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ANALYSIS OF TRENCH-RELATED FATALITIES IN CONSTRUCTION AND DEVELOPMENT OF INTERVENTION STRATEGIES

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ABSTRACT
Every year, there are over one hundred estimated fatalities associated with excavations and trenching operations, including cave-ins, contacts with electrical cables, equipment related accidents, improper rescues and utilities damages. In order for accident prevention programs to be effective in reducing injuries and fatalities in trenching operations, they must focus on those elements of the job environment that constitute the primary causes. Developing a database to identify the causes of fatalities in trenching operations is the first step in the development of effective intervention strategies.

This paper will describe an industry-wide study on trench-related accidents using the National Institute for Occupational Safety and Health (NIOSH) Fatality Assessment and Control Evaluation (FACE) program, which involves on-site investigations where fatalities have occurred. Data collected from these investigations can help explain the factors that may be overlooked by the Occupational Safety and Health Administration (OSHA)'s accident investigation summaries and the Bureau of Labor Statistics (BLS) reports. This paper will provide an overview of the chain of events that lead to excavation and trenching-related fatalities. The research study underlying this paper is funded through a grant from NIOSH to the Construction Safety Alliance (CSA)

KEYWORDS
Trenching, Accident Prevention, Fatalities, Injuries, FACE

1. INTRODUCTION

Construction is one of the most hazardous industries. Each year a substantial number of construction workers los their lives; many others are injured. Estimates of the number of fatalities range from several hundred to over 2,000 per year. (OSHA, 1990). During 2000, construction again recorded the highest number of fatal work injuries of any industry with 1,154 fatalities reported. Althought the total for the industry was down about 3% - the first decline for construction since 1996, if compared with 1999. (BLS, 2001).

Trenching fatalities continue to plague the construction industry. While accurate records of the actual number of fatalities ocurring in trenching incidents are not maintained, the estimate of 100 fatalities per year is perhaps a reasonable approximation of the magnitude of the problem (Hinze and Bren, 1997). According to an analysis by the National Institute for Occupational Safety and Health (NIOSH) of worker's compensation claims in the Supplementary Data System of the Bureau of Labor Statistics, there are approximately 1000 work related injuries each year due to excavation cave-ins. Of these, about 140 result in permanent disability and 75 in death. (NIOSH, 1995).

In addition to fatalities, injuries caused due to unsafe trenching practices are costly in terms of direct and indirect costs to the construction industry. The direct costs include medical and workers' compensation payouts. The employers and society also pay large indirect costs. (Hinze, 1991) estimated that the ratio of indirect to direct costs for injuries resulting in lost work time was 20 to 1. The indirect costs range from lost productivity among co-workers and management, and lawsuits, to reduced worker morale, especially when fatalities occurred. The previous data confirmed that cave-ins are an important cause of death in construction industry. This occur even though, employers are aware of the Occupational Safety and Health Administration (OSHA) regulations in the construction site.

This paper describes an industry-wide study on trench-related accidents using the NIOSH Fatality Assesment and Control Evaluation (FACE) program. The complete reports were studied in detail and all of them considered fatalities.The results were analysed and an overview of the main causes and the chain of events that lead to excavation and trenching-related fatalities is explained.

2. THE FATALITY ASSESMENT AND CONTROL EVALUATION (FACE) PROGRAM

In order to understand the fatalities causes associated with trenching operations, and to develop the intervention strategies, it is necessary to access NIOSH, specifically the FACE program. The objectives of the program are to identify and study fatal occupational injuries. The FACE program focuses on investigations of fatal occupational injuries. The goal of the FACE program is to prevent occupational fatalities across U.S by identifying and investigating work situations at high risk for injury. The next steps are then formulating and disseminating prevention strategies to those who can intervene in the workplace (NIOSH, 2000).

The FACE program currently has two components:

- NIOSH In-house FACE began in 1982. Participating states voluntarily notify NIOSH of traumatic occupational fatalities resulting from targeted causes of death that have included confined spaces, electrocutions, machine-related, falls from elevation, and logging. In-house FACE is currently targeting investigations of deaths associated with machinery, deaths of youths under 18 years of age, and street/highway construction work zone fatalities.

- NIOSH State-based FACE began in 1989. Currently, 15 State health or labor departments have cooperative agreements with NIOSH for conducting surveillance, targeted investigations, and prevention activities at the State level using the FACE model.

The primary activities of the FACE program are:

- Conducting surveillance to identify occupational fatalities
- Performing investigations of specific types of events to identify injury risks
- Developing recommendations designed to control or eliminate identified risks
- Making injury prevention information available to workers, employers, and safety and health professionals.

During the on-site investigations, facts and data are collected on items such as: type of industry involved, number of employees in the company, company safety program, the victim's age, sex, occupation, the working environment, the tasks the victim was performing, the tools or equipment the victim was using and the role of management in controlling how these factors interact. The names of employers, victims, and/or witnesses are not used in written investigative reports or included in the FACE database.

Surveillance and investigative reports are maintained by NIOSH in a database. NIOSH researchers use this information to identify new hazards and case clusters. FACE information may suggest the need for new research or prevention efforts or for new or revised regulations to protect workers. NIOSH publications are developed to highlight these high-risk work situations and to provide safety recommendations. These publications are disseminated to targeted audiences and are available on the Internet through the NIOSH homepage or through the NIOSH publications office.

2.1 Data analysis

The information about fatalities was extracted from the reports available in the NIOSH web site using *trenching* as a key word. (NIOSH 2001). The reports are displayed as a links. In order to select the reports, every link was evaluated. More than 250 links were analyzed, selecting 52 reports related with trenching operations fatalities. These 52 reports were studied in detail, extracting the main data associated with the fatality. The reports are from 1985 to 2000.

The main information extracted from each report was: identification code, date, State, time, age, sex, accident description (BLS category), equipment, depth of the trench, crew size, weather, type of operation, occupation, race, worker status, competent safety site, official safety program, worksite inspection, training education, company description (Standard Industrial Classification SIC), recommendations. It should be noted that some reports, specially those from 1985-1990, have incomplete data.

Geographical distribution. The geographical distribution of the reports is presented in Table 1.

Table 1: Geographical distribution

State	Reports	State	Reports	State	Reports
Alaska	2	Maryland	4	Ohio	1
Arizona	2	Massachusetts	4	Pennsylvania	1
California	9	Michigan	1	South Carolina	1
Florida	1	Minnesota	4	Texas	2
Georgia	2	Nebraska	2	Wisconsin	1
Indiana	1	New Jersey	7	Wyoming	5
Iowa	1	North Carolina	1		

Type of accident. The first characteristic analyzed in the reports was the type of accident. In the reports, the accident description is related, but it is not classified under any codification system. In this paper, we considered the BLS classification (BLS,1992) to assign codes for every accident. The BLS classification is shown in Table 2.

It is important to note that FACE reports do not just include excavations or trenching cave-ins, although they are the most frequent cause of fatalities in trenching operations. Previous papers about trenching operations (Hinze and Bren, 1997), (Stanevich and Middleton, 1988) emphasized in analyzing cave-ins as a main cause of death in trenching operations. According with FACE reports, new causes of fatalities in trenching operations are identified, especially those related with equipment and underground utilities. In Table 2, 68% of the cases are not cave-ins. In other words, most trench-related accidents were not caused by cave-ins according with FACE reports.

The equipment related accidents involved mechanical failures and incorrect maneuver by the operators. Some reports explained how the workers were near the equipment and they did not respect the signals and warnings from the operator. Also, some accidents ocurred when the operator made risk operations without enough training and experience.

Table 2: BLS Classification

BLS Code	Code Description	Reports	Percentage (%)
041	Excavation or trenching cave-in	17	32
039	Caught in or compressed by equipment or objects	12	23
314	Contact with underground, buried power lines	7	14
1124	Fall from ground level to lower level	4	8
049	Caught in or crushed in collapsing material	3	6
021	Struck by falling object	2	4
313	Contact with overhead power lines	2	4
522	Explosion of pressure vessel or piping	1	2
031	Caught in running equipment or machinery	1	2
381	Drowing, submersion	1	2
3411	Inhalation in enclosed, restricted or confined space	1	2
9999	Not classifiable	1	1

Considering the Excavation or trenching cave-ins, 9 fatalities (53%) were reported in trenches between 5-10 ft deep and 8 fatalities (47%) in trenches deeper than 10 feet. According with OSHA, 38% of the fatalities occur in trenches less than 10 feet. (OSHA, 1990) Just one report showed that the trench had adequate protection, like shoring,shielding or sloping.

Hour of occurrence. The hour of ocurrence of the fatalities was provided for 30 cases. More fatalities occurred during p.m hours than a.m hours. Althought, the first hours of the day have an important incidence in the fatalities. This may be explained by a lack of planning for the daily activities. The Figure 1 shows the fatalities according to hour of ocurrence

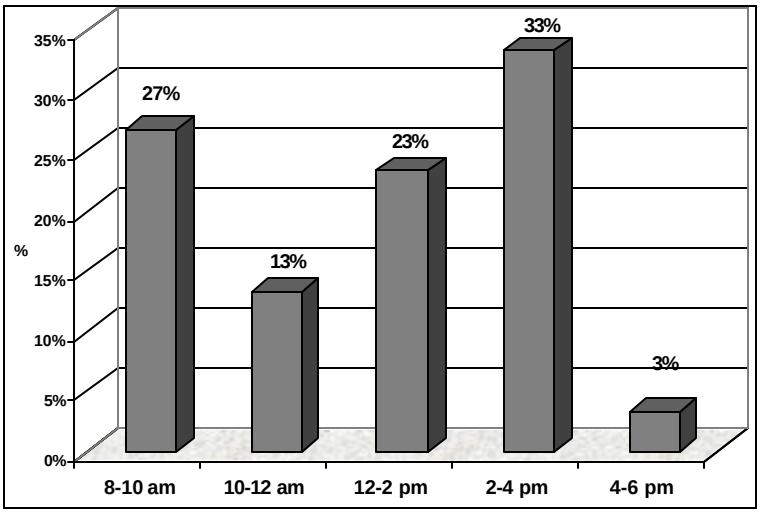

Figure 1. Fatalities according to hour of occurrence

Most of the accidents occurred between 12 pm and 4 pm. According with (Hinze and Bren, 1997), it is possible that during the lunch break, the apparent cohesion of the trench walls has begun to relax. If the trenching work does not commence for another hour, the trench walls would be even more unstable. Also, it is important to consider that after 3:00 pm, the workers are prepared to leave the site and sometimes the safety procedures are understimate because the labor hours are finishing.

Type of operation. In the evaluation of the type of operation under construction when the fatalities happened, it is important to note that sewer systems installations are the most frequent type of construction operation with 37% of the total reports. It is followed by water supply with 17% and electric installations 15%. Other operations reported are drains systems and foundations.

Month of the year. When examining the fatalities by month of the year, during the Summer season almost 42% of the accidents ocurred. It may be explained because most trenching work is developed during Summer. Also, the presence of more subsurface water in the ground during October, and the proximitiy of the Winter, may possible explain the high incidence during that month. The Figure 2 shows the fatalities distribution during the year.

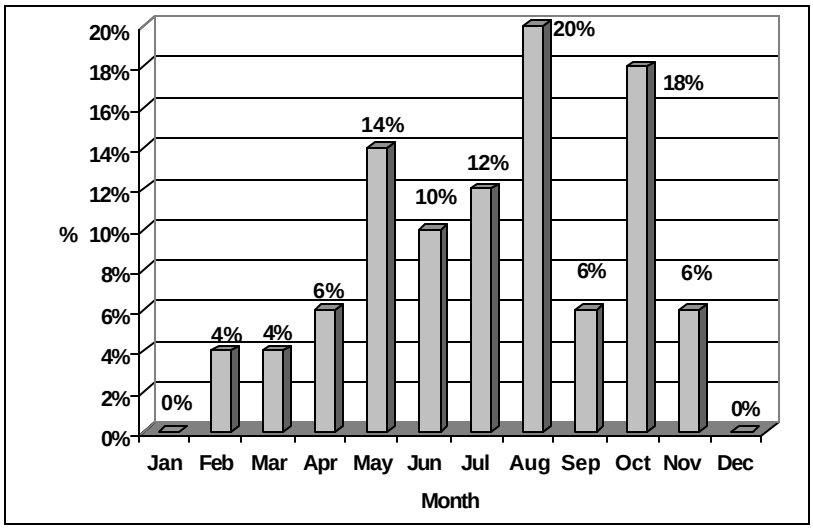

Figure 2. Fatalities according to month of occurrence

Workers age. Analyzing the workers age, the Figure 3 shows the age distribution. Data was available for 44 out of 52 reports studied. The average age at death was 37.2 years.

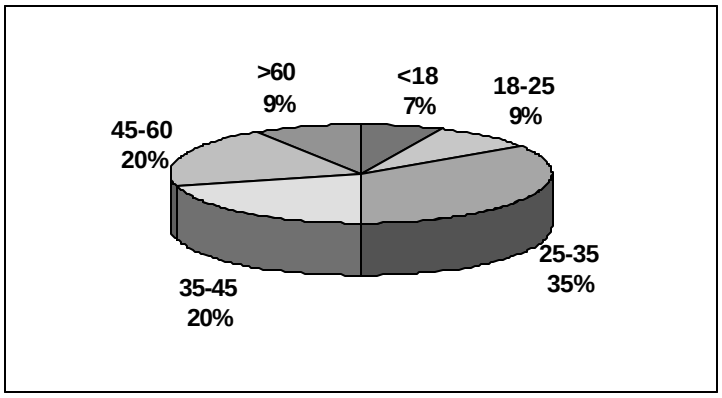

Figure 3: Age Distribution

Occupation of workers. The occupation of workers described in the reports is shown in Table 3. A 61% of the fatalities were labores/construction workers. Considering the gender, in 51 fatalities were men and 1 female.

Table 3: Occupation

Occupation	Percentage(%)	Occupation	Percentage (%)
Laborer	44	Pipe Layer	4
Construction worker	17	Line Man	4
Foreman	12	Subcontractor	2
Equipment operator r	6	Other	11

Companies Classification. The companies related in the reports, were classified following the Standard Industrial Classification-SIC, (OSHA, 2001). Table 4 shows the distribution by categories for the companies.

Table 4: SIC Classification

SIC Code	Code Description	Percentage (%)
1623	Heavy construction (Water, sewer, pipeline, communications and power line)	40
1794	Excavation work	13
1611	Highway and street construction	6
4911	Electric services	6
4923	Natural gas transmission and distribution	4
Others	Additional categories with one report	21
N.A	Not available data	10

Safety Program. Analyzing the companies's safety program, 50% of them reported official safety program, 35% did no report safety program and were not available data in 15% of the reports. Considering the work site inspection during the construction operations, 47% cases did not report site inspection and 38% reported site inspection. However, it is no clear in the reports, if the site inspections were done previous the accident or just at the beginning of the day. This is an important feature to consider because during the day, the site conditions could change and it is necessary to inspect again the work site before continuing the activities. Another aspect considered was the workers training. In 50% of the reports, the companies showed training certifications. They did not show certifications in 33% of the reports and 17 % of the reports did not have information about training previous to the activities execution

2.2 OSHA standard violations described in the reports

Every accident has at the last part of the written report, the OSHA standard violations ocurred and the respective recommendations that should be followed to avoid the same accident in the future. Some reports have more than one recommendation. For that reason, even though 52 reports were studied, 100 recommendations were classified. Table 4 shows the most frequent recommendations considered in the reports.

Table 4: OSHA Recommendations

ID	Description	Percentage (%)
1	Shoring – Shielding – Sloping	16
2	Competent person	13
3	Equipment improvement	13
4	Safety program	13
5	Job safety analysis	13
6	Equipment location	8
7	Worker age	3
8	Safety training	3
9	Safety meeting	2
10	Miscellaneous	16

In Table 4, it can be deduced that the first five recommendations are 68% out of the total. These are the most frequently and important recommendations that should be followed in accordance with OSHA standards in every trenching operation.

The first recommendation is based in OSHA standard 29 CFR 1926.652 a (OSHA, 2002). The recommendation says that employers should ensure that employees working in trenches are protected from cave-ins by an adequate protection system. Fatalities can be expected if a cave in occurs. These systems may include either sloping techniques or support systems such as shoring or trench boxes. Sloping involves positioning the soil away from an excavation trench at an angle that would prevent the soil from caving into the trench. This recommendation was ranked fifth in the List of the 100 most frequently cited OSHA construction standards related to physical hazards in 1991. (OSHA, 1995)

The second recommendation is based in 29 CFR 1926.651-k. This recommendation says that employers should ensure that excavations are inspected by a competent person prior to start of work and as needed throughout a shif to look for evidence of any situation that could result in possible cave-in. The OSHA stantards requires that daily inspections of excavations, the adjacent areas, and protective systems be conducted by a competent person for evidence of a situation that could result in cave-ins, failure of protective systems, hazardous atmospheres, or other hazardous conditions. A competent person is one who is capable of identyfying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has the authorization to take prompt corrective measures to eliminate them. This recommendation was ranked 11th in the List of the 100 most frequently cited OSHA construction standards related to physical hazards in 1991. (OSHA, 1995)

The third recommendation is related with equipment improvement. In this category, various suggestions were done in the reports. In general, the recommendations are related with new signals and devices to improve the equipment performance and safety by the manufacturers.

The fourth recommendation is based in 29 CFR 1926.21-b. This recommendations says that the employers should design, develop and implement a comprenhensive safety program. Employers should ensure that all employees are trained to recognize and avoid hazardous work conditions. A comprehensive safety program should address all aspects fo safety related to specific tasks that employees are required to perform.

Finally, the fifth recommendation is based in 29 CFR 1926.21-b. This recommendation instruct employees on how to recognize and avoid hazardous conditions on the construction site. This recommendation is related with the existence of the official safety program and the competent person role in the construction site.

3. CONCLUSIONS

In reviewing the causes and events that lead to fatalities in trenching operations, it is apparent that many accidents are a result of lack of planning at the beginning of the work. Also, it is relevant that during the execution, the supervision is not enough to assure workers safety. Trenches with improperly protection sytems or not systems at all, are under high risk of cave ins. All the fatalities due to cave ins could be prevented, according with OSHA recommendations.

The chain of events associated with the fatalities can be drawn based in the reports. During the pre job planning,it is very important to evaluate the soil condition so the employer can select an appropiate protective system. Once the protective system is selected, utilities companies must be contacted so they can identify underground lines. Without an appropiate utilities location, the job should not begin. Also, the equipment selection and mechanical conditions must be evaluated and the construction process defined, according with the previous experience and following all the safety reccomendations. The crew size designation should be done based on workers experience and training in the particular task. During the job execution, the site conditions should be verified every day and hazardous working conditions should be avoided. Also, supervision must be provided by the competent person and/or the forememans.

An important cause of accidents and fatalities in trenching operations is improper equipment operation around the trenching area. In some cases, the operators lack of experience, generated hazardous movements that could be prevented and the fatality avoided. Also, the equipment mechanical condition should be checked frequently to guarantee optimal performance.

The competent person role in trenching operations is very important. In some reports, nobody was responsible for the construction process and the supervision was nonexistence. The competent person is responsible to detect hazardous conditions and to take the necessary decisions that allow the workers develop their job under safe environment. Also, the competent person should be aware of new site conditions during the day due to weather, soil, and/or procedures, and make safety recommendations when the changes are representative.

In some cases, an official safety program was reported, but it was not implemented on the site. It is not enough to have a written safety program in the main office. It is necessary to assure that the workers and foremans follow the safety program instructions during the construction process.

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