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CHAPTER 26

Trenching Accidents and Fatalities: Identifying Causes and Implementing Changes

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INTRODUCTION

Trenching accidents can be caused by failure of the soil in which the trench was excavated, or the lack of protection of the trench walls by means of protective structures, or contacts with equipment or materials near the trench area, etc. While complete and accurate records of the actual number of fatalities occurring in trenching incidents are not maintained, 'the estimate of 100 fatalities per year in the USA due to cave-ins and other excavation accidents (Hinze and Bern, 1996)', and 7,000 injuries, is perhaps a reasonable approximation of the magnitude of the problem. In addition to the possibility of trench cave-ins, workers in trenches can 'be harmed or killed by engulfment in water or sewage, exposure to hazardous gases or reduced oxygen, falls, falling equipment or materials, contact with severed electrical cables or improper rescue (ELCOSH website)'.

The financial impact of poor excavation safety practices results in economic losses incurred from cave-ins and other accidents that are phenomenal in magnitude. When an accident occurs or when a contractor is cited for violations of safety codes and standards, the contractor incurs sizable, unnecessary expenses. Due to the risks of excavation work and the unknown nature of subsurface conditions, contractors' insurance costs to contractors can be excessive. These factors combine to increase excavation construction costs. Thompson (1982) reported that the cost of excavation failures resulting from not following safe excavation procedures adds about seven to eight percent to the cost of construction. Establishing and following safe excavation procedures makes good economic sense.

A worker performing excavation and trenching operations is protected by OSHA (Occupational Safety and Health Administration) standards, which involve most safety aspects: knowledge, training, and experience of the people responsible under the codes. Unfortunately, the codes are often misunderstood or ignored. OSHA inspections are limited to establishing the cause of the trenching related accident and verifying if the required measures, according to their standards, were used. If the required measures to ensure safety were not taken, then OSHA can impose fines to the company performing the work. However, these inspections may not indicate the reasons why the OSHA trench safety standards were not used or why they failed to protect the workers.

Many studies have analysed accident reports of agencies such as the Occupational Safety and Health Administration (OSHA) and the Bureau of Labor Statistics and determined the various reasons for trenching related accidents (Hinze and Bern, 1996, Suruda, Smith and Baker, 1988). These accidents can be caused by soil failure, the lack of protection of the trench walls by means of structures such as trench boxes, etc. A study conducted by OSHA in 1990 that analysed construction fatalities from 1985 to 1989 determined that 79% of trenching related fatalities occurred in trenches less than 15 feet (4.6 metres) deep and 38% percent occurred in trenches less than 10 feet (3.0 metres) deep.

Findings of a mail survey conducted by Equipment World (1998) show the following alarming statistics:

- Nearly 41% of all respondents said they experienced a trench collapse on one of their jobs. Out of this group, 29.4% said that someone was injured or killed in the collapse.
- Of the nearly 41% who had experienced a trench collapse on a job, 76.5% said that the trench collapse was due to unstable soil, 29.4% said it was due to human error, and 11.8% said it was due to insufficient shoring/shielding.

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. In 1995, construction accounted for 15% of all workers' compensation spending while construction workers accounted for only about 6% of the labour force. 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.

In order to determine possible intervention strategies, it is important to learn more about the circumstances under which the accidents occur, and to investigate the relationship between the accidents and the adherence/non-adherence to OSHA Safety Standards. Such an endeavor is pivotal in understanding why applicable standards were not used, or if they were used, why they were unsuccessful in ensuring safety in the trenching operation.

This chapter presents a discussion of recent efforts on investigating the causes of trenching-related fatalities, and determining the characteristics of these fatalities. It also discusses the existing OSHA excavation and trenching standards, specifically describing the requirements and the roles of a competent person, and other issues in OSHA Standard 1926 Subpart P. The research study underlying this chapter is funded by a grant from the National Institutes of Occupational Safety and Health (NIOSH) to the Construction Safety Alliance (CSA).

26.1 ROLE OF THE COMPETENT PERSON IN EXCAVATION SAFETY

To function as a competent person at an excavation site a competent person must be:

- Thoroughly knowledgeable with excavation safety standards including soil classification.
- Capable of identifying existing and predictable and hazards and unsafe conditions.
- Knowledgeable in the proper use of protective systems and trench safety equipment.
- Designated to have the authority to stop work when unsafe conditions exist.

A person must have documented experience and training in the first three requirements, and be designated as the competent person by the employer with the authority indicated in requirement four. Construction management must be aware of these requirements, and that the responsibility to comply with these requirements rests with the managers or owners of construction companies.

The role of the competent person must be completely understood by owners, contractors, and engineers. Managers of construction work need to be knowledgeable of the general and common legal applications of the OSHA Standard 1926 Subpart P. Some examples are presented in the following:

1. Training of the competent person must be done in an acceptable manner that complies with the standard. Training must cover the requirements listed in the section on Requirements of a Competent Person. Training can be either formal, or on-the-job, so long as it is documented and meets the competent person requirements. In as far as OSHA is concerned, the compliance officer will look at and inspect the conditions of the jobsite, and then question the competent person to determine his or her qualifications. If necessary, the compliance officer will conduct interviews with company management and employees to determine if the competent person has the ability, knowledge, and authority to ascertain and correct hazards at the jobsite.
   The competent person is the representative of the employer at the jobsite. However, as far as OSHA is concerned, the employer, not the competent person, is responsible for the safety of the employees.

2. The designated competent person may not always be competent in all areas of safety, but can still be considered competent. For example, the recognition of hazardous atmosphere may not be within the area of expertise of the site competent person. However, if an employer knows a person capable of recognising and evaluating hazardous atmosphere conditions, then that person can be called upon to assist the competent person. That person must be available to provide the competent person with the information needed to make decisions relative to protective systems and abatement measures. This has to be done only when the possibility of hazardous atmosphere conditions can be reasonably expected to exist at a construction site.
3. If an employer should override a decision or action of the competent person, then the employer is negating the authority of the competent person at a jobsite, and thus would be in violation of the standard. In any case, OSHA always holds the employer responsible for protection of employees.
4. Geographic location of the jobsite is not the determining factor for jobsite control by a competent person. Employee safety control at the jobsite is the determining factor. Each excavation with employees at risk or exposed must have a competent person at the site and must comply with the standard.
5. The competent person must perform daily inspections and other inspections as needed to ensure the safety of exposed employees. This means that if site conditions change, inspections and tests such as soil classification tests, must be taken to reevaluate and reclassify as necessary.
6. If an employer always slopes all excavations as if the soil were type C, then, technically, no competent person would be required at the site. However, this is not a practical approach to safety. When evidence of a condition arises indicating an existing or changed condition, such as hazardous atmospheres or the presence of water, then a competent person would be required.
7. Prior to the completion of an OSHA inspection, plans or manufacturer's tabulated data must be made available to the OSHA compliance officer. The plans or manufacturer's tabulated data must be signed and stamped by a registered professional engineer.
8. The standard requires that vibration producing machinery be kept at least two feet away from the edge of an excavation. However, distance is not as critical as are the effects of vibration on the ability of a support system to function safely. If a competent person notes that vibrations from traffic or heavy equipment causes visible distresses in a trench or excavation, the competent person must take corrective measures to ensure worker safety. A possible action would be to keep equipment further away than two feet.

26.2 LEGAL APPLICATIONS

The effects of 'competent person' training with respect to excavation and trenching safety are demonstrated by the following cases. They explain the concept of 'willful trenching charge':

1. A citation issued to a company charging it with willful failure to shore and protect the vertical faces of an eight foot deep trench in previously disturbed soil was appealed to an OSHA review board. The company's defence was isolated employee misconduct. A portion of the trench had been properly shored, but two employees were observed by an OSHA compliance officer in an unshored section of the trench during an inspection. The competent person had left the worksite to secure equipment and materials before the approaching storm struck. The workers were hurrying to complete work because of the threat of the storm and entered the unshored portions of the trench. The review board upheld the citation, because the competent person at the jobsite should have discovered the workers' presence in the unshored portion of the trench and should have removed the workers.
2. A prime or general contractor hired an excavation subcontractor to dig and protect a trench 12 feet deep at a large building construction site. The electrical subcontractor required to work in this trench and was cited for a willful excavation charge. During a site visit the president of the electrical subcontractor saw that the trench was too deep and unprotected. He then instructed his site foreman to stop working in the trench and, to instead fabricate pipe outside the trench until the excavation subcontractor made the trench safe. The site superintendent for the general contractor was instructed to and agreed to contact the excavation subcontractor and make the trench safe. The electrical subcontractor's president then left the site. The electrical foreman ordered the crew to reenter the trench and resume work after the president left the site. This action was against the president's specific instructions and outside of the scope of the foreman's authority. This electrical construction company had a well communicated, enforced, and documented safety programme which included weekly meetings and safety training covering 'competent person' requirements with the use of safety equipment. The review board dismissed wilful excavation charges on grounds of employee misconduct.

OSHA citations that are classified as wilful violations are based on the principle of intentional disregard of OSHA standards. When a wilful violation is upheld by the review board, the offending company must pay the determined fine. On the other hand, if a wilful charge is dismissed on the grounds of employee misconduct, then no fine is paid, as in the case above. At present in the USA, no individual (employee) can be required to pay a fine. Fines are only paid by companies. If a review board dismisses charges, the citation no longer exists against the company or the individual. However, the offending employee may be subject to company discipline.

26.3 DANGEROUS TRENCHING SITUATIONS

Some of the more dangerous situations in trenching operations are: crossing under another pipeline; a broken or leaking water or sewer line; and trenching parallel to adjacent or intersecting pipelines. Other situations are: intersecting open trenches or manhole excavations; excavation in an old backfilled trench or *previously distributed* soil; sudden change in the type or condition of a soil; and excavation in a fissured soil.

An explanation of particularly dangerous situations must be included as a key part of excavation safety training. For example, the term *previously disturbed* refers to more than the actual excavated area itself. When an excavation is made the soil is disturbed a distance back from the face of the excavation an amount equal to one or two times the depth of the excavation. This explains the severity of the situations of crossing pipelines and trenches, and trenching parallel to existing pipelines, both of which occur in previously distributed soil.

The competent person at the jobsite must be able to recognize these and other dangerous situations and take prompt corrective measures. These are practical examples of how the standard requires the competent person to be 'capable of identifying existing and predictable hazards'. Analysis of numerous fatal trench accidents indicates that in most cases, the hazard was a dangerous trenching situation that was not recognised by jobsite supervisors or employees due to lack of experience or training.

26.4 OSHA REGULATIONS RELATED TO EXCAVATION SAFETY: OSHA STANDARD 1926 SUBPART P

The OSHA (Occupational Safety and Health Act) standard consists of three main sections with six appendices. The first section contains definitions clearly explaining the terms used in the excavation standard. It is important that these definitions be understood before reading the standard and applying the rules of the standard to the worksite. The competent person can use the standard to a maximum depth of 20 feet. Excavations deeper than 20 feet require the approval of a registered professional engineer

The second section contains the general requirements. The General Requirements of the OSHA standard can be used as the basis of a trench safety programme. All underground and above ground installations must be located before approaching them with a trench. These installations must be supported so as to safeguard employees so that an existing utility line will not fail, causing an accident. Installations must be located prior to the start of excavation work to prevent accident, injuries to workers, and damage to the utility line itself. Access and egress must be provided for employees in excavations over 4 feet in depth to prevent falls when entering or exiting excavations. Employees working in trenches shall be protected from cave-ins, loose rock and soil, and from falling loads. Employees shall be protected from hazardous atmospheres. Both surface and subsurface water must be controlled with water removal equipment or diversion ditches and this process must be supervised by a competent person. Adjacent structures must be underpinned before start of excavation work. All required inspections shall be conducted by a competent person on a daily basis. Also, inspections must be conducted while employees are in the excavation, as needed to identify any signs of cave-ins or unsafe conditions. Fall protection must be provided where appropriate in excavations and over trenches.

The third section specifies the actual Requirements for Protective Systems that must be provided by the employer to protect workers who enter excavations. The standard requires that employees entering excavations which are five feet or greater in depth be protected from cave-ins. The requirements for protective systems are divided into two categories, *sloping and benching* and *support systems*, each of which contains four options, thus eight OSHA options are available to the competent person. *Support systems* include *shoring systems* and *shielding systems.*

These eight OSHA options are the methods that must be used to protect the employees and must be understood by the competent person.

Sloping is defined in the OSHA standard as *a method of protecting employees from cave-ins by excavating to form sides of an excavation that are inclined away from the excavation so as to prevent cave-ins'*. Workers must be instructed to slope both sides of an excavation. The competent person must classify the soil, and then select the correct angle of inclination. Fatalities have been reported in excavations sloped at 45 degrees.

Shoring is defined in the OSHA standard as '*a structure such as a metal hydraulic, mechanical or timber shoring system that supports the sides of an excavation and which is designed to prevent cave-ins'*. The use of aluminum hydraulic shoring requires the use of manufacturer's tabulated data and extensive training in the use of the equipment and a complete understanding of manufacturer's recommendations. The advantage of aluminum hydraulic shoring is that workers can install and remove them quickly outside the trench.

A *shield* is defined in the OSHA standard as '*a structure that is able to withstand the forces imposed on it by a cave-in and thereby protect employees within the structure'*. Trench shields are commonly called trench boxes. Shields are commercially available and can be fabricated from aluminum or steel. Shields are easy to assembly and install with the properly sized piece of equipment, and they provide safe work areas. The use of shields requires the use of manufacturer's tabulated data and extensive training in their use and the accompanying manufacture's recommendations.

The primary appendices of the standard are: Appendix A - Soil Classification; Appendix B: Sloping and Benching; Appendix C: Timber Shoring; and Appendix D: Aluminum Hydraulic Shoring.

26.5 CAUSES OF ACCIDENTS

Data on occupational accidents can be obtained from several agencies: the Bureau of Labor and Statistics (BLS), the Occupational Safety and Health Administration (OSHA), and the National Institute for Occupational Safety and Health (NIOSH). Each agency maintains its database for different specific objectives; thus, the types of information included in the database and the focus of the investigation varies from agency to agency.

In 1991 OSHA conducted a study to analyse the most cited standards in the construction industry in order to identify the causes of accidents and provide suggestions on how to eliminate, control or mitigate such hazards. This study showed that 4 of the top 25 standards cited were related to trenching as shown in Table 26.1.

Table 26.1 Most cited trenching related standards (adapted from OSHA, 1991)

RANK	DESCRIPTION OF THE STANDARD		Standard (1926.
5	Trenching/Excavation	Protective Systems for trenching/excavation	652(a)(1)
11	Trenching/Excavation	Daily inspection of physical components of trench and protection systems	651(k)(1)
16	Trenching/Excavation	Spoil pile protection	651(j)(2)
22	Trenching/Excavation	Access/Egress from trench/excavation	651(c)(2)

The National Safety Council (NSC) has adopted the BLS figures (beginning with the 1992 data year), as the authoritative count for work related deaths in the United States. However, the categories in the BLS system on fatal injuries do not isolate 'trench-related' injuries. While most injuries would be classified as 'caught in or crushed in collapsing materials' or 'excavation or trenching cave-in', trench-related injuries could also be categorised as 'falls', 'contact with electric current', etc. Using the BLS data alone, the death or injury counts can be misleading and they are in most cases, understated. Therefore, to measure the trenching hazard and to study the causes of trench-related accidents, the database from all three agencies should be used concurrently.

In order to understand the fatalities causes associated with trenching operations, and to develop the intervention strategies, it is necessary to access the National Institutes for Occupational Safety and Health (NIOSH), specifically, the Fatality Assessment and Control Evaluation (FACE) programme. This is a research programme designed to identify and study 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 and then formulating and disseminating prevention strategies to those who can intervene in the workplace.

The research project funded by NIOSH has considered and studied 52 (48 out 52 construction operations) reports associated with Trenching and Excavation Operations. All reports were extracted from NIOSH web site. The reports covered the period from 1985-2000.

The preliminary results show a similarity with previous research studies (e.g. Hinze, 1998, Hinze and Bern, 1997). Sewer systems (35%) and water supply systems (15%) are areas with the highest trenching related fatalities. The analysis also indicated that electrocutions in trenching accidents are increasing.

An analysis of the *type of accidents*, cave-in was cited as the main cause in seventeen cases. In cases (94%) that involved cave-ins, the walls were not protected by shoring, shielding or sloping. Eighteen equipment related accidents were included in the FACE reports. These accidents were due to improper equipment operations, equipment working near trenching areas, lack of signals, inexperienced operators and mechanical deficiencies.

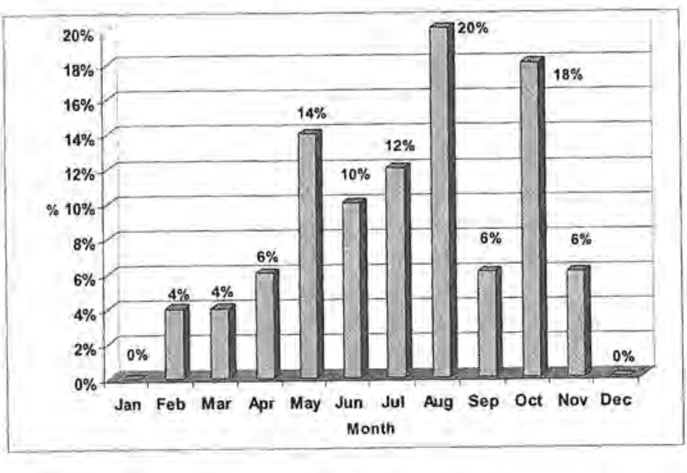

Figure 26.1 Month of occurrence vs. fatalities

The *month of occurrence* of the accident was examined. Figure 26.1 identifies August and October as the months with the highest percentages of fatalities. *Company Safety Programs* were also analysed. In 50% of the cases, the company had an Official Safety Programme, but in 60 of the cases, a competent person did not conduct a safety site evaluation prior to the accident.

Another characteristic that was analysed was the victim's age. In 70% of the cases, the victims were younger than eighteen. Figure 26.2 shows the age range for all cases in the FACE reports. It is noted that 51% of the workers were younger than thirty-five.

26.6 CHARACTERISTICS OF ACCIDENTS

Another source of important information related to trenching related accidents are the OSHA investigation reports, which make up the largest single source for this type of information. To analyse this information a total of fifty fatal and non-fatal cases were identified from 1996 to 1997. The data was obtained from the OSHA Database System. The following parameters were studied, and the observations of this study are discussed in this section:

- Month of event
- Accident outcome (injury or fatality)
  - Gender of workers affected
  - Classification by SIC code
  - Time of day of accident
  - Union status of workers
  - Trench characteristics.

Month of event: In 1996, 21% of the accidents occurred during the month of October. In 1997, 18% of the accidents occurred during the month of December. Overall the month with the highest incidence of accidents during the period of investigation (1996-1997) was October (16%). Figure 26.3 shows this information in a graphical format.

Accident Outcome: Of all the cases studied more than half (65%) resulted in fatalities and only 35% resulted in injuries.

Gender of workers: From the data obtained from the OSHA reports, it was observed that all of the workers involved in trenching accidents were male.

Classification by SIC code: According to the data from the OSHA reports 40% of the accidents reported involved workers for water, sewer, and pipeline contractors, i.e. SIC (Standard Industrial Classification) Code - 1623.

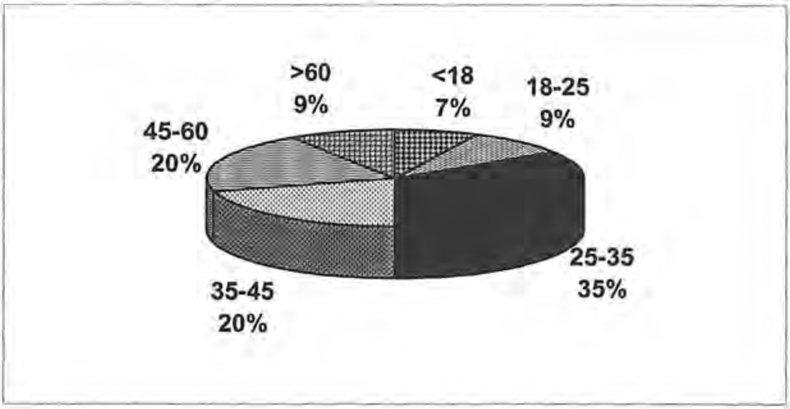

Figure 26.2 Age vs. percentage of trenching accidents

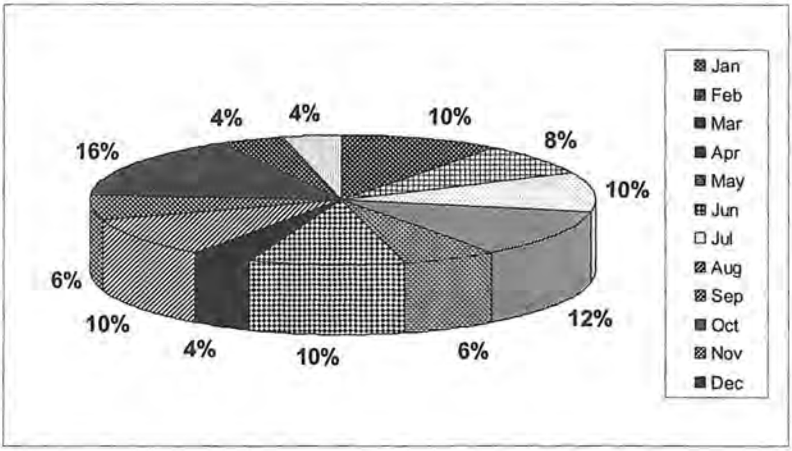

Figure 26.3 Total accident occurrence by month

Time of day: From the data available a comprehensive analysis of the time of day of occurrence of the accidents was not possible. The time of day of the accidents was reported on only seven (14%) of the 50 cases analysed.

Union status: The majority of the workers involved in trenching related accidents were non-union workers (98%). This gives us an indication that workers who are not union members are more likely to have accidents due to lack of proper training.

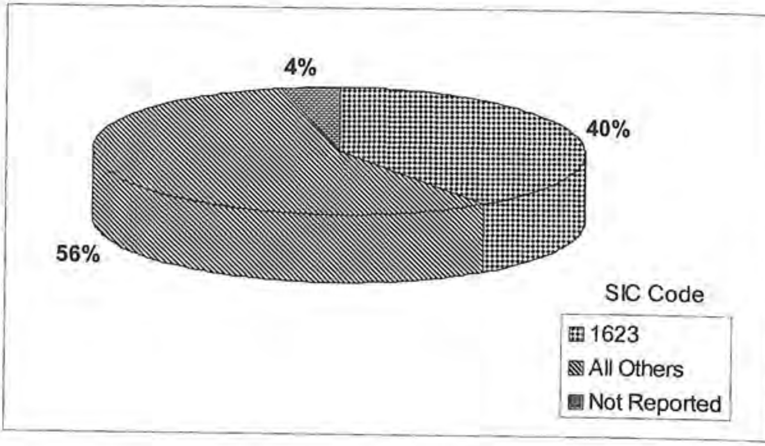

Figure 26.4 Total accident occurrence by SIC code

Trench characteristics: Of the 50 cases studied, 27 reported information related to the depth of the trenches in which the accidents took place. The depth of the trenches varied from 0 to 20 ft with ten instances (37%) in the range from 0 to 5 ft. This indicates that even in shallow trenches the possibility of accidents still exists.

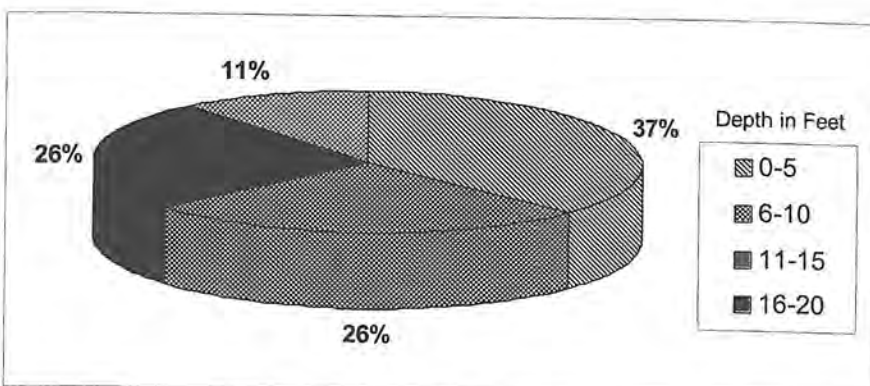

Figure 26..5 Total accident occurrence by trench depth

In five cases studied the presence of excavation support structures was reported. In eight cases there was no trench support structure present and in 37 of the 50 cases (74% of the cases analysed) the presence of excavation support structures could not be determined from the OSHA accident reports.

The type of excavation protection structures or methods depends on the characteristics of the trench. Depth and soil condition are the predominant factor when deciding if and what type of protection will be used. Of the five cases where excavation support structures were present, shoring was used to protect two of the trenches, trench boxes were used in two cases and sloping was used in one case.

Risk Factors: Various risk factors that contribute to trenching accidents were identified from the OSHA accident reports. Misjudgment of hazardous situations was identified in 39% of the instances, making it the most common risk factor. This reinforces the need to have a 'Competent Person' capable of correctly identifying risks so that actions can be taken to reduce the probability as well as severity of accidents.

26.7 CONCLUSIONS

This chapter discussed the role of the competent person in excavation safety and analysed characteristics of accidents based on FACE and BLS records. Based on these initial findings, continued site visits and interviews with craftspeople, and front-line supervisors, potential intervention strategies can be identified. Two key observations from the initial review and analysis of FACE records point to the need for a competent person at the excavation work site and effective worker training prior to the commencement of construction operations. Other intervention strategies that are being investigated include recommendations to OSHA regarding the existing standards for trench safety, engineering controls, and safety management issues in construction.

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