

Trench excavation health and safety in South African construction

Muziwandile Mabaso¹ and John Smallwood¹

¹Department of Construction Management,
Nelson Mandela University,

Email: muziwandile.mabaso@labour.gov.za

²Department of Construction Management,
Nelson Mandela University,

Email: John.Smallwood@mandela.ac.za

Abstract:

Construction work is hazardous by nature, and trench excavation collapses contribute to the disproportionate number of fatalities and injuries in construction. A quantitative study was conducted in South Africa to produce a framework of interventions to enhance excavation health and safety (H&S) and mitigate excavation related injuries and fatalities. A self-administered questionnaire was circulated among a sample stratum comprising construction supervisors, H&S Officers, design engineers, and construction managers. The salient findings include: a range of factors that contribute to excavation incidents; excavation hazard identification and risk assessment (HIRA) is important relative to a range of excavation-related hazards; a range of key excavation aspects are not addressed between a near major to major/major extent, and trench collapses impact primarily in the form of fatalities and other injuries, but also impact on performance relative to the other performance parameters. Conclusions include: a cocktail of interventions are necessary to mitigate excavation incidents; there is a need for enhanced supervision during excavations and enhanced excavation H&S knowledge and training; excavation H&S inspections are not effective, and trench collapses have a major as opposed to a minor impact. Recommendations include: an appropriate excavation H&S qualification and training should be developed and registered in terms of the National Qualifications Framework Act, 2000; employer associations should raise the level of awareness concerning excavation H&S; excavation H&S inspections must be comprehensive, and contractors should conduct detailed cost-benefit, and cost of accidents analyses relative to excavations.

Keywords: Construction, Excavation, Health and Safety, Trenches

1 Introduction

Historically, trench collapses have featured in the South African media. Three workers were buried in a five-metre-deep trench collapse near Klein Brak River, near Mossel Bay in the Western Cape Province in March 2005, and four out of the total six workers caught in a six-metre-deep trench collapse in Randburg, Gauteng province, lost their lives in May 2005 (Myer, 2005). Three workers were critically injured after a four-metre-high wall of sand collapsed on them pinning them against a concrete pipe in Mount Moriah, Kwazulu-Natal province in August 2015. The collapse was attributed to heavy rains experienced (Phoenix Tabloid, 2015). A worker was killed, and another injured after a trench they were working in collapsed in Knysna, Western Cape province in March 2016 (Singh, 2016). One of four municipal contract workers repairing a burst pipe, near the outskirts of Despatch, Eastern Cape province, in July 2019, died when one of the pipes they were working on burst filling the excavation with water

(Wilson, 2019). Excavation cave-ins are a major cause of fatalities within the American construction industry, and the fatality rate for excavation work is 112 % higher than the rate for general construction (Druley, 2018).

The Occupational Safety & Health Administration (OSHA) (2015) states that regardless of how many trenching, shoring, and backfilling projects a contractor has undertaken, it is important to approach each new project with care and preparation. OSHA adds that many on-the-job excavation incidents result from inadequate planning and waiting until after the work starts to correct mistakes relative to shoring or sloping, slows down the operation, adds to the project's cost, and makes a cave-in or other excavation failure more likely.

Given the high number of fatalities and injuries resulting from trench excavation collapses in South Africa, a study was conducted, the aim of which was to produce a framework to enhance excavation H&S, the objectives being to determine the: causes of excavation incidents; importance of excavation HIRA relative to a range of hazards; extent to which aspects are addressed during the inspection of excavations, and impact of excavation incidents.

2 Literature Review

2.1 Health and Safety legislation and standards

The Construction Regulations (Republic of South Africa, 2014) require the following relative to excavations:

- Excavations must be inspected periodically by a competent person, namely daily, prior to commencement of each shift, after every blasting operation, after an unexpected fall of ground, after damage to supports, and after rain;
- All excavation work must be undertaken under the supervision of a competent person;
- Excavation supervisors must evaluate the stability of the ground before excavation work begins;
- Shoring or bracing must be designed and constructed in a manner that renders it strong enough to support the sides of the excavation, and
- Excavations must be protected by a barrier or fence of at least one metre in height, and close to the excavation as possible.

According to the South African Bureau of Standards (SABS) 1200 DB-1989 standard (SABS, 1989), pipe trenches should be excavated in lengths approved by the engineer, to widths that, in each case, provide at least the appropriate side allowance such that half of the base width is on either side of the designated centreline of the pipe. Furthermore, the sides of each trench from the bottom up, must be as nearly vertical as possible for at least the height of the bedding. Clearly, SABS 1200 DB-1989 guides concerning the proper construction techniques that need to be implemented during trench excavation works and complements the South African Construction Regulations in terms of promoting proper shoring and bracing.

The issue of a ‘competent person’ is often the subject of debate in South Africa, primarily due to the broad definition of a competent person as a “person who has the required knowledge, training, and experience, and where applicable, qualifications specific to the work or task.” unless there are appropriate qualifications and training registered in terms of the National Qualifications Framework Act, 2000, in which case such qualifications and training are regarded as the required qualifications and training (Republic of South Africa, 2014).

OSHA (2015) defines a competent person as “an individual, designated by the employer, who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous or dangerous to workers, and who is authorised to take prompt corrective measures to eliminate them.”

2.2 Excavation hazards

According to WorkSafe New Zealand (2016), the categories of excavation-related hazards are: excavation hazards per se; falls and falling objects; hazardous atmosphere in an excavation; manual handling tasks; natural hazards and weather; overhead services; site H&S; underground services, and vibration and hazardous noise. The Occupational Safety & Health Administration (OSHA) (2015) states that cave-ins pose the greatest risk during excavations and are more likely to result in fatalities than other excavation-related incidents. They also mention falling loads, hazardous atmospheres, and hazards from mobile equipment.

The Health & Safety Executive (HSE) (2006) recommends that before commencing excavations, the form of temporary support should be decided upon, and the precautions that are going to be taken against the following should be planned: collapse of the sides; people and vehicles falling into the excavation; materials falling onto people working in the excavation; undermining nearby structures; underground and overhead services, and the inflow of ground and surface water.

2.3 Causes of excavation incidents

According to Plog *et al.* (2006) in Ruttenberg *et al.* (2019) an American study determined the main barriers to preventing trench-related incidents were attitude, lack of training, insufficient enforcement, and perceived costs. Smallwood (2010) conducted a study that required respondents to rate the South African construction industry relative to thirteen excavation H&S aspects. 12 / 13 (92.3%) Aspects achieved mean scores (MSs) $> 2.60 \leq 3.40$, which indicates the rating was between poor to average / average. The lower part of the range featured culture, ranked last, preceded by the design of shoring, education, training, and geotechnical reports. These in turn were preceded by the following which featured in the upper part of the range, namely enforcement of legislation, awareness, technology, pre-planning, access, ‘managing’ existing services, and contractor inspections. Only barricading was rated average to good / good.

2.4 Interventions to prevent excavation incidents

OSHA (2015) states that the competent person responsible for excavations should be capable of classifying soil, inspecting protective systems, designing structural ramps, monitoring water removal equipment, and conducting site inspections. Pre-planning is important for addressing factors such as soil, weather, water, traffic, and utilities. Workers also need a safe means of entering and exiting trenches, and any excavation in which workers face a potential cave-in must be equipped with one of the three protective systems in the form of sloping, shoring, or shielding (Johnson, 2011).

2.5 The impact of trench collapses

The outcome of incidents and accidents is fortuitous. However, statistics indicate that construction fatalities are often attributable to such collapses (Druley, 2018). OSHA (2015) mentions delays, and additional costs.

Within the context of South Africa, should a fatality occur, the incident must be reported to the Occupational Health and Safety Inspectorate, Department of Employment and Labour, and to the South African Police Service, and work in the area where the fatality occurred must cease, and the scene of the fatality must remain undisturbed. Furthermore, accident investigations are a requirement, which require management, supervisory, and worker participation, and contributions (Republic of South Africa, 1993). These requirements have obvious implications in the form of distracted management, supervision, and workers; delays; idle workers; decreased productivity; increased costs, and reduced profitability. However, generally, media coverage of such accidents is common as noted in the 'Introduction' above, which in turn may result in a tarnished image and reputational damage of the contractors concerned.

3 Research Methodology

The study was conducted on sewer reticulation projects in the Eastern part of the Eastern Cape Province, South Africa, and the sample stratum consisted of construction managers and supervisors, H&S officers, and design engineers. The study entailed a self-administered questionnaire survey, and the questionnaire consisted of nine questions in the form of eight close-ended questions, and one open-ended question. The eight close-ended questions were Likert scale type questions. 27 Responses were received from 38 potential respondents, which equate to a response rate of 71.1%. The analysis of the data entailed the computation of frequencies, and a measure of central tendency in the form of a mean score (MS), to enable the interpretation of percentage responses to the sub-questions, and to rank the variables.

4 Findings and Discussion

Table 1 indicates the extent to which factors contribute to excavation incidents on construction sites regarding percentage responses to a scale of 1 (minor) to 5 (major), and MSs ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint score of 3.00, which indicates that in general, the respondents perceive that these factors contribute to excavation incidents on construction sites to a major as opposed to a minor extent. However, it is notable that 3 / 10 (30 %) of the MSs are $> 4.20 \leq 5.00$, which indicates that the contribution is between a near major to major / major extent - inadequate excavation H&S knowledge, poor H&S culture, and inadequate inspections. Furthermore, 7 / 10 (70 %) of the MSs are $> 3.40 \leq 4.20$, indicating that the contribution is to a near major / near major extent. However, it should be noted that 6 / 7 factors are in the upper part of the range, namely $> 3.80 \leq 4.20$. The Construction Regulations (Republic of South Africa, 2014) emphasise that contractors must appoint competent site management and ensure that adequate inspections are conducted timeously to prevent trench excavation related fatalities and injuries.

Table 2 indicates the extent to which the respondents agree with statements relating to trench excavation projects regarding percentage responses to a scale of 1 (strongly disagree) to 5 (strongly agree), and MSs ranging between 1.00 and 5.00. The results show that all the MSs are above the midpoint score of 3.00, which indicates that in general, the respondents agree with the statements instead of disagree. However, it is notable that 4 / 6 (66.7%) of the MSs are $> 3.40 \leq 4.20$, indicating that the concurrence is between neutral to agree / agree. Notably, the statements relate to deficiencies relative to supervision, H&S competencies, HIRA, and toolbox talks. The literature review confirmed that inadequate H&S competencies, HIRA, and toolbox talks leads to trench excavation fatalities and injuries. 2 / 6 (33.3%) MSs are $> 2.60 \leq 3.40$, which indicates that the concurrence is between disagree to neutral / neutral. Notably, the two statements relate to SWPs.

Table 1. The extent to which factors contribute to excavation incidents on construction sites

Factor	Response (%)						MS	Rank
	Un- sure	Minor Major						
		1	2	3	4	5		
Inadequate excavation H&S knowledge	3.7	3.7	0.0	14.8	11.1	66.7	4.48	1
Poor H&S culture	0.0	0.0	7.4	3.7	25.9	63.0	4.44	2
Inadequate inspections	0.0	3.7	11.1	3.7	18.5	63.0	4.26	3
Incompetent site management	0.0	0.0	3.7	18.5	33.3	44.4	4.19	4
Inadequate shoring	7.4	3.7	11.1	14.8	14.8	48.2	4.15	5
Inadequate hazard identification and risk assessments	0.0	7.4	7.4	7.4	18.5	59.3	4.15	6
Inadequate supervision	0.0	3.7	7.4	11.1	29.6	48.2	4.11	7
Lack of safe working procedures	0.0	7.7	3.9	15.4	26.9	46.2	4.00	8
Excavated material piled on the edges of the excavation	0.0	3.7	11.1	11.1	29.6	44.4	4.00	9
Poor organisational culture	0.0	7.4	11.1	18.5	25.9	37.0	3.74	10

Table 2. The extent to which the respondents agree with statements relating to trench excavation projects

Statement	Response (%)						MS
	Unsure	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
Supervision during trench excavation operations is inadequate	0.0	3.7	0.0	18.5	37.0	40.7	4.11
Site management lack excavation and H&S competencies	0.0	0.0	8.0	12.0	44.0	36.0	4.08
Employees are not trained to identify the hazards and risks associated with excavation work	0.0	3.7	7.4	0.0	63.0	25.9	4.00
Excavation and H&S toolbox talks are not effectively communicated to all employees	0.0	7.4	14.8	22.2	29.6	25.9	3.52
Excavation safe work procedures are not developed by competent H&S personnel	0.0	11.1	22.2	18.5	25.9	22.2	3.26
Excavation safe work procedures are not communicated to employees	0.0	11.1	29.6	18.5	14.8	25.9	3.15

Table 3 indicates the importance of excavation HIRAs relative to six hazards in terms of percentage responses to a scale of 1 (not) to 5 (very), and MSs ranging between 1.00 and 5.00. Notably, all the MSs are above the midpoint score of 3.00, which indicates that in general, the respondents perceive that excavation HIRAs are more than important instead of less than important in mitigating the hazards. However, it is notable that 5 / 6 (83.3%) of the MSs are >

4.20 $\leq$ 5.00, which indicates that excavation HIRAs relative to these hazards is between more than important to very / very important - likely adjacent plant and equipment, existing services, access to / exit from the excavation, type of soil, and excavated material. The literature review confirmed that the type of soil, excavated material piled at the edges of the excavation, and excavation method contribute to a high percentage of trench excavation incidents (OSHA, 2015). Only 1 / 6 (16.7%) MS is $> 3.40 \leq 4.20$, which indicates that the importance of excavation HIRA relative to groundwater table is between important to more than important / more than important.

Table 3. The importance of excavation hazard identification and risk assessments

Hazard	Response (%)						MS	Rank
	Un-sure	Not Very						
		1	2	3	4	5		
Likely adjacent plant and equipment	0.0	0.0	0.0	11.1	18.5	70.3	4.59	1
Existing services	0.0	0.0	7.4	3.7	11.1	77.8	4.59	2
Access to / exit from the excavation	0.0	0.0	7.4	3.7	14.8	74.0	4.56	3
Type of soil	0.0	0.0	3.7	11.1	18.5	66.7	4.48	4
Excavated material	0.0	0.0	7.4	7.4	22.2	63.0	4.41	5
Groundwater table	0.0	3.7	11.1	18.5	7.4	59.3	4.07	6

Table 4 indicates the extent to which aspects are addressed during the inspection of excavations in terms of percentage responses to a scale of 1 (minor) to 5 (major), and MSs ranging between 1.00 and 5.00.

Table 4. The extent to which aspects are addressed during the inspection of excavations

Aspect	Response (%)						MS	Rank
	Un-sure	Minor Major						
		1	2	3	4	5		
Existing underground services	3.7	7.4	11.1	11.1	33.3	33.3	3.85	1
Personal protective equipment	0.0	3.7	11.1	18.5	29.6	37.0	3.85	2
Ground stability	3.7	0.0	18.5	18.5	33.3	25.9	3.78	3
Means of access and exit	0.0	7.4	29.6	3.7	25.9	33.3	3.48	4
Excavated material close to the excavation	0.0	7.4	14.8	29.6	22.2	25.9	3.44	5
Weather conditions	3.7	7.4	18.5	22.2	29.6	18.5	3.44	6
Type of soil	3.9	3.9	26.9	19.2	30.8	15.4	3.38	7
Tightness of the bracing and shoring	7.4	18.5	14.8	18.5	18.5	22.2	3.33	8
Equipment moving or standing close to excavations	3.7	3.7	33.3	14.8	25.9	18.5	3.33	9
Protection of the edges of excavations	3.7	11.1	25.9	14.8	22.2	22.2	3.30	10
Presence of soil cracks	3.7	7.4	33.3	7.4	33.3	14.8	3.26	11

Notably, all the MSs are above the midpoint score of 3.00, which indicates that in general the aspects can be deemed addressed during the inspection of excavations. However, it is notable that 6 / 11 (54.5%) MSs are $> 3.40 \leq 4.20$, which indicates that aspects can be deemed to be addressed between some extent to a near major / near major extent - existing underground services, personal protective equipment, and ground stability predominate, followed by means of access and exit, excavated material close to the excavation, and weather conditions. The remaining 5 / 11 (45.5%) MSs are $> 2.60 \leq 3.40$, which indicates the aspects can be deemed to be addressed between a near minor extent to some extent / some extent - type of soil, tightness of the bracing and shoring, equipment moving or standing close to excavations, protection of the edges of excavations, and presence of soil cracks. These are notable findings as type of soil, bracing and shoring, equipment moving or standing close to excavations, and presence of soil cracks are key issues relative to excavation H&S, especially the latter, presence of soil cracks, which is a key indicator of a pending collapse, and which is ranked last (OSHA, 2015).

Table 5 indicates the impact of trench collapses in the construction industry in terms of percentage responses to a scale of 1 (minor) to 5 (major), and MSs ranging between 1.00 and 5.00. It is notable that all the MSs are above the midpoint score of 3.00, which indicates that in general, the respondents perceive that trench collapses have a major, as opposed to a minor impact in the construction industry. However, it is notable that all six MSs are $> 3.40 \leq 4.20$, which indicates that the impact is between some extent to a near major / near major extent.

Table 5. The impact of trench collapses in the construction industry

Impact	Response (%)						MS	Rank
	Un-sure	Minor Major						
		1	2	3	4	5		
Fatalities	3.7	7.4	7.4	11.1	25.9	44.4	4.04	1
Injuries other than fatalities	3.7	7.4	7.4	11.1	40.7	29.6	3.89	2
Rework	3.7	7.4	7.4	18.5	29.6	33.3	3.85	3
Cost escalation / overruns	3.7	3.7	11.1	25.9	25.9	29.6	3.78	4
Project delays	3.7	7.4	3.7	29.6	29.6	25.9	3.74	5
Poor productivity	3.7	11.1	7.4	11.1	44.4	22.2	3.70	6

Fatalities is ranked first, followed by injuries other than fatalities, which indicates the human impact. This is followed by the opposite of synergy in the form of the negative impact in terms of rework, financial loss, delays, and poor productivity. According to Othman (2012), accidents can marginalise the project team's efforts at achieving the project deliverables on time and within budget, due to the direct and indirect costs associated with accidents.

5 Conclusions

In terms of the extent to which factors contribute to excavation incidents on construction sites, the findings lead to the conclusion that a cocktail of interventions are necessary to mitigate such incidents, namely both optimum organisation and H&S culture; competent site management and supervision, excavation H&S knowledge, optimum excavation HIRA,

adequate shoring, safe working procedures and the following thereof, and the positioning of excavated material away from the edges of excavations. Furthermore, the potential exists to reduce the number of excavation-related fatalities and injuries.

Given the extent to which the respondents agree with statements relating to trench excavation projects, it can be concluded that there is a need for: enhanced supervision during trench excavation operations; enhanced site management excavation H&S knowledge; training of supervisors and workers in terms of excavation HIRA; more effective excavation H&S toolbox talks, and development of SWPs by competent people and the communication and implementation thereof to supervisors and workers.

Given the importance of excavation HIRA relative to a range of excavation-related hazards, it can be concluded that excavation HIRA training, excavation H&S toolbox talks, empowerment of workers in terms of excavation H&S, and constant management and supervision of excavations are critical.

Given the extent to which aspects are addressed during the inspection of excavations, and especially the key aspects, it can be concluded that such inspections are not effective, the knowledge of inspectors is inadequate, and the potential of excavation-related incidents is heightened.

In terms of the impact of trench collapses in the construction industry, it can be concluded that trench collapses have a major as opposed to a minor impact in the construction industry. Furthermore, they impact negatively on the other project parameters in the form of cost, productivity, quality, and time, which constitutes a motivator for investing in and realising optimum excavation H&S.

6 Recommendations

An appropriate excavation H&S qualification and training should be developed and registered in terms of the National Qualifications Framework Act, 2000. Furthermore, the term competent person must be elaborated upon relative to activities such as excavation H&S. A national excavation H&S guideline should be developed by the umbrella employer associations, or the Construction Industry Development Board.

Employer associations should raise the level of awareness concerning excavation H&S, especially the hazards, and appropriate interventions. Excavation H&S-related training in the form of induction, toolbox talks, and excavation HIRA are critical. Furthermore, workers must be empowered through HIRA training to be vigilant and to conduct continuous HIRA while working in excavations.

Excavation H&S inspections must be comprehensive, which implies competent management, and supervision.

Financial provision for excavation H&S, in tandem with H&S in general, should be facilitated in contract documentation, and especially in bills of quantities. Contractors should conduct detailed cost-benefit and cost of accidents analyses relative to excavations, which will enable them to motivate appropriate actions by their staff, and which can serve as case studies.

7 References

- Druley, K. (2018), Trenching and excavation safety. *Safety + Health*. Available from: <https://www.safetyandhealthmagazine.com/articles/print/17490-trenching-and-excavation-safety> [Accessed 6 June 2021].
- Health and Safety Executive (HSE) (2006), *Health and safety in construction*. 3rd Edition. Norwich: HSE Books.
- Johnson, A. (2011), Pre-planning and protective systems can help prevent excavation incidents. *Safety + Health*. Available from: <http://www.safetyandhealthmagazine.com/articles/safety-in-the-trenches-4>. [Accessed 26 May 2018].
- Myer, D. (2005), Trench deaths – can they be avoided? National Safety and Occupational Hygiene, May / June, 5-7.
- Occupational Safety and Health Administration (OSHA) (2015), *Trenching and Excavation Safety*. Washington D.C.: OSHA.
- Othman, A.A.E. (2012), A study of the causes and effects of contractors' non-compliance with the health and safety regulations in the South African construction industry. *Architectural Engineering and Design Management*, 8(3), 180-191.
- Phoenix Tabloid (2015), Construction workers rescued after trench collapses. *Phoenix Tabloid*, 4 August, 5.
- Republic of South Africa (RSA) (1993), *Occupational Health and Safety Act No. 85 of 1993*. Pretoria.
- Republic of South Africa (2014), *No. R. 84 Occupational Health and Safety Act, 1993 Construction Regulations 2014*. Government Gazette No. 37305. Pretoria.
- Ruttenberg, R. Schneider, S. and Obando, M. (2019), *Recent Trenching Fatalities: Causes and Ways to Reduce Them*. Silver Spring: The Center for Construction Research and Training (CPWR).
- Singh, K. (2016), Man killed in Knysna trench collapse. *News 24*, Available from: <http://www.news24.com/SouthAfrica/News/mankilledinknysnatrenchcollapse20160329> [Accessed 02 February 2017].
- Smallwood, J.J. (2010), Excavation health and safety (H&S): a South African perspective. In: Egbu, C. (Ed.) *Proceedings 26th Annual Association of Researchers in Construction Management (ARCOM) Conference*, Leeds, United Kingdom, 6-8 September, 233-241.
- South African Bureau of Standards (SABS) (1989), *Standardized specification for civil engineering construction, DB: earthworks (pipe trenches)*. Pretoria: SABS.
- Wilson, G. (2019), Death probe delays pipe-burst fix, *The Herald*, 31 July, 4.