Proceedings of the International Conference on Industrial Engineering and Operations Management
Washington DC, USA, September 27-29, 2018

Management of Health and Safety Risk Associated with Excavation Cave-in

Wellington Didi Thwala[1]
[1]Sustainable Human Settlement and Construction Research Centre, Department of Construction Management & Quantity Surveying, University of Johannesburg, Doornfontein Campus, Johannesburg, 2028, South Africa,
didibhukut@uj.ac.za

Zakari Mustapha[2, 1]
[2, 1] Department of Building Technology, Cape Coast Technical University, Cape Coast, Ghana,
zakari.mustapha1967@gmail.com

Clinton Aigbavboa[3]
[3] Sustainable Human Settlement and Construction Research Centre, Department of Construction Management & Quantity Surveying, University of Johannesburg, Doornfontein Campus, Johannesburg, 2028, South Africa,
caigbavboa@uj.ac.za

* Corresponding author Email: zakari.mustapha1967@gmail.com

Abstract

The most dangerous construction tasks are trenching and excavation related works, resulting in accidents among construction employees. The study assessed health and safety risk associated with excavation cave-in. Delphi method of data collection was employed in the administration of questionnaires, among six academics and seven construction professionals in Cape Coast Metropolis. Findings from the study show that adequate measures were put in place by the contractors to minimize cave-in. The employed safety measures with high response rate are: heavy equipment should be kept away from trench edges, appropriate training on shoring should be provided to all workers and trenches should be inspected on regular basis, and at the start and end of each shift. While the employed safety measures with low response rate are attributed to: trench evaluation should be rigorous when there was heavy down pour and shoring of trenches should be carried out by specialists. Further findings indicate that all the construction sites applied one or two of the installation preventive systems, namely shoring and sloping the ground. These installation preventive systems fall within the minimum criteria for a good system. Preventive system for excavation works are employed by the firm, was considered by the experts to have reached consensus with IQD cut-off (IQD ≤1) score set. Contractors and construction professionals must ensure that preventive measures for cave-in safety should be also applied to areas with potential risk within the site, to prevent any unforeseen dangers.

Keywords: Atmospheric Risk; Fatalities; Hazards; Installation; Preventive Systems.

1. Introduction

Excavation and trenching are among the most hazardous construction operations [6]. The Occupational Safety and Health Administration's (OSHA) Excavation standards, OSHA defines an excavation as any man-made cut, cavity, trench, or depression in the Earth's surface formed by earth removal, while, a trench is defined as a narrow excavation (in relation to its length) made below the surface of the ground [11]. Trenching and excavation work presents serious

hazards to all workers involved. Cave-ins pose the greatest risk and are more likely than some other excavation-related incidents to result in worker fatalities. An unprotected trench can be an early grave for employees in the construction industry [11]. Employers must ensure that workers enter trenches only after adequate protections are in place to address cave-in hazards. Other potential hazards associated with trenching work include falling loads, hazardous atmospheres, and hazards from mobile equipment [11]. Excavation accidents is always on the high side, and a lot of employees are injured annually. Almost of excavations works are considered to have potential high risk activities such as, foundations, sewers and drainage and the depth for any of the activities varies from one task to another. Several factors can affect excavation works, such as, rainfall, weather, adjoining structures, ground conditions and vibration or other external loading factors [12]. Cave-ins are the most potentially catastrophic risks that affect excavation projects and the people who work on them. Excavation cave-in occurs more often than any other type of excavation hazard, resulting in employees' fatalities [9]. In order to minimize or prevent the occurrence such accidents, adequate protection should be provided against any collapse [12]. The study assessed health and safety risk associated with excavation cave-in. The paper discussed means of controlling weather conditions in cave-in, requirements for excavation and trench operation and risk management associated with excavation cave-in. Others are preventive measures for cave-in safety and installation preventive systems for cave-in.

2. Literature

Excavation work includes open excavations, potholing, pit excavations, trenches and retaining walls, shafts and drives [4]. Working in and around excavations and trenches can result in serious injury and death if hazards are not properly identified and controlled at all times [7, 6]

Gurley [6] posited that most of the excavation accident occur at depths not less than 10 ft.3, due to lack of protective systems and finally, leading to trench-related fatalities [6]. There are many potential hazards when working in excavations and trenches. Probably the most common hazard at any work site is the threat of cave-in. A cave-in occurs when walls of an excavation collapse and can result in death. Wall failures often occur suddenly, with little or no time for the worker to react. The weight of the soil crushes and twists the body, causing death or serious injury in a matter of minutes. Excavations need not be deep or large to create a life threatening hazard. Cave-ins occur when undisturbed soil is kept in place by natural horizontal and vertical forces of the nearby soil [7, 6]. Cave-ins pose the greatest risk and are much more likely than other excavation-related accidents to result in worker fatalities" [6].

Natural forces are no longer able to hold back the soil left behind during excavation. The laws of gravity take over during the excavation, since there is support and the soil from the excavation walls move downward and inward into the excavation. The result is a cave-in and are likely to occur in unprotected excavations. They are as follows:

i. The excavation is dug in unstable soil, or in soil that has been dug in before;
ii. There is excessive vibration from construction equipment or vehicle traffic around the excavation;
iii. Too much weight near the sides of an excavation, most frequently from equipment or the excavated material (spoil pile) too near to the edge;
iv. Water has collected in the excavation;
v. Changes in weather conditions (freezing, melting, sudden heavy rain, etc.).

2.1 Means of Controlling Weather Conditions in Cave-in

The Occupational Safety and Health Administration (OSHA) requires that excavations and trenches should be inspected on daily basis to ascertain the nature of the ground, in order to prevent accidents [8].

Cave-in is termed as the sudden movement of soil or rock that that causes these materials to fall into the excavation or trench that causes the employee to become entrapped buried or immobilized. All employees using the excavation or trench shall use it as instructed by the Competent Person and report any problems immediately to the competent person [3,8].

There are various ways to help control weather condition. In order to be safe and work efficiently around excavations and prevent cave-ins from occurring.

The following precautions must be followed:

i. Re-route traffic whenever possible, and keeping only the heavy construction equipment needed near the excavation;
ii. Keeping the spoil pile at least 2 feet back from the edge of the excavation;
iii. Pumping water out of the excavation before anyone enters it;
iv. Using protective systems when required [7, 8].

2.2 Requirements for excavation and trench operation

The specific excavation and trench operation should be reviewed and implemented as required. They are as follows:

i. Removal of all support encumbrances located near the surface of the excavation or trench.
ii. Underground utility installations located.
iii. Access and egress from the excavation or trench provided.
iv. Any employee exposure to vehicular traffic and employees provided with visible warning vest or garments.
v. Employees protected from falling loads while in the excavation or trench.
vi. A warning system provided when mobile equipment nears the edge of the excavation or trench.
vii. Hazardous atmospheres evaluated prior to entry and during work based on containment(s) present.
viii. Water hazards associated with excavation or trench are evaluated and controlled.
ix. The stability of any adjacent structures is evaluated and controlled.
x. Loose rock or soil is kept back from excavation or trench by at least 2 feet.
xi. Walkways are provided where employees or equipment are permitted to cross over excavation.
xii. Daily inspections shall be done of excavations, adjacent areas, and protective systems by the Competent Person [3,8].

Figure 1: Excavation exercise
Source: Development of Draft Construction Safety Standards for Excavations (n.d.)

Information from the U.S. Bureau of Labor Statistics (BLS) data show that Sixty-eight percent of trenching or excavation cave-ins fatalities occurred in companies with fewer than 50 workers. Forty-six percent of the deaths occurred in small companies with 10 or fewer workers. BLS reports indicates that regulations and consensus standards which describes engineering controls, protective equipment, and safe work practices should be employed during excavation works, in a situation similar to Fig. 1 to minimize hazards for workers during trench work and excavations [2].

2.3 Risk management associated with excavation cave-in

Cave-in has been found to be the greatest excavation risk. Employees are likely to be in danger in a situation in Fig.2, where the excavation depth is beyond 1.5m. Risk prevention associated with cave-ins should be carried out in such a way that all construction employees will be protected and it must be among the list of health and safety checklist of the safety officer. Hence, the use of an excavator to prevent any unforeseen. Adequate measures in the form of reinforcement of all trenches, relevant safety checks at regular intervals which should be in compliance with official health and safety guidelines should be put in place before any employee begins any excavation works [5,8]

Figure 2: Excavation works with an excavator
Source: Gurley, 2012).

Many on-site accidents result from inadequate planning and non-execution of an excavation safety plan [6]. Planning for excavation operations is one of the most important steps in avoiding accidents. The employee should have an idea of all the required equipment and materials needed for a task to be carried out [6].

2.4 Preventive measures for cave-in safety

Occurrence of cave-ins can be minimized when adequate measures are put in place. Such as follows:

i. Heavy equipment should be kept away from trench edges
ii. Trenches should be inspected on regular basis and at the start and end of each shift
iii. Trench evaluation should rigorous when there was heavy down pour
iv. Shoring of trenches should be carried by specialists
v. Appropriate training on shoring should be provided to all workers [5,8]

2.5 Installation Preventive Systems for cave-in

It is important to institute an installation preventative systems to minimize risk associated to cave-ins. The most important system is the one which reinforces the trench and protects workers. The system also protects employees from any other hazards posed by loose rock or soil, unsecured equipment or routine health and safety issue, such as, trips or falls [5,8].
A good system must include at least one of the following measures: sloping the ground, shoring, shielding (e.g. with a trench box) and benching the ground [5,8].
Table 1 shows the probability scale, ranged from one to ten and it represents zero to 100% with interval ranges set at ten (Table 1).

Table 1: Influence or likelihood scale

0-10 %	10-20 %	21-30 %	31-40 %	41-50 %	51-60 %	61-70 %	71-80 %	81-90 %	91-100 %
1	2	3	4	5	6	7	8	9	10

Table 2 shows the impact scale, ranged from one to ten and it represents No impact to Very high impact.

Table 2: Impact scale

No impact		Low impact		Medium impact		High impact		Very high impact	
1	2	3	4	5	6	7	8	9	10

3. Methodology

A Delphi survey was conducted to identify the factors that have influence on SME contractors' growth. Experts were asked to rate the likelihood of an attribute influencing Small and Medium-Sized Enterprise (SME) contractors' growth in the construction industry in Cape Coast Metropolis, if they were present. Thirteen experts made up of six academics and seven construction professionals from Cape Coast Metropolis were involved in the Delphi survey. The professionals were made up of a health and safety personnel, a quantity surveyor, a structural engineer, a construction manager, a project manager, a building technologist and an architect. The number of experts was considered adequate based on literature recommendations from scholars [10, 1, 14] who have previously employed the technique. Experts were asked to rate the impact of other factors in predicting SME contractors' growth. Data obtained were analyzed using Microsoft Excel spread sheet.

4. Findings and Discussion of Results

The preceding section presents the findings and discussion of results (Tables 3 to 6).

Table 3: Measures to minimize the o occurrence of cave-in

Variable	Frequency	Percent (%)
Heavy equipment should be kept away from trench edges	12	92
Appropriate training on shoring should be provided to all workers	12	92
Trenches should be inspected on regular basis and at the start and end of each shift	13	100
Benching the ground	6	46.15
Trench evaluation should be rigorous when there was heavy down pour	4	30.77

Table 3 shows that most of experts considered the first three variables with the highest percent, ranging from 100 to 92, as the variable in practice for the most appropriate measures used to minimize the occurrence of cave-in. The remaining two variables (Benching the ground and trench evaluation should be rigorous when there was heavy down pour) are not usually practiced on sites in Cape Coast Metropolis.

Table 4: Installation Preventive Systems for cave-in

Variable	Frequency	Percent (%)
Sloping the ground	13	100
Shoring	11	84.62
Shielding (e.g. with a trench box)	2	15.38

Benching the ground	3	23.08

Table 4 shows that most of the SME contractors employed sloping the ground and shoring as the installation preventive systems for cave-in used. Shielding (e.g. with a trench box) and benching the ground were not common among the SME contractors in Cape Coast Metropolis.

Table 5: Influence of Installation Preventive Systems

Installation Preventive Systems	Median	Mean	SD	IQD≤ 1
Routine health and safety exercise are conducted prior to the excavation works	7	7.71	1.58	2
Unsecured equipment are removed from the excavation area before the exercise begins	9	8.43	1.05	1.25
Loose rock or soil with potential hazard are protected from cave-in before the actual excavation works	8	7.71	1.48	1.25
Protection are provided to any side of the excavation with potential safety risk	8	7.67	1.11	1.5
Preventive system for excavation works are employed by the firm	9	8.57	1.05	0.82

SD= standard deviation; IQD = Interquartile deviation

Out of the five (5) variables identified, only one (1) variable (Preventive system for excavation works are employed by the firm) was considered by the experts to have reached consensus with IQD cut-off (IQD ≤1) score set to achieve consensus. Four (4) of the variables were considered by the experts to have very high impact (HI: 7-9) under the median score (Table 5).

Table 6: Impact of Installation Preventive Systems

Installation Preventive Systems	Median	Impact Scale
Routine health and safety exercise are conducted prior to the excavation works	7	High
Unsecured equipment are removed from the excavation area before the exercise begins	9	Very high
Loose rock or soil with potential hazard are protected from cave-in before the actual excavation works	8	High
Protection are provided to any side of the excavation with potential safety risk	8	High
Preventive system for excavation works are employed by the firm	9	Very high

Table 6 shows the variables of installation preventive systems with a very high impact (VHI) degree as unsecured equipment are removed from the excavation area before the exercise begins and preventive system for excavation works are employed by the firm. The remaining three variables for the installation preventive systems have a high impact (HI).

5. Conclusion and Recommendation

Almost all the variables for preventive measures or to minimize the occurrence of cave-in, are put in practice by the SME contractors. Sloping the ground and shoring methods of installation preventive systems for cave-in are also enforced. Consensus was reached with IQD cut-off (IQD ≤1) score set for only one variable. It is recommended that trenches and excavations should be inspected by the safety personnel before any excavation works begins, to avert any unforeseen during weather conditions. Stringent safety measures should be put in place by contractors' safety personnel to cater for all cave-ins.

References

[1] Brill, J., Bishop, M. and Walker, A. (2006). The competencies and characteristics required of an effective project manager: A web-based Delphi study. Educational Technology Research Development, 54(2):115-40.

[2] Development of Draft Construction Safety Standards for Excavations (n.d.). Trenching and Excavation, DHHS (NIOSH) Publication No. 83-103 (Volumes I & II). Available from: https://www.cdc.gov (accessed 30 March 2018).

[3] Environmental and Health Safety (n.d.). Excavation & Trenching, Available from: https://ehs.research.uiowa.edu (accessed 30 March 2018).

[4] Good practice guidelines (2016). Excavation Safety, Work safe, Newzaland, July 2016.

[5] Ground force specialist construction solutions (n.d). What is the Greatest Risk with Excavations?

[6] Gurley, E. (2012). Prevent Excavation Cave-in Fatalities, National Precast Concrete Association / Precast Magazines / Precast Inc. Magazine / 2012 – March-April. Available from: http://Ex- precast.org. (accessed 02 April 2018).

[7] Hazards of Excavation (n.d.). Available from: https://www.afscme.org (accessed 30 March 2018).

[8] Jamison, B. (2018). Trench Cave-Ins: How to Prevent Them, Health Day, News for healthy living, Jan 20, 2018. Available from: https://consumer.healthday.com (accessed 03 April 2018).

[9] Kiganda, A. (2017). Association of Building and Civil Engineering Contractors of Ghana (ABCECG), Mar 7, 2017.

[10] Mustapha, Z., Aigbavboa, C. and Thwala, W. (2018). Contractor Health and Safety Compliance for Small to Medium-Sized Construction Companies, Routledge 2017, Print ISBN: 978-1-138-08155-0, eBook ISBN: 978-1-351-62316-2, https://doi.org/10.1201/9781315112817.

[11] Occupational Safety and Health Administration (OSHA) (2015). Trenching and Excavation Safety, U.S. Department of Labor, 2226-10R 2015. Available from: www.osha.gov (accessed 01 April 2018).

[12] Risk Control Guide (2017). Safety on construction sites, RCG014 (E)-v1-01/2017, 2017 Royal & Sun Alliance Insurance plc. Available from: http://www.hse.gov.uk (accessed 29 March 2018).

[13] Risk management guidance for the construction industry (n.d.). Redefining/standards, AXA Insurance UK plc Registered in England and Wales No 78950. Registered Office: 5 Old Broad Street, London EC2N 1AD. Available from: www.axaconnect.co.uk (accessed 26 March 2018).

[14] Saizarbitoria, I.H. (2006). How quality management models influence company results –conclusions of an empirical study based on the Delphi method (ISO 9000 and EFQM quality management standards of Europe). Total Quality Management and Business Excellence, 17(6):775-94.