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Safety as a Part of Construction Means and Methods: A Complimentary Teaching and Learning Approach for Occupational Safety

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ABSTRACT

Construction safety is a critical and required educational component for construction programs. In the United States, most of the construction programs deliver this content in a stand-alone and dedicated course that aligns with the Occupational Safety and Health Administration (OSHA)'s outreach training content. The typical content includes an introduction to OSHA, regulations, compliance, focus four hazards (falls, electrocution, struck-by, and caught-in/between), personal protective and life-saving equipment, health hazards, and elective topics (selected from a limited list). The long list of topics usually concludes the semester with some optional content and exams. Although this structure provides comprehensive coverage, it does not allow an opportunity to cover activity-specific hazards. This paper proposes a complementary approach to teach safety as a part of construction means and methods. This approach consists of two activities: identifying activity-specific hazards and developing solutions for these hazards. To illustrate the approach, multiple years of fatality data from the Census of Occupational Fatalities and Injuries were collected and analyzed for Concrete Contractors (NAICS 238110). The analysis resulted in major categories of root causes, circumstances, and environmental factors of fatal accidents. Examples of incorporation into the means and methods courses are included in the paper. This approach can be replicated with other specific construction activities and used as a valuable tool throughout the construction curriculum.

INTRODUCTION AND BACKGROUND

Construction is one of the most dangerous industries in the United States that accounted for 976 fatalities in 2020, with the second-largest rate of fatal work injuries with a 13.5 per 100,000 full-time equivalent workers rate [1]. Safety is recognized as an essential part of professional practice, and construction education programs take this into account by requiring occupational safety classes in their curriculum.

Professional accreditation standards include safety as a mandatory part of their student learning outcomes. For example, the American Council for Construction Education (ACCE) lists "create a construction project safety plan" as one of the higher-level student learning outcomes [2]. Most construction programs address these requirements by creating stand-alone and dedicated courses aligned with the Occupational Safety and Health Administration (OSHA)'s outreach training content. Initiated in 1971, OSHA outreach programs offer 10 and 30-hr training for the construction industry to recognize, avoid, abate, and prevent safety and health hazards in workplaces [3]. The typical content includes an introduction to OSHA, regulations, compliance, focus four hazards (falls, electrocution, struck-by, and caught-in/between), personal protective and life-saving equipment, health hazards, and elective topics (selected from a limited list).

When combined with safety plan development, the long and comprehensive list of OSHA training topics usually completes a semester-long class and addresses the accreditation requirements. However, this approach does not leave a lot of room for activity-specific hazards and prevention.

This paper proposes a complementary approach to teach safety as a part of construction means and methods. This approach consists of two activities: identifying activity-specific hazards and developing solutions for these hazards. The project environment and circumstances are essential to understand the worker's exposure level and type and severity of injuries [4]. Over the years, activity-specific analysis or job safety (hazard) analysis procedures have been used in practice to address the specific risk associated with construction activities and sequences [5, 6]. OSHA accident investigation reports provide a valuable resource to understand the circumstances of any given incident.

OSHA has been investigating workplace accidents since its inception in 1970. The data from the OSHA investigations and statistics collected by the Bureau of Labor Statistics (BLS) are used to establish OSHA's programs and target high-risk activities and industries. OSHA and BLS use a standard classification system for accident/investigation records and labor statistics defined by the government regulations. Multiple studies utilized the information and data from the specific accident investigation reports that provided insight into the circumstances of the fatal incidents [4, 7, 8].

To illustrate the complementary teaching approach, multiple years of fatality data from the Census of Occupational Fatalities and Injuries were collected and analyzed for Concrete Contractors (NAICS 238110). The analysis resulted in major categories of root causes, circumstances, and environmental factors of fatal accidents. Examples of incorporation into the means and methods courses are included in the paper.

DATA COLLECTION

OSHA maintains an online database of accident investigation reports [9] (for fatal and non-fatal injuries) searchable for specific North American Industry Classification System (NAICS) codes [10]. The data presented in this paper were collected in 2021 for Concrete Contractors (NAICS 238110). Figure 1 shows a sample screenshot of an investigation report.

The database search was filtered for non-fatal accidents between January 1, 2018, and December 31, 2019, resulting in 33 fatal accidents. Detailed accident reports were downloaded for each of the 33 accidents for further analysis. One accident (Accident Number: 109836.015) included two recorded fatalities. The investigation reports contain a wide range of data, including the accident description, cause, project type, and demographics. Each record is also linked to specific inspection and injury information. Figure 2 presents the fatality cause, fatality age, end use, and project type of the 34 fatalities in the dataset.

Accident Report Detail

Accident: 122038.015 - Employee Is Killed In Building Collapse

Accident: 122038.015 -- Report ID: 0522000 -- Event Date: 11/25/2019			
Inspection	**Open Date**	**SIC**	**Establishment Name**
1447797.015	11/26/2019		Gateway Concrete Forming Services, Inc.

At 1:30 p.m. on November 25, 2019, an employee spraying water onto concrete colu mns underneath the framework constructed to hold a concrete pour of the seventh floor of a building under construction. The poured concrete weighed more than th e form could accommodate and the seventh floor collapsed onto the employee. The employee was killed by crushing injuries sustained when the concrete fell on him .

Keywords: building collapse, concrete, crushed, crushing, frame

End Use	**Proj Type**	**Proj Cost**	**Stories**	**NonBldgHt**	**Fatality**
Other building	New project or new addition		7		X

Employee #	**Inspection**	**Age**	**Sex**	**Degree**	**Nature**	**Occupation**	**Construction**
1	1447797.015	58	M	Fatality		Laborers, except construction	**FallDist**: **FallHt**: **Cause**: Pouring or installing floor decks **FatCause**:

Figure 1. Sample Accident Investigation Report

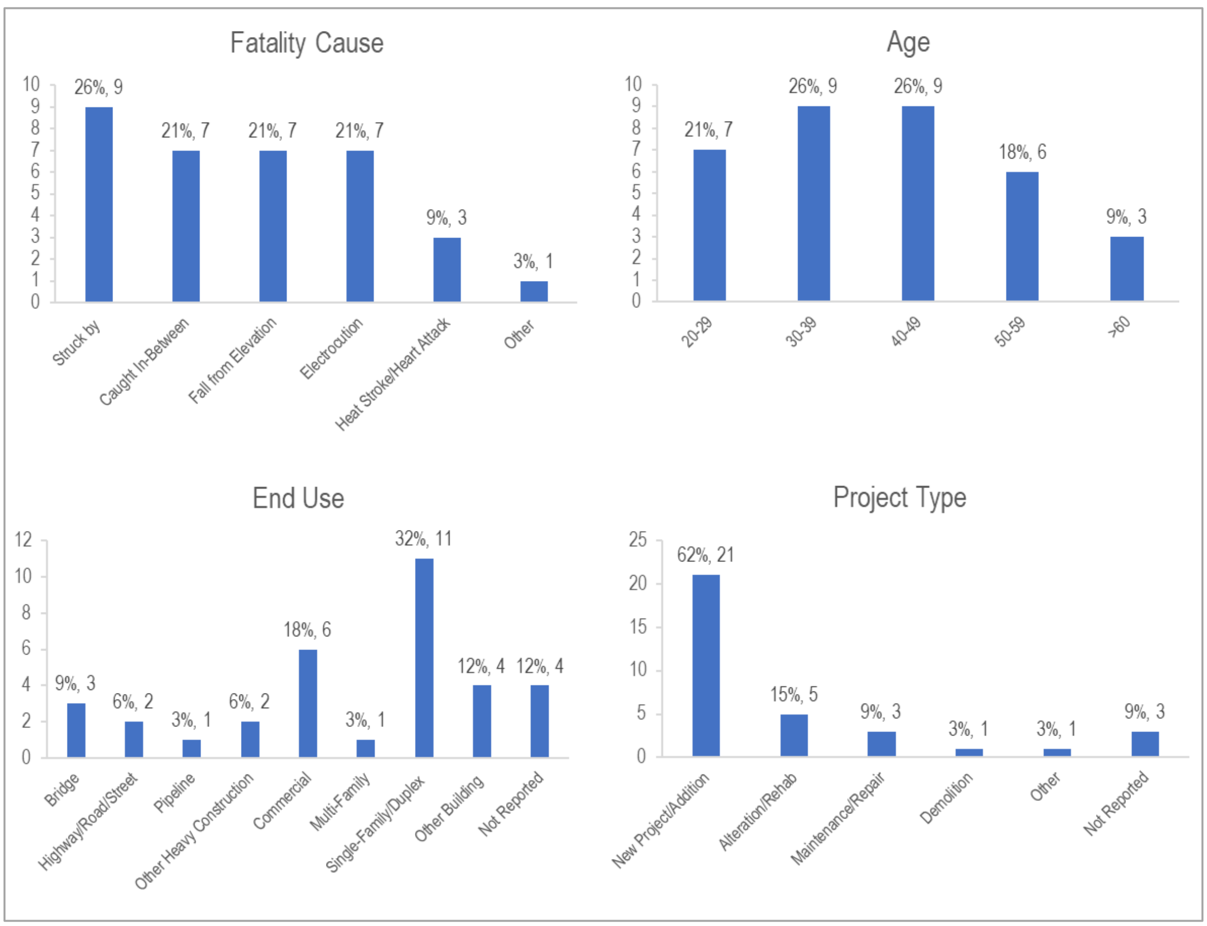

Figure 2. Fatality Cause, Age, End Use, and Project Type Distribution

Figure 2 shows struck-by incidents lead the fatality causes with 26%, followed by caught-in-between (21%), fall (21%), and electrocution (21%). Fatality age shows a normal distribution. Single-family/duplex construction leads the end use category with 32% of the fatalities. 62% of the fatal incidents were in a new construction/new addition project.

ACTIVITY AND ROOT CAUSE/CIRCUMSTANCE ANALYSIS

The activity reports in the dataset are further analyzed using the information contained in the description and keywords. Tables 1 and 2 present each fatality category's activity type and root cause/circumstance. Table 3 is a cross-reference of activity type and root cause/circumstance data.

As shown in Table 1, 29% of the fatalities occurred during pumping or pouring concrete activities leading to incidents of electrocution (40%), struck by (30%), and fall (30%). All incidents during earthwork activities resulted in caught-in-between fatalities, while material handling resulted in incidents of struck-by, fall, and heat stroke/heart attack.

All electrocution incidents were caused by contact with overhead powerlines, as shown in Table 2. The structural collapse caused struck by (60%), fall (20%), and caught-in-between (20%) incidents. Table 2 also identifies the “fall from work platform” and “fall from lift/vehicle” as the circumstances from the fall category.

The cross-referencing in Table 3 provides a different perspective for the electrocution fatalities. As noted in Table 2, all electrocution fatalities were caused by contact with overhead powerlines; however, 57% of those incidents happened during pumping or pouring concrete, 29% during ariel lifts, and 14% (one incident) was during concrete finishing activities. When the accident description is reviewed for the concrete finishing activity, it noted contact with overhead lines while using a jointer with an extended handle. 40% of structural collapses occurred during pumping or pouring concrete, and 40% occurred during demolition and repair activities.

Tables 1 and 2 listed “not reported,” “other,” and “shelter during storm” incidents. The “not reported” accident description included a statement that the worker fell over a guardrail without a reference to the work activity. The “other” accident description reported a worker found dead during sidewalk repair activities without a specific cause of death. The “shelter during storm” accident was described as workers taking shelter in a small structure that eventually collapsed and struck the workers.

Additional cross-referencing tables can be created to address project types, end use, and demographics with the additional information derived from the descriptions and keywords. It is important to note that this paper uses a limited dataset for illustration purposes. A more extensive data set may increase the understanding of the fatal incidents and identify different patterns. However, activities/hazards that may not be easily associated with concrete work, such as loading/unloading, cleanup, and maintenance, are visible even with a limited dataset.

Table 1. Fatality Cause and Activity Type

	ACTIVITY TYPE														
CAUSE	Pump/Pour Concrete	Demo/ Repair	Earthworks	Material Handling	Aerial Lift	Finish Concrete	Survey/ Inspect/ Supervise	Carpentry/ Installations	Cleanup	Equipment Operation	Formwork	Loading/ Unloading Equipment	Shelter During Storm	Not Reported	TOTAL
Struck by	3 (30%)	2 (50%)	-	1 (33%)	1 (33%)	-	1 (50%)	-	-	-	-	-	1 (100%)	-	**9 (27%)**
Electrocution	4 (40%)	-	-	-	2 (67%)	1 (50%)	-	-	-	-	-	-	-	-	**7 (21%)**
Fall from Elevation	3 (30%)	-	-	1 (33%)	-	-	-	-	-	1 (100%)	1 (100%)	-	-	1 (100%)	**7 (21%)**
Caught In-Between	-	1 (25%)	3 (100%)	-	-	-	-	1 (100%)	1 (100%)	-	-	1 (100%)	-	-	**7 (21%)**
Heat Stroke/Heart Attack	-	-	-	1 (33%)	-	1 (50%)	1 (50%)	-	-	-	-	-	-	-	**3 (9%)**
Other	-	1 (25%)	-	-	-	-	-	-	-	-	-	-	-	-	**1 (3%)**
TOTAL	**10 (29%)**	**4 (12%)**	**3 (9%)**	**3 (9%)**	**3 (9%)**	**2 (6%)**	**2 (6%)**	**1 (3%)**	**1 (3%)**	**1 (3%)**	**1 (3%)**	**1 (3%)**	**1 (3%)**	**1 (3%)**	**34 (100%)**

Table 2. Fatality Cause and Root Cause/Circumstance

	ROOT CAUSE/CIRCUMSTANCE										
CAUSE	Contact w/ Overhead Powerline	Structural Collapse	Pinned by/in Equipment	Fall from Work Platform	Struck by Vehicle/ Equipment	Medical/ Physical	Cave-In	Struck by Falling Object	Fall from Lift/Vehicle	Unknown	TOTAL
Struck by	-	3 (60%)	-	-	4 (100%)	-	-	2 (100%)	-	-	**9 (27%)**
Electrocution	7 (100%)	-	-	-	-	-	-	-	-	-	**7 (21%)**
Fall from Elevation	-	1 (20%)	-	4 (100%)	-	-	-	-	2 (100%)	-	**7 (21%)**
Caught In-Between	-	1 (20%)	4 (100%)	-	-	-	2 (100%)	-	-	-	**7 (21%)**
Heat Stroke/Heart Attack	-	-	-	-	-	3 (100%)	-	-	-	-	**3 (9%)**
Other	-	-	-	-	-	-	-	-	-	1 (100%)	**1 (3%)**
TOTAL	**7 (100%)**	**5 (15%)**	**4 (12%)**	**4 (12%)**	**4 (12%)**	**3 (9%)**	**2 (6%)**	**2 (6%)**	**2 (6%)**	**1 (3%)**	**34 (100%)**

Table 3. Activity Type and Root Cause/Circumstance

ACTVITY TYPE	ROOT CAUSE/CIRCUMSTANCE										
	Contact w/ Overhead Powerline	Structural Collapse	Pinned by/in Equipment	Fall from Work Platform	Struck by Vehicle/ Equipment	Medical/ Physical	Cave-In	Struck by Falling Object	Fall from Lift/Vehicle	Unknown	TOTAL
Pump/ Pour Concrete	4 (57%)	2 (40%)	-	1 (25%)	2 (50%)	-	-	-	1 (50%)	-	**10 (29%)**
Demo/ Repair	-	2 (40%)	-	-	-	-	-	1 (50%)	-	1 (100%)	**4 (12%)**
Earthworks	-	-	2 (50%)	-	-	-	1 (50%)	-	-	-	**3 (9%)**
Material Handling	-	-	-	1 (25%)	1 (25%)	1 (33%)	-	-	-	-	**3 (9%)**
Aerial Lift	2 (29%)	-	-	-	-	-	-	1 (50%)	-	-	**3 (9%)**
Finish Concrete	1 (14%)	-	-	-	-	1 (33%)	-	-	-	-	**2 (6%)**
Survey/ Inspect/ Supervise	-	-	-	-	1 (25%)	1 (33%)	-	-	-	-	**2 (6%)**
Carpentry/ Installations	-	-	-	-	-	-	1 (50%)	-	-	-	**1 (3%)**
Cleanup	-	-	1 (25%)	-	-	-	-	-	-	-	**1 (3%)**
Equipment Operation	-	-	-	-	-	-	-	-	1 (50%)	-	**1 (3%)**
Formwork	-	-	-	1 (25%)	-	-	-	-	-	-	**1 (3%)**
Loading/ Unloading Equipment	-	-	1 (25%)	-	-	-	-	-	-	-	**1 (3%)**
Shelter During Storm	-	1 (20%)	-	-	-	-	-	-	-	-	**1 (3%)**
Not Reported	-	-	-	1 (25%)	-	-	-	-	-	-	**1 (3%)**
TOTAL	**7 (21%)**	**5 (15%)**	**4 (12%)**	**4 (12%)**	**4 (12%)**	**3 (9%)**	**2 (6%)**	**2 (6%)**	**2 (6%)**	**1 (3%)**	**34 (100%)**

COMPLEMENTARY TEACHING APPROACH FOR SAFETY

The data presented in Figure 2 and Tables 1, 2, and 3 provides an opportunity to enhance the content of other construction classes. In this case, a materials and methods course would be an ideal target since the "concrete contactor" data will likely overlap with the concrete-related portion of the course.

Four different approaches can be used for the delivery of the content:

- **Activity-Based Approach:** Multiple individual sections can be added to the concrete construction means and methods using the information presented in Tables 1, 2, and 3. For example, when concrete placement methods are discussed, the struck by, electrocution and fall incidents can be presented, and hazard mitigation ideas can be introduced.

- **Trade-Based Approach:** The information can be presented at the end of the concrete content as the potential activities/hazards facing the concrete contactors. This approach would provide an overall perspective of the expected work environment.

- **Hazard-Based Approach**: The information can also be presented using the major fatal cause categories with root causes and activity types. A more comprehensive dataset may provide an in-depth analysis which can also be used as a part of the stand-alone safety course.

- **Case Study Approach**: An individual accident can be presented as a case study to include the fatality details with demographics, causes, and project activities and circumstances. This approach may be more challenging since the majority of the accident investigation reports do not include very detailed descriptions. The National Institute for Occupational Safety and Health's Fatality Assessment and Control Evaluation Program (NIOSH FACE) uses this approach [11]. FACE database may provide a more complete set of information considering the limitations of the publicly available accident investigation reports.

Although the approaches noted above provide a simplified list of ideas, combining one or more of these approaches may be more effective.

SUMMARY AND CONCLUSIONS

This paper proposed a complementary approach to teach safety as a part of construction means and methods. To illustrate the approach, multiple years of fatality data from the Census of Occupational Fatalities and Injuries were collected and analyzed for Concrete Contractors (NAICS 238110). The analysis resulted in major categories of root causes, circumstances, and environmental factors of fatal accidents. Examples of incorporation into the means and methods courses are listed included in the paper using the analysis.

For a specific NAICS category, a more extensive data set may increase the understanding of the fatal incidents and identify different patterns. This approach can also be replicated with other specialty trade contractors (NAICS 238) to create a valuable tool used throughout the construction curriculum.

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