Use of Trench Boxes for Worker Protection

Jimmie Hinze[1]

Abstract: Work in trenches can be very dangerous if workers are not provided with adequate protection against trench cave-ins. One method of providing for worker protection in trenches is with the use of trench boxes, widely used, engineered structures that permit workers to work safely in trenches. A study of the experiences of utility contractors with the use of trench boxes provided several notable findings that can help in implementing safe work practices in trenches. Most safety problems with the use of trench boxes are attributed to human error or judgment. For example, several respondents commented that workers were observed exiting from the trench boxes by walking up the backfill, a practice that exposes workers to the dangers of trench cave-ins. The importance of training was also evident in the results. Firms with better safety performance records conducted specialized training courses for their employees, and they provided more frequent training courses.

DOI: 10.1061/(ASCE)0733-9364(2005)131:4(494)

CE Database subject headings: Trenches; Safety; Training.

Introduction

Each year, many construction workers die as a result of trench cave-ins, possibly as many as 100 workers (Hinze and Bren 1997). These deaths are needless losses as trenching work can be performed safely. Whenever workers are working in trenches, appropriate safety precautions are to be taken to ensure worker safety. There are three typical ways that workers can be protected in trenches. These include sloping the trench walls, placing shoring in the trenches, and utilizing trench boxes. Various considerations will be involved when making the decision about the method to use. Sloping the trench walls to the angle of repose is perhaps the most preferred way of ensuring the safety of workers in trenches, but this is not always feasible. For example, sloping when trenches are deep will result in a very wide top of the trench that may encroach on other surface encumbrances (streets, buildings, fences, etc.). Shoring is a means by which the trench wall is supported by wood shores, screw jacks, or hydraulic shores. Trench boxes, the newest type of trench protection, are made of two heavily reinforced steel plates that are separated by strong strut members. Trench boxes are moved forward in the trench as work progresses. When properly used, trench boxes offer a very viable means of providing for worker protection in trenches.

Most information on trench boxes is prepared and publicized by the manufacturers of trench boxes. These brochures and pamphlets describe the physical features of trench boxes (material components, overall size, width variation, etc.) and also basic instructions on the proper use of trench boxes in trenches. Trench boxes are widely used in the United States and they provide well for the protection of workers in trenches. Most workers who die in trench cave-in accidents work in trenches that were not shored or which were not sloped at the proper angle. Historic injury data confirms that relatively few workers die as a result of cave-ins that involve trench boxes (Hinze and Bren 1997). While trench boxes do not offer the perfect solution for every trenching situation, they are a viable safety consideration on many trenching operations. Unfortunately, little information is publicized about any of the problems that contractors should watch for when working with trench boxes. This paper presents information on a research study that obtained information that was focused primarily on the extent of trench box use in the construction industry and on some of the problems that contractors face when working with trench boxes.

Review of Literature on Trench Boxes

Although trench boxes are the newest development to provide for worker protection in trenches, their introduction to the construction community is not recent. The earliest known reference to trench boxes was in 1938 when a "sliding trench shield" was mentioned that was originally developed by a Seattle, Wash. utility contractor (Otter 1962). This early form of worker protection in trenches consisted of a steel box made of steel plates used on edge and connected by welded steel cross braces (see Fig. 1). There are now many different manufacturers of trench boxes. As trench box design has evolved, the trench boxes have become more versatile, with interchangeable cross braces and stackable side plates for various trench widths and depths (Otter 1962).

Trench boxes offer several clear advantages to the contractor. When compared with conventional shoring systems, trench boxes offer large open spaces within the trench. This makes it easier for workers to maneuver in the trench and it also makes it much easier to lower pipe lengths into the trench. Another advantage is that trench boxes tend to be conservatively designed so that they provide for worker protection in all types of soil types. Note that the term trench shield is often used interchangeably with the term trench box. There are also other names that have been used for

[1]Professor, M. E. Rinker Sr. School of Building Construction, College of Design, Construction and Planning, Univ. of Florida, Gainesville, FL 32611-5701.

Note. Discussion open until September 1, 2005. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on August 1, 2003; approved on May 25, 2004. This paper is part of the ***Journal of Construction Engineering and Management***, Vol. 131, No. 4, April 1, 2005. ©ASCE, ISSN 0733-9364/2005/4-494–500/$25.00.

J. Constr. Eng. Manage., 2005, 131(4): 494-500

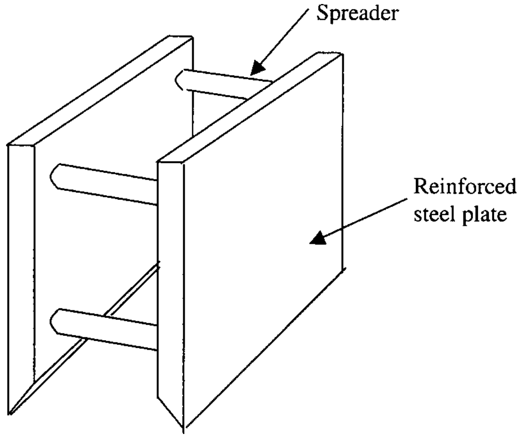

Fig. 1. General configuration of trench box

trench boxes, but these tend to be specific to regional locations.

Contractors have recognized the advantages and value of trench boxes for many years. For example, in 1958 the Associated General Contractors (AGC) of America *Manual of Accident Prevention in Construction* (AGC 1958) stated when "bracing or shoring trenches is not practical or economical due to unstable ground, movable steel trench shields may be used effectively." Earth pressures generally increase with an increase in the depth of trench. Because of the significant potential earth pressures that might be encountered, the manual stressed that these shields "should be substantially constructed of steel plate sides, welded to heavy steel framework of structural shapes and/or pipe. Such shields should be so constructed as to be at least equivalent in strength to other forms of trench protection. Cross bracing should be adequate to support the earth pressure to which the shield may be subjected."

Another early reference to trench boxes was made in the First Edition of the *Construction Safety Standards* that was published by the United States Department of the Interior, Bureau of Reclamation (1968). These standards stated "sheeting, sheet piling, bracing, shoring, trench boxes, and other methods of trench protection shall be designed and installed on the basis of the calculated pressures exerted by, and the condition and nature of, the materials to be retained. These calculations shall include the surcharge imparted to the sides of the trench by equipment and stored materials."

Although trench boxes were being used extensively before the passage of the Occupational Safety and Health Act of 1970s, the early Occupational Safety and Health Administration (OSHA) standards made only a brief acknowledgement of the use of trench boxes. These standards *(1926.652(k))* stated, "Trench boxes or shields providing protection equal to or exceeding that of the wood shoring system are acceptable for employee protection." In the more recent version of the OSHA regulations trench boxes are discussed to a greater extent. The primary regulations pertaining to the use of trench boxes include the following:

1. Trench boxes must be capable of resisting the lateral earth pressures;
2. Trench boxes must be installed so lateral movement of the shield is restricted;
3. Employees must be protected from cave-in when entering and exiting trench boxes;
4. Employees are not allowed in trench boxes while they are being installed, removed, or moved vertically;
5. The trench bottom is to be no more than 0.6 m (2 ft) deeper than the bottom of the trench box; and
6. The trench box shall extend no less than 0.45 m (18 in.) above the top of the vertical trench walls.

In a survey of AGC members involved in trenching operations, several interesting comments were received regarding the use of trench boxes (Salomone and Yokel 1979). For example, one respondent stated "The use of trench boxes is the best advance in trench safety in 20 years." Most comments about trench boxes by contractors were favorable.

In another study of trenching practices involving 100 utility contractors, specific information was sought regarding trench boxes. Several contractors commented that they were supportive of OSHA standards that would encourage the increased use of trench boxes. One contractor said, "OSHA should evaluate and strongly recommend the use of engineered steel trench boxes, with automatic fine credits given to those contractors who use them." The results of that study showed that utility contractors who made greater use of trench boxes also reported lower injury frequency rates (Hinze and Carino 1980).

The need to comply with good work practices when working with trench boxes is clearly stated in the OSHA. Others have also stressed this need, along with the various manufacturers of trench boxes. For example, in his text Nunnally (1987) stated "Trench shields or trench boxes are used in place of shoring to protect workers during trenching operations… The top of the shield should extend above the sides of the trench to provide protection for workers against objects falling from the sides of the trench. The trench shield is pulled ahead by the excavator as work progresses."

Another author on the subject of trench boxes, Roberts (1987), noted the advantages of trench boxes. He stated, "For deep trenches and unstable ground, the trench box is the best shoring system. It's a large mobile box with enough strength to withstand the side pressure of deep excavations." It was also stated that, "Trench shields are steel or aluminum boxes placed in the trench to provide a safe environment for workers. As the work progresses, the shield is pulled forward. The workers inside the shield are protected continuously from any caving in of the trench walls." It should be noted that trench boxes act differently than do traditional shores. Shores are designed to support the trench walls to prevent cave-ins. Trench boxes do not prevent cave-ins but they protect workers in the event of a cave-in. To be protected by the trench box, the workers must be inside the trench box, and it must be installed to prevent side-shift or lateral movement during a cave-in.

Ringwald (1993) described trench boxes as steel or aluminum prefabricated support systems complete with cross braces. He noted that single trench box sections typically come in 2.44 m (8 ft) or 3.05 m (10 ft) heights and lengths up to 6.1 m (20 ft). Trench boxes can be stacked if trench depths require it, with some conditions warranting three trench boxes being stacked in deep trenches. Most manufacturers build pre-engineered trench boxes that readily meet the OSHA standards.

In a recent study of 114 trench box-related injuries and fatalities investigated by OSHA from 1984 to 2001, it was concluded that trench boxes "appear to give relatively good protection to workers in trenches." It was also concluded, "it is apparent that the OSHA regulations regarding trench shields appear to be adequate." Most accidents involving trench boxes were found to be the "result of the failure to comply with the OSHA regulations." Finally, it was concluded that minimizing injuries in trench boxes

J. Constr. Eng. Manage., 2005, 131(4): 494-500

Table 1. Characteristics of Utility Contractor Respondents

Description of firm	Mean	Median	Low value	High value
Annual revenues (millions)	$20	$10	$.25	$250
Number of projects undertaken per year	67	26	3	1,500
Number of employees	98	50	4	1,000
Sewer pipe laid per year	21,000 m	7,500 m	0	260,000 m
Length of trench dug each year	39,000 m	18,000 m	0	400,000 m

depends on "following good work practices and in complying with the OSHA regulations" (Hinze 2002).

Research Methodology

The objective of this study was to examine the current status of the extent of use of trench boxes and to identify any worker practices that might compromise safety on a trenching project. A two-page survey on trench boxes was prepared. This survey was sent to 1,000 contractor members of the National Utility Contractors Association. This survey was sent out in October 2002. A total of 151 responses were received. These replies were analyzed and provide an overview of the current status of the use of trench boxes.

Results

Relevant descriptive information about the utility contractor respondents was obtained in the surveys. In general, firms can be classified as being small, as half of the firms conducted annual volumes of business of less than $10 million. The typical utility contractor entered into less than 26 project contracts each year, employed less than 50 employees, and laid less than 7,500 m of sewer pipe each year. Since the lengths of sewer pipe laid each year is less than the total length of trenches dug each year, it is evident that other forms of utilities are also installed, e.g. water, gas, telephone, electric, etc. From the summary information shown in Table 1, it is clear that there is considerable variation in the size parameters of the responding firms.

Most responding firms were involved in the installation of sewer pipe and water pipe (see Fig. 2). While company revenues presumably are derived from various types of work, most appear to be related to trenching work. For example, a few firms are involved in paving work, but this type of work is often associated with the installation of utilities where paving must be restored after utilities have been installed. The type of work being referenced by "other" includes diverse types of projects including bridges, excavations, grading, site development, concrete, etc.

The OSHA regulations require trenching work to be performed under the guidance of a competent person. Since the competent person on a trenching operation carries a major responsibility for the safety of the workers in and around the trench, the designation of the competent person is not a trivial decision. A question was asked about the identity of the individual who is generally designated as the competent person. The large majority of the replies show that the foreman is the individual who is most commonly designated as the competent person on trenching operations (see Fig. 3). Seven percent gave this responsibility to assigned workers, but there was no information provided about the level of experience that these workers had. Some companies apparently have larger projects than others, as some indicated that the superintendent was designated as the competent person. Others gave this responsibility to the general superintendent or operator. On some utility construction operations, the entire crew could consist of the equipment (excavator) operator, two or three workers in the trench, and a loader operator. On such a project, the operator might very well be designated as the foreman of the crew. The survey did not ascertain if the foreman was also an equipment operator, but some did specifically state that the operator was the competent person on most of their projects.

Trench-related accidents can be complex in nature, making it difficult to ascertain the root causes of all incidents. The survey asked respondents about their perceptions of the most common causes of trench-related accidents. Respondents were to indicate

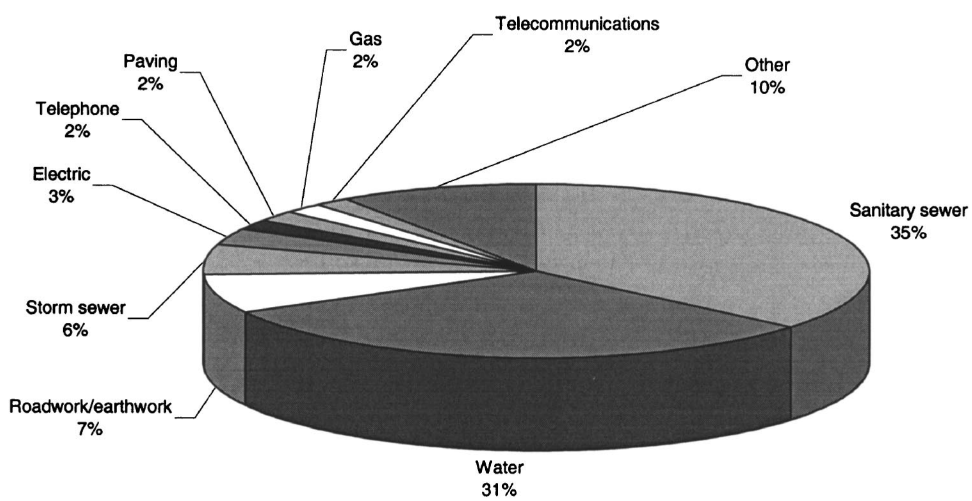

Fig. 2. Work distribution of utility contractor respondents

J. Constr. Eng. Manage., 2005, 131(4): 494-500

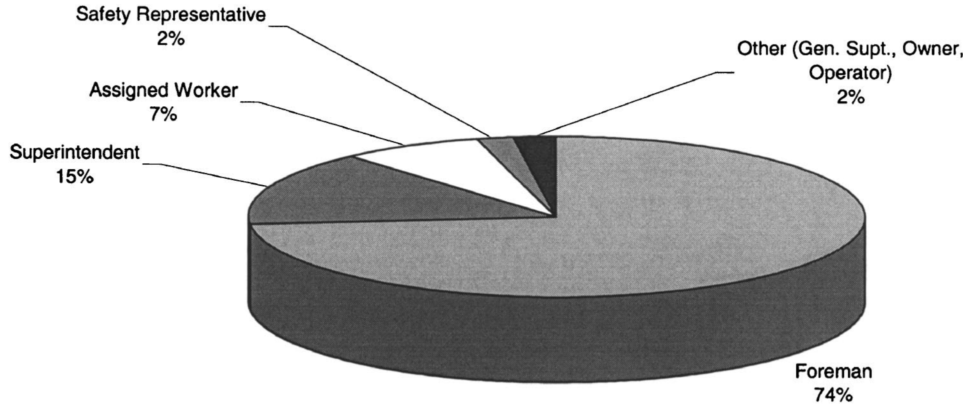

Fig. 3. Individual generally designated as competent person on trenching projects

Table 2. Perception of Causes of Trench-Related Accidents

Cause of trench accidents	Mean rank (0–10)
Worker factors	
Poor work practices	7.8
Worker inexperience	6.5
Lack of worker training	6.1
Supervisory factors	
Lack of supervision	5.9
Lack of planning	5.9
Physical conditions	
Previously disturbed soil	4.8
Excess water	4.2
Spoil pile or equipment near the trench	4.0
Unforeseen soil conditions	3.8
Adverse weather	2.9
Nearby traffic	2.9
Other factors	
Inadequate equipment	4.5
Poor contract documents	0.9
Inadequate regulations	0.9

with a ranking (ranging from 0 as the least common to 10 as the most frequent) of how often each of several factors were involved in accident causation. These factors were randomly placed in the survey, but as shown in Table 2, these causes can be grouped by related categories. The respondents stated that the most common causes of accidents were perceived to be worker related factors, including poor work practices, worker inexperience, and lack of training. Supervisory factors also received relatively high ranks, followed by physical conditions. Few respondents had the perception that the OSHA regulations were inadequate or that poor construction documents were involved in trenching accidents.

Trenches that are deeper than 1.5 m (5 ft) in depth must include the provision of some form of worker protection. Trench boxes are only one of these means, along with sloping the trench walls and the installation of trench shores. The survey asked about the type of worker protection generally provided in such trenches. Responding contractors indicated that trench boxes were the most common means (54%) of providing for the protection of workers in trenches deeper than 1.5 m (see Fig. 4). The next most common method used was sloping, followed by benching which is a specialized form of sloping that is warranted by some soils. Although some utility contractors utilize shoring, it is not extensively used. Past studies have shown that shoring often becomes the only option for worker protection in trenches when the trenches begin to exceed the depth of 4.5–6 m (15–20 ft).

Additional questions were asked about the trench boxes used by utility contractors. For example it was revealed that contractors generally reported that 60% of the trenches are deeper than 1.5 m (see Table 3). When trench boxes are used, they are gener-

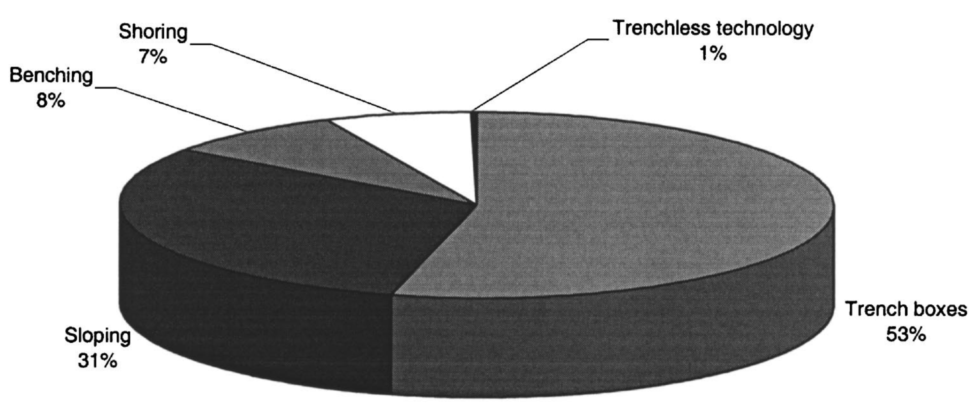

Fig. 4. Frequency of use of methods to protect workers in trenches

J. Constr. Eng. Manage., 2005, 131(4): 494-500

Table 3. Experiences with Trench Boxes

Description of firm	Mean	Median	Low value	High value
Trenches deeper than 1.5 m	60%	70%	1%	100%
Number of trench boxes owned	11	6	0	107
Number of trench boxes rented	0.9	0	0	25
Projects with stacked trench boxes (%)	20	10	0	100

ally owned by the contractors with the average contractor owning an average of 11 trench boxes with another trench box being rented. This does not mean that the average contractor has 11 ongoing projects, as more than one trench box can be used on a single project. Even when there is only one trenching crew, more than one trench box may be required as about 20% of the projects involve trench depths that require the trench boxes to be stacked, at least at some locations.

With the average contractor using trench boxes in 60% of their trenches, there is obviously a considerable use of trench boxes. There are also many ways that trench boxes can be misused. Contractors were asked about the frequency that they observed certain unsafe trenching activities. Specifically, they were asked to indicate how often specific unsafe trenching practices involving trench boxes were observed in the past year. The most frequently observed unsafe practice was using trench boxes without bulkheads (see Table 4). Workers can be placed in danger if they are asked to work near the open end of a trench box, without a bulkhead that could prevent debris and excavated material from falling into the trench box. The next most common unsafe practice was workers venturing out of the safety of the trench box, possibly to exit the trench or to perform work in the unprotected portion of the trench. Some workers were exposed to cave-ins below the bottom of the trench boxes, by trenches being dug too deep within the trench box. Another unsafe practice that was observed included workers exiting from the trench box without using ladders, probably walking up the backfill bank behind the trench box. Some workers were observed not staying clear of materials (pipe, ballast materials, or backfill) being lowered into the trench box. Some trenches were set too low in the trenches, allowing materials to fall into the trench box from the top. Finally, some respondents observed equipment (excavators, trucks, loaders, etc.) getting dangerously close to overhead power lines.

It is particularly when workers exit trench boxes that safety must be observed. The survey asked about the means used by workers to exit trench boxes. The OSHA regulations state that trench boxes are to be exited by means of ladders within the trench boxes. Most respondents (70%) stated that ladders were

Table 4. Frequency that Unsafe Trench Box Practices were Observed in Past Year

Unsafe practice observed	Average number of observations in past year
Using a trench box without a bulkhead	4.6
Workers ventured out of the trench box	3.9
Setting trench boxes too high above trench bottom	3.6
Using trench boxes without ladders	2.0
Workers not staying clear of materials being lowered	1.6
Setting trench boxes too deep	1.5
Equipment getting dangerously close to power lines	1.1

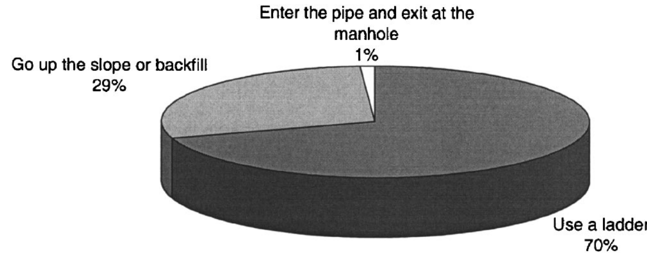

Fig. 5. Methods of exiting from trench boxes

used to exit trench boxes, but nearly 30% reported that workers exit trenches by going up the slope or backfill, a practice that places workers in harm's way (see Fig. 5). One respondent reported that workers walked inside the large diameter pipe to the manhole to exit. One respondent stated that workers exited by way of a ladder placed "outside the trench box," a practice that is in clear violation of the OSHA standards and that would generally place workers in a hazardous situation.

Survey participants were asked to offer additional comments about major concerns they had regarding the safe use of trench boxes. These comments are summarized in Table 5. The most frequent comment made was that workers were sometimes forced out of the trench box by the work being performed by the excavator in the trench box. They recognized the importance of keeping workers safely inside the trench box, but this was seen as compromising work productivity. A frequent comment made by several respondents was that trench boxes must be used when they are available and they should not be allowed to sit idly next to the trench when workers could be protected by them. One contractor recognized the life-saving features of trench boxes and said it is vital for trench boxes never to be regarded as "lawn ornaments." Several contractors mentioned the need to follow proper safety procedures when offloading trench boxes on the job site and also when setting them down in the trenches. Many other comments were provided and, when taken as a group, they provide valuable evidence of the complexity of maintaining safe trench box operations. It is also apparent that different contractors seem to have varying concerns related to the use of trench boxes. Note that no distinction was made in the analysis of the depth of trenches or the types of soil conditions that were commonly encountered by the respondents. Clearly, the soil conditions vary considerably across the United States. The types of projects (whether water line, sewer line, gas line, or other utility) would also influence the experiences of contractors. Further study would be warranted to discover more specific concerns related to trenching operations.

One question was asked about safety practices that were not specific to the use of trench boxes. Respondents were asked to indicate the types of safety program elements they had implemented on their projects. Note that only a small sampling of common safety program elements was listed. Of those listed, the most common practice employed by the utility contractors was the requirement for workers to wear hard hats followed by specific training provided on trenching safety (see Table 6). Most contractors hold preconstruction meetings. Less than half of the contractors use worker incentives or daily safety meetings.

Detailed information about the safety programs of utility contractors was not obtained in this study, as this was not the primary objective of this study. Nonetheless, the safety program practices of utility contractors appear to be reasonably effective in reducing worker injuries. The utility contractors responding to the survey

J. Constr. Eng. Manage., 2005, 131(4): 494-500

Table 5. Comments about Concerns with Using Trench Boxes

Type of Concern	N
Keep workers in the trench box and don't push them out with the excavator	19
Trench boxes must be used when needed, instead of leaving them on the bank	15
Proper lifting and setting of boxes (offloading from lowboy)	12
Adequately sized/designed; right size box for soil conditions	10
Workers being properly trained; workers following safe procedures	8
Working around existing utilities	7
Set box too high, more than 2 ft (0.6 m) above the trench bottom	6
Make sure all pins are in place (connectors and struts are in good repair); kept in good condition	5
Trench boxes are used properly and not abused but get damaged from use	5
Assembly of boxes with wide spreaders (over 10 ft wide)	5
Workers getting accustomed to dangers, not staying alert	5
Proper exit/entry (into and from the trench box)	5
Trench boxes too short for 20 ft pipe and still have room for the hoe bucket; need long enough box to protect workers (need 26 ft box for 20 ft pipe and 20 ft box for 13 ft pipe)	4
Inadequate supervision	4
Lowering pipe and material into the trench box	4
Proper lifting cables/ improper rigging	3
Handling trench boxes above ground without cables	3
Spoil pile clearance	2
Too much overburden above box	1
Proper slope above box	1
Sizing the equipment to handle the box	1
Access from edge of trench to trench box	1
Inspection of boxes for cracked welds, wear	1
Proper placement in jacking pits	1
Operators pulling on cross braces with machines under pressure	1
Trench boxes should be in the trench before workers	1
Moving the box with workers in box	1
Using ladders	1
Qualified operator	1
Safe movement in the trenches	1
Foremen feel trench boxes slow them down	1
Always having a good top man to assist the pipe layer with the ladder and tools; watching for danger	1
Planning so workers do not take shortcuts	1
Language problems (not knowing English)	1
Potential danger to pipe when pulling box	1

reported an average injury frequency rate of 3.02 OSHA recordable injuries per 200,000 h of worker exposure. This level of safety performance is considerably better than the construction industry which is about 7.0. Of these practices, training had the most apparent impact on safety performance. For example, the firms stating they conducted no specialized trenching safety training sessions reported an average OSHA recordable injury rate of 5.78 while those offering specialized training sessions reported an average OSHA recordable injury rate of 2.56. In fact, the injury rate appeared to decline with an increase in the number of training sessions offered per year (see Table 7). It was also noted that the injury frequency rates were lowest among the smaller firms. That is, the injury rates appeared to increase with an increase in company size. The data did not provide any clear indication to explain this phenomenon, but this has been observed with other studies involving utility contractors (Hinze and Pannullo 1978).

Table 6. Safety Program Practices Employed by Utility Contractors

Safety program practice	Proportion of respondents (%)
Hard hats required to be worn	94.7
Specific training in trenching safety	80.8
Preconstruction meetings	66.2
Worker incentive program	41.7
Daily safety meetings[a]	32.5

[a]Most respondents stated that safety meetings were held weekly.

Since this study was not conducted to draw solid conclusions about how safety performance is influenced by various practices, little more can be concluded about how utility contractors achieve their good safety performance records. There are obviously some practices that differ between the different respondents. These may very well also have an impact on the safety records.

Conclusions

While the use of trench boxes generally appears to be a simple sequence of operations, the results of this study indicate that safety concerns are presented at various times in their use. The most serious infraction that was noted is when trench boxes are available but not used. A common problem occurs with workers venturing out of the safety of trench boxes. Trench box safety begins when they are offloaded at the jobsite and the safety concerns continue as they are lowered into the trenches. Other safety infractions were also noted.

Many infractions of the safe use of trench boxes may stem from the perception that time is of the essence and that safety must be compromised at times to satisfy production objectives. This results in short cuts being taken. For example, it might be felt that time could be saved if no trench box was used (even when one is present on the jobsite), if a pipe or other materials are lowered into the trench box with workers still inside the trench box, or if workers are not required to exit the trench box while it is being moved. These result in minor savings in time and jeopardize the lives of workers.

Performing work safely requires planning. With proper planning, the work can progress smoothly. Of course, with trenching operations the work plan needs to be flexible to accommodate work interruptions. Such interruptions may occur frequently, as a bend in the pipe layout must be addressed, existing utilities are

Table 7. Number of Training Sessions and Safety Performance

Number of sessions per year	OSHA injury frequency rate
none	5.78
1 or 2	3.04
3 or 4	2.90
6 or more	1.78

J. Constr. Eng. Manage., 2005, 131(4): 494-500

encountered, rock or underground concrete structures are encountered, a change in the soil type is encountered, excess water is encountered, etc.

Although this study was not conducted to identify the types of safety practices that are most effective in ensuring good safety performance, some insights about safety performance were obtained. For example, the utility contractors generally enjoy a level of safety performance that is better than the construction industry as a whole. It was not determined how these safety performances were actually achieved, but the findings did indicate that training is probably one of the primary factors that improve safety performance.

There seems to be reasonable consistency in the utility construction community about the use of trench boxes and the types of problems that continue to exist on trenching operations involving trench boxes. The problems do not appear to be shortcomings in the OSHA regulations but rather the failure of workers to fully comply with the existing safety regulations. Additional guidance on safety practices is provided by trench box manufacturers.

Recommendations

Since the OSHA regulations appear to adequately address safe work practices with trench boxes, contractors are encouraged to make greater attempts to ensure that field operations fully comply with them. Additional guidance should be sought from the various suppliers of trench boxes.

As most of the serious safety problems are associated with worker behavior, contractors are encouraged to set up more stringent jobsite rules and to fully enforce them. When trenching operations are being conducted, any failure to use good safety practices and good judgment could be fatal. A beginning point would be to conduct a series of training sessions to ensure that all workers are fully informed about the expectations of the company.

With the unacceptable number of serious safety infractions occurring on many trenching projects, it is incumbent on utility contractors to stress safety with their employees. Just as many companies have a zero tolerance for drug abuse, utility contractors should have zero tolerance for worker behavior that places their lives at risk.

References

Hinze, J. (2002). "Analysis of trench shield injury accidents." *Proc., CIB W-65 Symp. on Organization and Management of Construction*, Cincinnati.

Hinze, J., and Bren, K. (1997). "The causes of trenching related fatalities and injuries." *Proc., 5th Construction Congress: Managing Engineered Construction in Expanding Global Markets*, ASCE, Reston, Va.

Hinze, J., and Carino, N. (1980). "A study of work practices employed to protect workers in trenches." Dept. of Labor, Occupational Safety and Health Administration, Washington, D.C.

Hinze, J., and Pannullo, J. (1978). "Safety: Function of job control." *J. Constr. Div., Am. Soc. Civ. Eng.*, 104(2), 241–249.

Nunnally, S. (1987). *Construction methods and management*, 2nd Ed., Prentice-Hall, Englewood Cliffs, N.J.

Otter J. (1962). "The sliding trench shield: A way to increased safety and more efficient construction." *Constructor*, XX, XXX-XXX.

Ringwald, R. (1993). *Means heavy construction handbook*, R.S. Means Co., Inc.

Roberts, D. (1987). *Pipe & excavation contracting*, Craftsman Book Co.

Salomone, L., and Yokel, F. (1979). "An analysis of the responses from an Associate General Contractors of America (AGC) survey of trenching and shoring practices." Dept. of Labor, Occupational Safety and Health Administration, Washington, D.C.

The Associated General Contractors of America, Inc. (AGC). (1958). *Manual of accident prevention in construction*, 5th Revised Ed., Washington, D.C.

United States Dept. of the Interior. (1968). *Construction safety standards*, 1st Ed., Bureau of Reclamation.

J. Constr. Eng. Manage., 2005, 131(4): 494-500