common ground from which construction safety educators can develop the courses.

In this research, the authors analyzed the serious violation data reported by OSHA as well as construction safety course syllabi from ten universities in the USA. Through the analysis of the violation data, this study identified the safety-related problems that are commonly occurring in the construction industry. Moreover, it also identified the safety topics that are being taught in universities. This study performs those analyses to answer the following two research questions: 1) what are the most commonly occurring safety-related problems in the industry? and 2) what construction safety contents are being taught in universities? These questions form the basis of the writers' analyses regarding what construction safety courses' contents are required for a construction professional practicing in the 21st century. After examining the safety course outlines, the authors understand that little focus has been made for a common understanding and recognition of what is required for the development of professionals with the ability to address the alarming health and safety situation of the construction industry. Data obtained from the study provides a basis for recommendations to academia about potential changes which would bridge the gap between the current safety education and the reality of the workplace.

## **2 Methodology**

The aim of the research is to understand the extent to which construction safety courses taught in universities cover the critical areas of safety highlighted in the OSHA's inspection data. The authors performed the following two tasks to meet this aim: 1) a review of OSHA's inspection data as well as OSHA's Focus Four hazards, and 2) an analysis of construction safety course syllabi. Undergraduate construction programs were studied because graduates from construction program usually join the construction industry. Finally, the authors compared the topics listed in the syllabi with the OSHA standards related to the top 30 most frequently cited serious violations and Focus Four hazards. The following subsections discuss the methods of collecting and analyzing information from OSHA's database and university syllabi.

## **2.1 Data Collection**

The analysis of the most frequently cited serious violations from 2011 to 2015 was carried out, and a list of top 30 violations was developed. OSHA publishes a report of most frequently cited serious violations in the construction industry every year. The data provides important information to employers about the areas of weakness in construction safety so that “they can take steps to find and fix recognized hazards addressed in these and other standards before OSHA show up” (OSHA 2016). Additionally, this study collects the syllabi of construction safety courses. First, the authors identified university programs in the United States that offer construction management degrees. The universities are identified using information in the Construction Management Association of America (CMAA) and the Associated Schools of Construction (ASC). Then, the official websites of those institutions are explored to identify the syllabi for those universities. The construction safety syllabi of the universities are downloaded if available. This study only collects construction safety syllabi offered at the undergraduate level and does not focus on safety content that could be taught in other classes. The following information is collected from the syllabi:

1. Course name and course code
2. Credit hours
3. Textbooks and reference material used
4. Content outlined in the syllabi
5. Information about the content from learning objectives of the course

Information for the study was obtained strictly from what was noted in the course description and/or syllabi. This study did not evaluate several years to determine whether the courses have changed over time or whether a particular pedagogical strategy is being used. Additionally, it was not the intent of this study to assess the teaching and learning styles, the credentials of the instructor teaching the safety course or the class size; but rather to determine whether the course covers OSHA’s most frequently serious citation and Focus Four hazards. There could be safety content in other classes, but this study focuses on safety course only. Although this a relatively small sample of course evaluation, the authors feel that is probably an indicator of reality.

## **2.2 Data Analysis**

Each course syllabus was reviewed to identify and determine whether it covered the standards related to the OSHA’s top 30 citations and Focus Four hazards. The authors checked against each field in the database if the citation related topic area was noted and/or described in the material. The assessment measures were only based on the university course syllabi. Some interpretation had to be made since all the syllabi were not designed to provide details of subtopics of OSHA standards. In many cases, though the actual topic area may not have been indicated in the syllabi, it is inferred that the particular topic would have to be taught as other base themes are covered. For example, while the syllabus may not indicate the specific study of fall protection, if the university teaches all OSHA subparts, then fall protection is naturally included as part of the subpart instruction. Thus, the authors, based on their experience and expertise make interpretations about whether the citation related standards are covered.

## **3 Results and Discussion**

This section reports the results of analyzing the inspection data and safety course syllabi. The section starts by reporting the most frequently cited standards and top hazards in construction projects. Then, the topics in construction safety courses are reported. Finally, the comparison between the most frequently cited standards plus top hazards, and course topics are presented.

### 3.1 Most Frequently Cited Standards and Top Hazards in Constructions Projects

Table 1 shows the top 30 serious violations that were most frequently cited by OSHA between 2011 and 2015. The repetition rates of those violations shown in the table indicate the number of times during five years a specific OSHA's safety standard was among the top 30 violations. The results illustrate that there are repetitive violations between those five years. Specifically, there are 39 areas of violations between 2011 and 2015. From these violations, six violations appeared only once on the list, while 33 violations appeared more than once. In other words, more than 80 percent of the top 30 violations appeared more than once over the five years period.

Furthermore, about 50 percent violations remained unchanged over the period of the study. These repeated violations were related to all the most frequently cited OSHA standards except safety standards for concrete and masonry construction. In general, the violation data provides information to both academia and the industry to take action through the development of effective safety training and education system. From the data, it is evident that almost half of the standards keep changing which may be an indicator of emerging safety challenges. Therefore, designing a curriculum which can accommodate the emerging issues of safety is critical. For instance, all the violations which regularly appear on the top citation list are important to address through training and retraining the workers. However, the new violations which enter into the list also require close attention to stop them from becoming permanent members of the list through training and workplace safety management. This information of safety standard violation would provide areas from where instructors can select topics to prepare future generation to work safely on construction projects.

OSHA has identified the four leading causes of fatalities in the construction industry. The four causes are electrical hazards, fall hazards, struck-by hazards, and caught-in or -between hazards (OSHA 2017). These hazards are responsible for more than half (64.2%) of the construction workers' deaths in 2015 (OSHA 2017). Moreover, eliminating these Fatal Four hazards would save 602 workers' lives in America every year (OSHA, 2017). OSHA has developed training modules to train the workforce in the construction industry to understand the hazards on their job site and employee responsibility to prevent workers from hazards present in the workplace. Accordingly, the topics about Focus Four hazard recognition and control are the mandatory part of the 10- and 30-hour OSHA Construction Outreach Training Program classes (OSHA 2011).

From these findings, educators should consider preparing students with the skills, knowledge or ability to address these repetitive violations and hazards. Preparing students with those competencies may improve the existing safety culture.

Table 1: The list of the top 30 serious violations that are most cited from 2011 to 2015 and their repetition rate

<b>OSHA Health and Safety Regulations</b>	<b>Description</b>	<b>Repetition Rate</b>
Subpart C-General Safety & Health [1926.20 – .35]	Inspection by a competent person	5
	Employee training program	5
	Initiate and maintain accident prevention program	5
	Housekeeping	2
Subpart E-Personal Protective & Life Saving Equipment [1926.95 – .107]	Head protection	5
	Eye and face protection	5
	PPE-provided, used & maintained	4
Subpart K-Electrical [1926.400 – .449]	Grounding path	5
	Flexible cord strain relief	5
	Equipment installation and use	5
	Worn/frayed cords and cables	4
	Ground fault protection	3
	Use of GFCI or Assured Grounding Program	1

<b>OSHA Health and Safety Regulations</b>	<b>Description</b>	<b>Repetition Rate</b>
Subpart L-Scaffolds [1926.450 – .454]	Aerial lifts - fall protection	5
	Scaffolds - Fall protection	5
	Training for scaffold users	4
	Full planking	4
	Safe access	3
	Scaffolds - access	1
	Scaffolds - platform	1
	Protection by PFAS or Guard Rail system	1
Subpart M-Fall Protection [1926.500 – .503]	Fall protection- residential construction	5
	Fall protection- unprotected sides & edges	5
	Fall protection - training	5
	Fall Protection- Roofing work on steep slopes	5
	Fall protection-roofing work on low - sloped roofs	3
Subpart P-Excavations [1926.650 – .652]	Safe egress	5
	Protection from falling /rolling materials and equipment	5
	Competent person-inspections	5
	Cave-in protection	4
	Employee protection in excavations- protective system use	1
Subpart Q-Concrete & Masonry Construction [1926.700 – .706]	Reinforcing steel guarding	3
Subpart R-Steel Erection [1926.750 – .761]	Fall protection over 15 feet	1
Subpart X-Stairways and Ladders [1926.1050 – .1060]	Portable ladders not extended 3 feet above landing	5
	Stairways and Ladders - appropriate use	5
	Using top step as a step	5
	Ladder & stairway hazard training	4
	Stairways or ladder provided for a 19-inch break in elevation	3
	Use of defective portable ladders	2

### 3.2 Topics in Construction Safety Courses

Out of fifty universities surveyed, construction safety syllabi from ten universities were available to download. Those ten syllabi were then analyzed to identify the safety topics taught in those courses. Figure 1 shows the range of safety topics that were identified from the ten syllabi and the percentages of universities teaching those topics. Most of these topics are related to the OSHA standards. Of the ten institutions, nine taught topics such as an introduction to OSHA, workers' right, employer responsibilities, health hazards. These are all required topics of OSHA's 10- and 30-hour Construction Outreach Training Program classes. Six institutions taught crane safety, material handling, and hazard communication. A few institutions taught additional topics in the classroom including ergonomics, emergency response plan, tool box talk, health and safety management, development of safety plans, ethics, signs and signals, and traffic control.

There are institutions that teach topics to satisfy the requirements of OSHA's 10-hour or 30-hour classes. Specifically, out of the course surveyed, 60 percent taught the topics that satisfy the requirements of OSHA's 30-hour training, and 10 percent satisfy the requirements for OSHA's 10-hour training. Students

are awarded respective cards if they meet the training requirements. Each institution has their preference to offer the safety course during the degree program. For example, one of the institution offers safety course to second-year students in construction engineering and management program. Students graduating from the course can apply for internships providing them the opportunity to work safely. Other institutions may have a similar approach for placing the course in any particular year, but the writers could not find such information from the syllabi. In the study, the writers found that there were also three institutions that taught topics other than OSHA standards such as the theories of accident causation, the cost of accidents, and environment safety. There were three institutions that offered ergonomic hazards which are not an OSHA standard, but it is covered under the General Duty Clause of OSHA. Ergonomic-related hazards may not directly cause any accidents, but consideration of ergonomic on workplace can help prevent work-related musculoskeletal disorders (OSHA n.d.). The results show that there were only four common topics among most of the institutions, specifically nine out of ten institutions. This fact highlighted the inconsistencies in the topics among all institutions. Moreover, the time required to teach certain topics varied extensively. For example, one institution taught all OSHA standards from subpart A to subpart Z in five lectures over three weeks' period. Then, rest of the lectures during the semester were dedicated to teaching case studies. This study could not verify whether the case studies were related to OSHA Subparts or otherwise because no details were given in the syllabi. From this example, the authors question how did syllabi meet the OSHA 30-hour training requirements. Too little-detailed course content may result in key theories and topics such as accident the theory of accident causation, accident cost and information on OSHA standards being missed rendering the construction safety education in some cases useless.

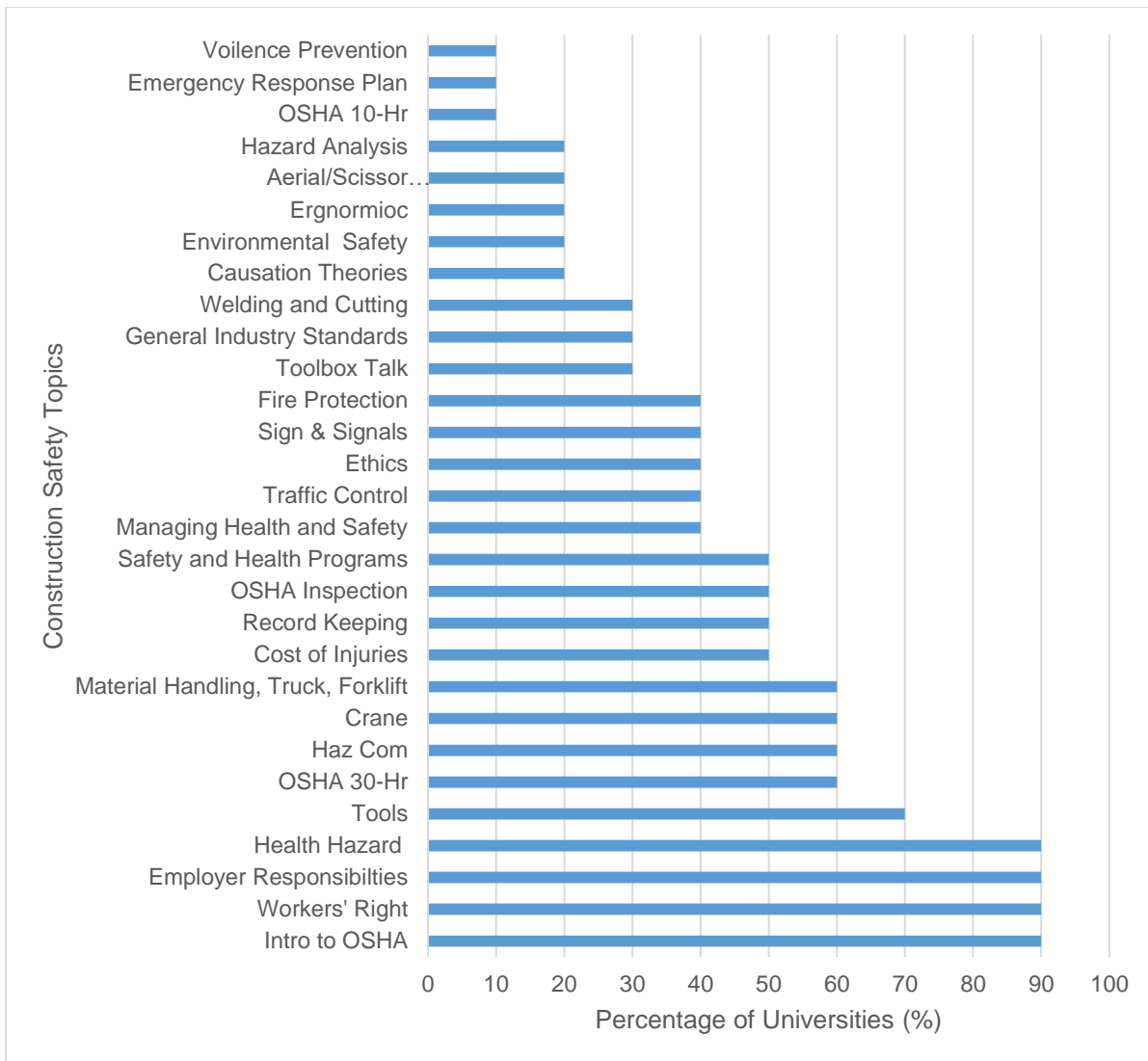


Figure 1: Extent of coverage of Safety topics in universities

This study also analyzed the textbooks that are being used to teach safety. From the analysis, it was found that most of the courses focused on teaching OSHA's standards. These courses did not mandate the usage of any textbooks because OSHA's website has all the information on health and safety standards for free. On the other hand, there were three courses that teach topics that were other than OSHA standards. These topics were being taught from specified textbooks. Interestingly, one institute offered a construction safety course that did not mention any topic about OSHA in the syllabi and the topics covered in the classroom were selected from a safety textbook providing general education on safety. Otherwise stated, besides the inconsistencies between the course topics, there is also an inconsistency between the resources that are being used in the courses.

### 3.3 Most Frequently Cited Standards and Focus Four vs. Topics in Construction Safety Courses

There were a handful of institutions, 50 percent, that discussed all topics related to most frequently cited standards as shown in Figure 2. There was a consensus among all ten institutions to teach electrocution, fall protection, and excavation standards. Two of them, fall protection and electrocution are part of the Focus Four hazards in construction as shown in Figure 3. Overall, 80 percent institutions taught Fatal Four hazards. It is obvious that not a single school out of 10 taught all Focus Four hazards.

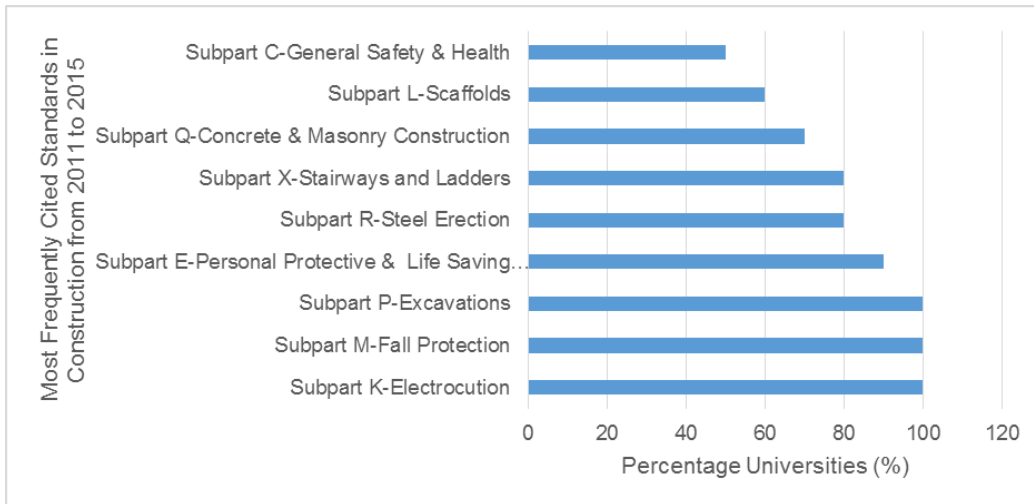


Figure 2: University courses teaching standards related to most Frequently Cited OSHA Standards in construction

Figure 2 shows that the most neglected standard was Subpart C. This subpart elicits basic requirements of safety and health program including topics such as record keeping, injury reports, and sanitation reports. The standards related to scaffolds which have its permanent presence on the most frequent citation list was taught by only 60 percent of the courses. This shows that problems related to scaffolds will continue to exist if all the construction graduate are not being trained in the degree program. Similarly, another important standard of ladders which is directly linked to one of the top causes of fatalities-fall from height is taught by 80 percent of the programs.

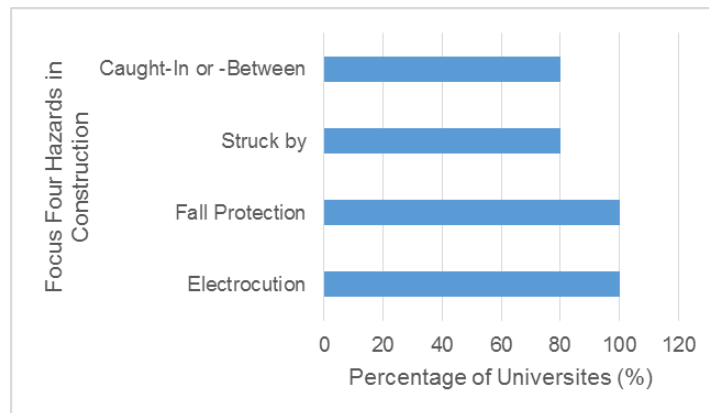


Figure 3: University courses teaching standards related to Focus Four hazards in construction

The consensus on topics such as Fatal Four hazards and most frequently cited standards will help the industry to achieve the goal of zero accidents. It is also important to continuously monitor the changes in frequent violations data to update the course topics. The authors consider that understanding of the basic theories of accident causation and motivation can also help managers to look beyond standards that can help them to develop a safety culture in organizations.

#### 4 Conclusion

The main conclusions derived from the research include: few universities have the most comprehensive and specific syllabi regarding construction safety. There is no uniformity or consistency in the course syllabi, textbooks, or reference materials used in the various institutions in the United States. This study found only



four topics were common among all ten syllabi studied. Only 80 percent institutions taught the topics related to top causes of fatalities. As a result of the lack of consistency in the teaching of construction safety, the knowledge base of those graduating and then applying construction safety to construction projects enormously varies. To address the issues of better construction safety and to eliminate the number of fatalities in the industry, there is a need to move toward comprehensive guidelines in the areas of construction safety education. These guidelines should comprise at a minimum the base topics that should be included in any teaching on construction safety course.

### **Acknowledgement**

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