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Research Article

Characteristic analysis and prevention strategy of trench collapse accidents in the U.S., 1995-2020

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Abstract: Statistics show that many workers have lost their lives because of trench collapse although the dangers of trenching are well known and defined. Thus, the question of "why" should be asked again. The most comprehensive data set in the literature has been created to determine the reason for the recurrence of accidents even though the risks are known. A total of 723 accidents caused by trench collapse in the last 25 years were selected from the Occupational Safety and Health Administration's database. Variables were created using accident summaries, and the frequency distribution of the categories was interpreted. Results showed that these accidents have a high frequency and a high severity level (58.1% fatalities). The main reason for a half of the accidents was the lack of protective systems (49.7%). A total of 2596 violations including four main categories were detected for 723 accident reports. Employers paid approximately 23 million in penalties. The investigated accidents showed that trench collapse accidents are rarely survivable but can be completely prevented if necessary precautions are taken.

Keywords: construction industry; accident investigation; excavation; trench collapse; cave-in.

1. Introduction

Excavation work, which is one of the most basic jobs in the construction field, generally means work that involves the removal of soil or rock from a site to form an open face, hole, or cavity using tools, machinery, or explosives. Almost no construction work is completed without excavation. Trench collapses and excavation cave-ins are few of the most fatal occupational accidents in construction (OSHA, 2020). The data on occupational accidents can be obtained from several agencies, such as the Occupational Safety and Health Administration (OSHA), the Bureau of Labor and Statistics (BLS), the National Institute for Occupational Safety and Health (NIOSH), and the National Safety Council. The seriousness and importance of the issue are revealed when the alarming statistics published by these agencies on the occupational fatalities in the excavation works is examined (Table 1).

OSHA (2002) indicated that the fatality rate for excavation work is 112% higher than the rate for general construction (Arboleda and Abraham, 2004). According to The Center for Construction Research and Training (CPWR), 34 workers passed away in 2011–2014 and 29 in 2015–2016 because of trench collapses (Ruttenberg et al., 2019). Current trench collapses and fatalities seem to continue in alarming numbers. Schriver and Schoenbaum (2003) stated that fatal trench collapses inspected by OSHA in 1991–2001 accounted for 4.7% of the fatal construction events. According to statistics, an average of 81.6% of trench collapse accidents occurred in the construction industry. Trench fatalities in the construction industry are presented in Figure 1.

Table 1. Number of fatalities resulting from trenching and excavation.

Agency	Time range	Identified cases	Source
OSHA	1985-1989	239 fatalities	Culver et al., 1990
BLS	1992–1999	54 fatalities per year	McCann, 2006
BLS	1992-2001	542 fatalities	MMWR, 2004
NIOSH	1992-2006	759 fatalities	Ruttenberg et al. 2019
OSHA	1998	33 fatalities	Boom, 1999
BLS	2000-2006	271 fatalities	Elcosh, 2020
BLS	2000-2009	350 fatalities	BLS, 2010
BLS	2003-2005	159 fatalities	CPWR, 2007
BLS	2008-2017	180 fatalities	BLS, 2019

The fact that the accidents occurring in excavation works are frequent and severe has led researchers to work on this issue. Rampuri (2019) aimed to identify the potential sources of harm during excavation and trenching activity by searching the literature. Thwala et al. (2018) employed the Delphi method by using questionnaires to assess health and safety risks associated with excavation cave-in in Cape Coast Metropolis. Flynn and Sampson (2012) aimed understand the existing trenching practices and to increase the effectiveness of safety training by using a qualitative approach. Lan and Daigle (2009) reviewed regulations and guides in the excavation and trench work of several countries. Jannadi (2007) aimed to explain the potential risk and present safety precautions of trenching works in Saudi Arabia by surveying contractors. Hinze (2005) analyzed 151 responses collected from the contractor members of the National Utility Contractors Association to provide an overview of the status of the use of trench boxes. Lee (2003) measured productivity loss from an accident in terms of a delay in utility trenching operations. Suruda et al. (2002) conducted a study to examine the impact of the revised rule on fatal injuries in the construction industry from trench cave-in. Table 2 summarized the literature mainly in 1988–2006 that focused on fatal accidents caused by trench collapses. Trench collapse fatalities in 2016, which have more than doubled than that in 2015, is concerning. A worker in a collapsed trench is more likely to be killed than injured (ASH, 2020).

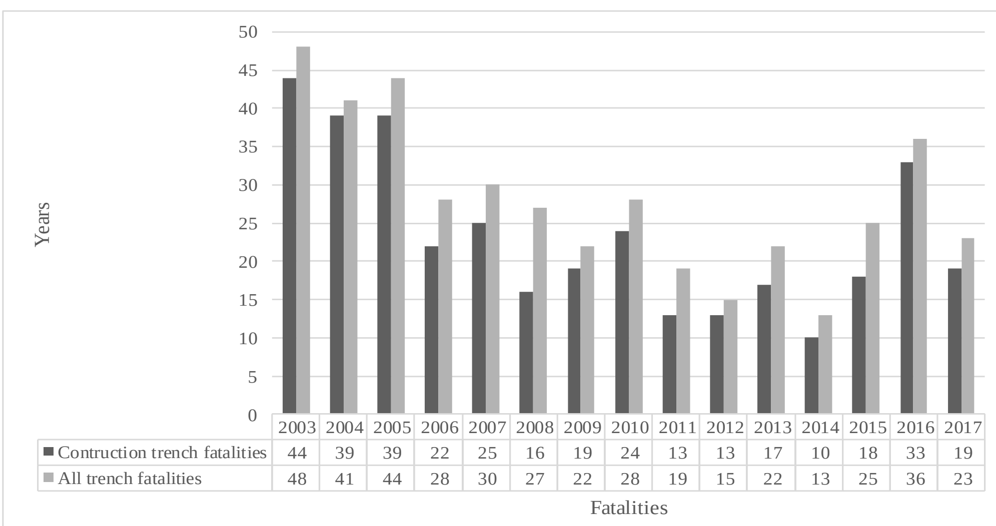

Figure 1. Trench fatalities, 2003-2017 (Source Census of Fatal Occupational Injuries-CFOI)

To reduce occupational accidents that have occurred in excavation works, which often result in loss of life, the hazards of the process must first be well defined. Excavation works carry many dangers and risks because of the nature of the work and environmental conditions. These dangers and risks include trench collapse; falling into an excavation area; flood or water accumulation; confined spaces; heavy and mobile equipment; excavation vehicles, load, or equipment falling on the workers;

oxygen deficiency; toxic, flammable, and explosive gases; entries and exits to the excavation; underground cables; and hazards related to material handling (e.g., lifting, struck by, and crushed between) (CCOHS, 2016).

Table 2. Summary of selected reports on trench collapse related fatalities in construction.

Author(s)	Scope and data source	Findings/insights
Plog et al., 2006	Detailed data of serious or fatal trenching-related injuries 162 cases from Cal/OSHA, 1993-2004	Public awareness of trench safety should be increased.
		A training module for competent persons that teaches how to conduct effective tailgate trainings for trenching crew workers should be developed.
McCann, 2006	Heavy equipment- and truck-related deaths in the excavation work industry in construction. 253 deaths from BLS, 1992-2002	Heavy equipment operators and construction laborers made up 63% of the heavy equipment- and truck-related deaths.
		Rollovers were the main cause of death.
Deatherage et al, 2004	Physical conditions and organizational factors associated with fatal trench collapses. 44 deaths from OSHA, 1997-1999	Improper protection of the excavation site was the leading fatality cause.
		No training had been provided for trenching.
Arboleda and Abraham, 2004	Analyzing the fatality reports and finding the major relationships between the ‘‘how’’ and the ‘‘why’’ of trenching fatalities 296 deaths from OSHA, 1997-2001	In 94% of cave-ins, no protective systems in place.
		84% of companies had received at least one prior OSHA citation.
		Identified need for trench protective systems, proper job planning, and compliance with the OSHA standard to help prevent deaths.
Wagner, 2004	Identification of contributed factors of the fatalities to determine the causation of collapses. 44 deaths from OSHA, 1997-1999	Many trenches without any type of protective devices being used.
		Fatal events might have been prevented if there was compliance with OSHA regulations for protective devices in the trenches, training of employees, and having an OSHA trained competent person on site.
Lew et al., 2002	Discussion the role of the competent person in excavation safety and analyzing characteristics of accidents 52 deaths from NIOSH, 1985-2000	Two key observations from the initial review of records point to the need for a competent person at the work site and effective worker training prior to the commencement of construction operations.
Suruda et al., 1988	Providing information on cave-in fatalities that would call attention to the problem and would support a revision of OSHA standards for trenches. 306 deaths from OSHA, 1974-1986	Most of the deaths occurred in shallow trenches while digging sewer lines and were caused by falling to shore or brace the walls of the trench.
		The risk of cave-in death was higher in young workers and those in small firms.
		Only 12% of the deaths were in unionized companies.

Among these sources of danger, trench collapse causes the most work accidents, deaths, and injuries. It occurs in the form of the soil being thawed and loosened at the edge of the excavated area because of various reasons during work and the workers suddenly slipping or falling into the excavated area. Various studies have shown that the most common cause (71%) of trench related fatalities are trench collapses (Hinze et al., 1998).

Therefore, this study is conducted to understand the causes of trench collapse accidents associated with trenching operations through the analysis of 723 occupational accidents that occurred because of trench collapse in the U.S. between 1995 and 2020 and to develop intervention strategies to identify the causes of trench collapse accidents and review of the literature. Consequently, the findings of this study will give an opportunity to provide further precautions for preventing future accidents. It is expected that the findings obtained in the study will guide the companies in the field of excavation, guide the occupational safety departments of the companies, inform the occupational safety experts and inspire the researchers.

2. Data acquisition

OSHA was created to maintain a reporting and recordkeeping system to monitor job-related injuries and illnesses. Data used in this study were acquired from OSHA accident reports commonly used in construction safety studies in the U.S. and in other countries (McCann, 2006; Hinze et. al., 2005). The Accident Investigation Search enables searching the OSHA Integrated Management Information System enforcement database for accident abstracts that contain specified terms. This database contains abstracts dating back to 1984 and injury data dating back to 1972. Fatality and catastrophe investigation summaries provide a complete description of the incident, generally including events leading to the incident and causal factors.

This study focuses on accidents due to the trench collapse in the last 25 years. Standard Industrial Classification (SIC) codes were taken as a basis while creating the data set. SIC codes are four-digit numerical codes assigned by the U.S. government to institutions for identifying the primary business of the establishment. In the study, Division C: Construction was taken into consideration with Major Groups 15, 16, and 17 (Table 3). Finally, 723 cases with non-fatal and fatal consequences satisfied the criteria to establish the accidents caused by the trench collapse in 1995–2020.

Year of accident, end use and cost of project that accident occurred, degree of injury, type of injury, cause of accident, occupation and union status of worker, violations and penalties were examined as variables. By conducting a detailed examination of the abstracts, additional information, such as soil type, soil condition, the depth of the trench and the unsafe act, was extracted from the reports.

Table 3. Variation of Standard Industrial Classification (SIC) codes.

Division	Major Group	Industry group	Subgroup	n
c: construction	15: Building construction general contractors and operative builders	152: General building contractors-residential	1521 general contractors-single-family houses	19
			1522 general contractors-residential buildings, other than single-family	6
		154: General building contractors-non-residential	1541 general contractors-industrial buildings and warehouses	5
			1542 general contractors-non-residential buildings, other than industrial buildings and warehouses	30
	16: Heavy construction other than building construction contractors	161: Highway and street construction, except	1611 highway and street construction, except elevated highways	19
		162: Heavy construction, except highway and street	1623 water, sewer, pipeline, and communications and power line construction	263
			1629 heavy construction, not elsewhere classified	57
	17: Construction special trade contractors	171: Plumbing, heating and air-conditioning	1711 plumbing, heating and air-conditioning	85
		172: Painting and paper hanging	1721 painting and paper hanging	1
		173: Electrical work	1731 electrical work	13
		174: Masonry, stonework, tile setting, and plastering	1741 masonry, stone setting, and other stonework	4
		176: Roofing, siding, and sheet metal work	1761 roofing, siding, and sheet metal work	1
		177: Concrete work	1771 concrete work	18
		179: Miscellaneous special trade contractors	1794 excavation work	185
			1795 wrecking and demolition work	4
			1799 special trade contractors, not elsewhere classified	13
			total	723

3. Results discussion

A total of 723 summaries of accident investigations were analyzed to identify the causes of accidents specifically related to trench collapse in 1995–2020. The distribution of accidents caused by trenches per year is presented in Figure 2. April and June are the top two months have the highest frequency of accidents, followed by October. According to Hinze and Bren (1997), the presence of more subsurface water in the ground in October may perhaps explain the high incidence in October. Lew et al (2002) also found that October was the month with the highest incidence (16%) of accidents (1996–1997).

Excavations are indispensable for the construction industry. Many types of excavations exist depending on the construction site and the nature of the work. Open excavations; undergrounds; dams; hydroelectric power plants; road; tunnels; art structures; stripping, cleaning, and shaping excavations; and trench excavations are some of these excavation types. For this reason, saying that excavation works are a part of the process regardless of the end use is possible. Table 4 reveals how diverse project end uses are. The projects on which trench work is carried out is mostly single-family or duplex dwelling (26.3%), pipeline (16.6%), excavation and landfill (11.5%), and commercial building (11.5%). A great majority of the victims worked on a new project or a new addition to an existing project (65.8%). Approximately 17.9% of victims worked for maintenance or repair. Almost all workers (98.1%) who had an accident work in private ownership.

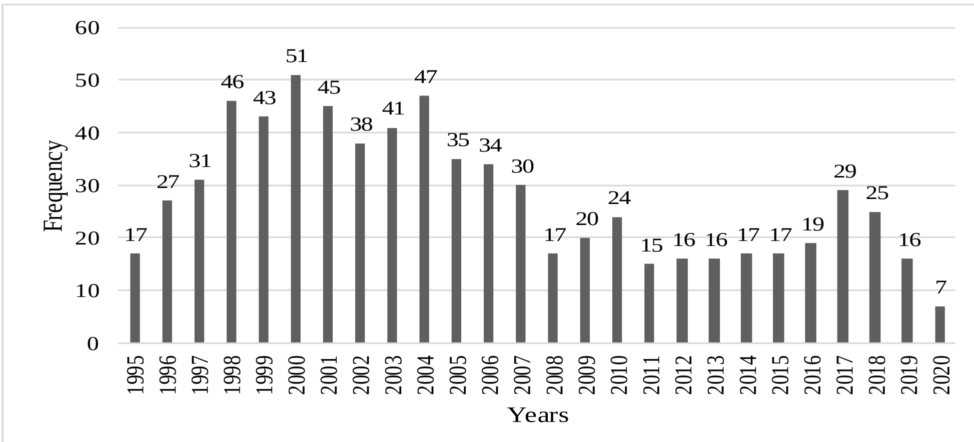

Figure 2. Distribution of accidents by years.

Approximately 28.4% of the injuries or fatalities due to trench collapse occurred in projects that cost under US$50000. According to the results, 46.1% of the accidents occurred in projects that cost less than US$250000 (Figure 3). Small and medium contractor companies may give less importance to occupational safety and health measures, may not necessarily address the safety standards adequately, or may have insufficient budget to provide safety precautions (Forteza et al, 2020; Arboleda and Abraham, 2004).

Table 4. Distribution of end use.

Variable	Categories	Frequency	Valid percent
End use	Single family or duplex dwelling	185	26.3
	Pipeline	117	16.6
	Excavation, landfill	81	11.5
	Commercial building	81	11.5
	Sewer/water treatment	77	10.9
	Highway, road, street	48	6.8
	Other building	36	5.1
	Multi-family dwelling	33	4.7
	Other heavy construction	31	4.4
	Powerline, transmission line	5	0.7
	Manufacturing plant	4	0.6
	Bridge	3	0.4

More than half of the accidents (58.1%) resulted in a loss of life (Table 5). Examining the type of injury caused by accident, asphyxia (34.4%) and fractures (23.0%) were the top two types of injuries. Almost all the accidents caused by asphyxia (98.0%) resulted in death when the distribution of the degree of injury according to injury types is examined. Fracture injuries (72.9%) resulted in hospitalized injuries (Table 6). Some of the information about the cause of the accident variable was not available in a small part of the dataset (9.5%). However, among the provided information, trenching and installing pipes (51.7%) and excavating (31.5%) were two prominent causes (Table 7). More than half of the workers had fatal injuries during excavation (59.7%) and trenching and installing pipe works (58.3%). In other words, one of two employees who carried out these two kinds of work within the analyzed data set died.

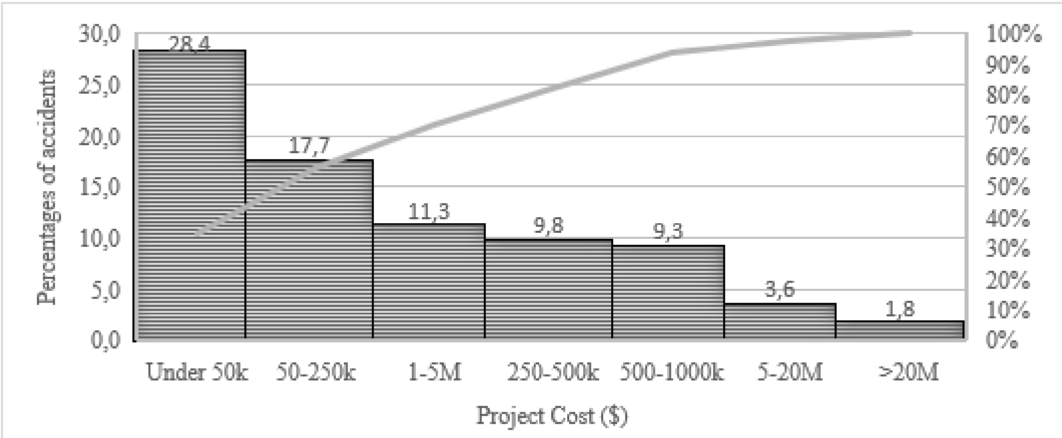

Figure 3. Project cost.

Table 5. Accident Characteristics.

Variable	Categories	Frequency	Percent
Degree of injury	Fatality	420	58.1
	Hospitalized injury	233	32.2
	Non-Hospitalized injury	70	9.7

Table 6. Contingency table-degree of injury vs. type of injury.

Type of injury	Degree of Injury			Total
	Fatality	Hospitalized injury	Non-hospitalized injury	
Asphyxia	244 (98.0%)	5 (2.0%)	-	249 (100.0%)
Fractures	38 (22.9%)	121 (72.9%)	7 (4.2%)	166 (100.0%)
Other	105 (68.2%)	37 (24.0%)	12 (7.8%)	154 (100.0%)
Bruises/contusions/abrasions	19 (18.8%)	45 (44.6%)	37 (36.6%)	101 (100.0%)
Sprain/strain	-	9 (50.0%)	9 (50.0%)	18 (100.0%)
Concussion	7 (43.8%)	6 (37.5%)	3 (18.8%)	16 (100.0%)
Dislocation	1 (12.5%)	5 (62.5%)	2 (25.0%)	8 (100.0%)
Cuts/lacerations	5 (71.4%)	2 (28.6%)	-	7 (100.0%)
Amputation	1 (33.3%)	2 (66.7%)	-	3 (100.0%)
Puncture	-	1 (100.0%)	-	1 (100.0%)
Total	420 (58.1%)	233 (32.2%)	70 (9.7%)	723 (100.0%)

Knowing the characteristics of employees who had work accidents and determining what characteristics do individuals prone to accidents have are important. The first thing to draw attention to is that the occupation of the victim was not reported in 37.3% of the cases (Table 8). The majority of the victims were construction laborers (35.3%). A similar result was obtained in OSHA's 2003 investigation. According to the investigation, most of the workers who have lost their lives were construction laborers, followed by plumbers and pipe fitters (Laborer's Health and Safety Fund of North America, 2020). The CFOI data from 2011 through 2014 showed that construction laborers were the most likely to die in trenches, but plumbers and pipelayers also suffer losses (Ruttenberg, 2019). Hinze et al. (1998) indicated that plumbers and pipefitters are most often involved in accidents resulting from trench cave-ins. Approximately 91.7% of the victims were non-union. Lew et al. (2002) also found that most of the workers (98%) were non-union. It was found that employees in unions compared to non-unionized employees are more likely to self-report injuries and illnesses in the workplace and follow through with filing workers' compensation claims (Le et al., 2021). This also may be attributed to those in unions working more dangerous and laborious jobs (e.g., construction, steel work), working in larger industries, being educated by their union about their employee rights, and their union's contributions to workplace safety culture where self-reporting injuries is encouraged (Fenn and Ashby, 2004; Gillen et al., 2002; Goldenhar et al., 2003).

Table 7. Contingency table-degree of injury vs. cause.

Cause	Degree of injury			Total
	Fatality	Hospitalized injury	Non-hospitalized injury	
Trenching, installing pipe	197 (58.3%)	113 (33.4%)	28 (8.3%)	338 (100.0%)
Excavation	123 (59.7%)	56 (27.2%)	27 (13.1%)	206 (100.0%)
Installing underground plumbing conduit	17 (39.5%)	23 (53.5%)	3 (7.0%)	43 (100.0%)
Installing plumbing, lighting fixtures	6 (50.0%)	1 (8.3%)	5 (41.7%)	12 (100.0%)
Installing culverts and incidental drainage	6 (50.0%)	5 (41.7%)	1 (8.3%)	12 (100.0%)
Waterproofing	3 (33.3%)	5 (55.6%)	1 (11.1%)	9 (100.0%)
Backfilling and compacting	5 (83.3%)	1 (16.7%)	-	6 (100.0%)
Site grading and rock removal	3 (60.0%)	2 (40.0%)	-	5 (100.0%)
Other activities-post decking detail work	2 (50.0%)	2 (50.0%)	-	4 (100.0%)
Landscaping	4 (100.0%)	-	-	4 (100.0%)
Pouring concrete foundations and walls	1 (25.0%)	1 (25.0%)	2 (50.0%)	4 (100.0%)
Installing equipment (HVAC and other)	1 (33.3%)	1 (33.3%)	1 (33.3)	3 (100.0%)
Steel works	1 (50.0%)	-	1 (50.0%)	2 (100.0%)
Pile driving	1 (50.0%)	1 (50.0%)	-	2 (100.0%)
Forming	-	2 (100.0%)	-	2 (100.0%)
Exterior carpentry	1 (50.0%)	1 (50.0%)	-	2 (100.0%)
Total	371 (56.7%)	214 (32.7%)	69 (10.6%)	654 (100.0%)

Table 8. Worker characteristics.

Variables	Categories	Frequency	Percent
Occupation	Occupation not reported	270	37.3
	Construction laborer	255	35.3
	Plumbers, pipe fitters and steamfitters	59	8.2
	Excavating and loading machine operators	33	4.6
	Construction trades n.e.c.	30	4.1
	Supervisors	24	3.3
	Laborers, except construction	15	2.1
	Helpers, construction trades	13	1.8
	Pipelayer	9	1.2
	Carpenter	5	0.7
	Electricians	5	0.7
	Welders, cutters, and metal workers	3	0.4
	Concrete and terrazzo finishers	2	0.3
Union status	Union	60	8.3
	Non-union	663	91.7

The main reason for half of the accidents was a lack of protective systems (49.7%) (Table 9). A few examples taken from accident reports highlight the importance of the issue. As understood from the accident summaries, the main root cause of the accidents is the lack of protective systems.

> …The investigation findings included unsupported and unprotected underground installations; water accumulation; lack of a competent person performing daily inspections; spoil piles not positioned at least 2 feet from the excavation edges; lack of sloping or use of a protective system; lack of a hazard communication program; and lack of Global Harmonized System training…

…There was no protective system in place to protect workers from collapse hazards, no safe egress in place, no provision for dealing with water accumulation in the trench, inadequate control of heavy equipment location in regard to the top edge of the trench, and inadequate inspection of trench conditions…

…In addition to the lack of any protective system, it was determined that the spoil pile was left at the edge of the trench with no safe route of egress from the trench. Employees were not required to wear protection while in the trench. There was also no competent person on site. Their employer did not have a safety program and no training was provided to the employees…

The lack of a protective system was the leading cause of trench-related fatalities in a review of OSHA inspections (Deatherage et al., 2004). Québec Occupational Health and Safety Board (CSST) analyzed 44 serious and fatal accident reports that occurred in 1974–2008 and indicated that no shoring or inappropriate shoring was used in 33 of the 44 worksites (Lan and Daigle, 2009). OSHA's 2003 investigation also indicated that the main reason trenches collapse is that they are not properly protected by the protection systems such as shoring. According to the investigation, protective systems were properly employed in only 24% of the trenches. In the remainder, protective systems were improperly used (24%), available but not in use (12%), or simply unavailable (64%) (Laborer's Health and Safety Fund of North America, 2020). NIOSH also concluded in 2011 that "Lack of a protective system (such as shoring, shields, or sloping) was the leading cause" of six trench cave-ins (Ruttenberg, 2019).

Table 9. Unsafe act.

Variable	Categories	Frequency	Percent
Unsafe act	Lack of protective system	359	49.7
	Unidentified	252	34.9
	Unsafe method or sequencing	58	8.0
	Unsafe site conditions	25	3.5
	Poor attitude toward safety	17	2.4
	Deficient enforcement of safety	8	1.1
	Not using provided safety equipment	4	0.6

Information on the depth of the trench was available for 479 of 723 accidents. The depth of the excavations the accident occurred was investigated (Figure 4). According to the findings, 35.9% of the accidents occurred in excavations with a depth of more than 10.6 ft. Moreover, some limited findings were obtained about excavation characteristics (Table 10).

Table 10. Excavation characteristics.

Variables	Categories	Frequency	Percent
Soil type	Type A	4	7.8
	Type B	14	27.5
	Type C	33	64.7
Soil condition	Soil had been previously disturbed	29	36.3
	Unstable soil	28	35.0
	Wet conditions	17	21.3
	Frozen soil	6	7.5

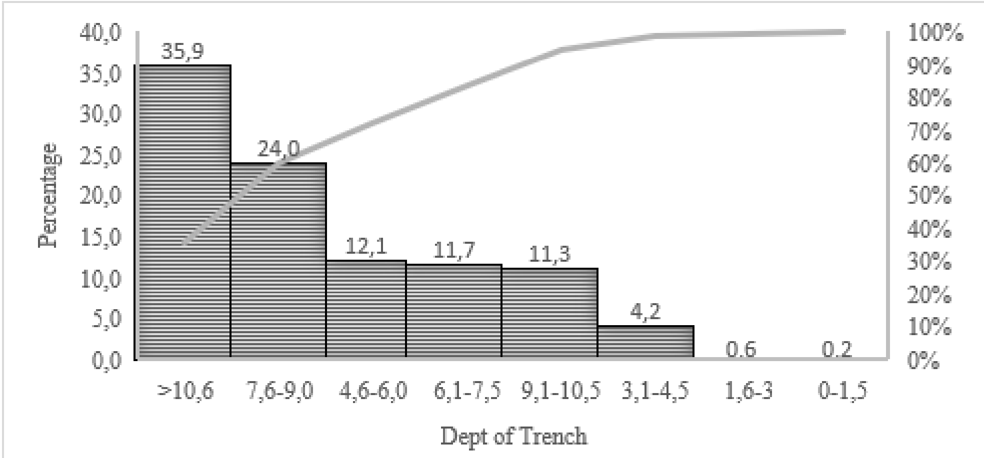

Figure 4. Dept of trench (ft).

Accidents result with the serious consequences not only with fatalities and injuries but also penalty fines. Citations inform the employer and employees of regulations and standards alleged to have been violated and the proposed length of time set for their abatement. Violations are also one of the techniques OSHA uses to convince or help force companies into compliance (Wagner, 2004). As a result of accidents, employers pay penalties at high rates based on the violations they have committed. OSHA citations and penalties are issued based on the nature and severity of the violation. A total of 2596 violations, including four main categories, were detected for 723 accident reports. Employers have paid approximately 23 million in penalties (Figure 5). CPWR (2018) also indicated that more than half (54%) of the citations issued in heavy and civil engineering construction (NAICS 237) were violations of the OSHA trenching standards, a higher proportion than any other construction subsector.

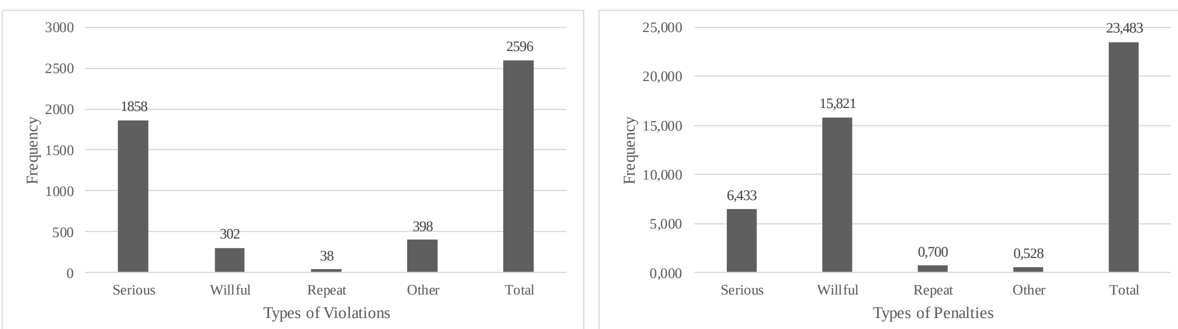

Figure 5. Types of violations and penalties (M).

4. Conclusions

In this study, 723 occupational accidents that occurred because of trench collapse in the U.S. between 1995 and 2020 were investigated to understand the causes of trench collapse accidents associated with trenching operations and develop intervention strategies to identify the causes of trench collapse accidents. Statistical analysis reveals the importance and seriousness of occupational safety in excavation work. The study findings show that 58.1% of occupational accidents caused by trench collapse resulted in death.

An unprotected trench is the main reason for accidents for workers who dig or excavate trenches. According to accident investigations, the most important point to be noted is the lack of protective systems. Safety precaution was not provided in a majority of the cases. OSHA's excavation standard requires employers to provide sloping (or benching), shoring, or shielding to protect employees in excavations 5 feet or more in depth (Boom, 1999). Trenches 20 feet deep or greater require a protective system designed by a registered professional engineer. In deeper excavations, although walls are supported, emergency exits must be provided (Oglesby, 1989). Moreover, NIOSH recommended that the shoring or sloping of trenches deeper than 24 feet be determined by an engineer (Suruda, 2002). Workers should never enter a trench that does not have a protective system in place designed and installed by a competent person.

A competent person is an individual who can identify existing and predictable hazards or working conditions that are hazardous, unsanitary, or dangerous to workers; soil types; and protective systems required. The competent person is also authorized to take prompt corrective measures to eliminate these hazards and conditions. The competent person should be trained and designated to ensure safety measures in the excavation site. The competent person should evaluate the type of soil to determine its stability before excavation works start. A type of protective system should be decided afterward. The excavation, adjacent areas, and the protective systems should be inspected routinely each day before the start of work. Besides, inspection should be done as needed throughout the shift and specifically after every rainstorm. The competent person must remove workers from the excavation upon any evidence of a situation that could cause a cave-in, such as accumulation of water in the trench or protective system problems. Researchers have suggested that fatal events which occurred during the study period because of trench collapse could have easily been prevented if a competent person on site had followed OSHA regulations (Deatherage, 2004).

For trenching operations, employees need to be trained in the safety of trenches, their hazards, and all the regulations required by OSHA (Wagner, 2004). Training should be regulated in a language that workers understand and at the appropriate literacy level (Lopez-Arquillos et al., 2019). Workers should be warned about not entering an unprotected trench, inspecting the protected trench before entering and exiting the trench, and calling the competent person in case of any evidence of a problem with a protective system.

Moreover, employers pay high penalties for violations they committed because of occupational accidents resulting in deaths and injuries. Employers have paid approximately 23 million dollars for 2596 violations for the accidents examined within the scope of the study.

In summary, to prevent trench collapses, safety should be ensured when entering and exiting the trench, cave-in protection must be supplied, materials should be kept away from the edge of the trench, water accumulation and other hazards should be controlled, and entering improperly inspected trenches should be prevented. Moreover, exposure to falling loads should be prevented, employees should be protected from being injured or killed by vehicles, warning systems for mobile equipment should be used, atmospheric measurements should be made, and a trench emergency action plan should be developed. Besides, discussing what can be done to reduce the frequency and severity of accidents by taking lessons from past accidents in terms of the value of human life and the country's economy is necessary. OSHA's standard for excavation and trenching, known as "1926 Subpart P – Excavations," describes in detail the precautions needed for safe excavation work (OSHA, 2020b).

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