EXCAVATION HEALTH AND SAFETY (H&S): A SOUTH AFRICAN PERSPECTIVE

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A range of H&S hazards exist relative to excavations. Furthermore, excavations occur in the elements and are exposed to a range of non-activity influences such as passing vehicles. Excavations also impact on the stability of adjacent structures and buildings, and temporary plant. International research indicates the primary barriers to excavation H&S to be: casual attitude; failure to provide trench protection; lack of daily inspections by competent persons; lack of training; inadequate enforcement, and costs. The paper reports on a study conducted among excavation H&S seminar delegates using a structured questionnaire. Selected findings include: barricading is ranked first in terms of the frequency interventions are undertaken relative to excavations, and scientific design of shoring last; relative to excavations the South African construction industry is rated below average relative to geo-technical reports, training, education, design of shoring, and culture; the South African construction industry is rated marginally below average in terms of excavation H&S, time pressure predominates in terms of barriers to excavation H&S; excavation H&S requires a multi-stakeholder effort, and excavation H&S training predominates in terms of the extent interventions could contribute to an improvement in excavation H&S. Conclusions include: a scientific approach is not adopted relative to excavation H&S; a multi-stakeholder effort is required, and education and training is a pre-requisite for improving excavation H&S.

Keywords: excavations, health and safety.

INTRODUCTION

Exacavation is one of the most hazardous construction activities (Myer, 2008), and historically, excavation accidents have featured prominently 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 (Myer, 2005). A further four out of a total of six workers caught in a six-metre deep trench collapse in Randburg, Gauteng Province, lost their lives in May 2005 (Myer, 2005). Thereafter, van Jaarsveld (2008) reports on the death of two female construction workers who were killed when the three-metre deep trench they were working in at Mandlankala in the Kwazulu-Natal Province collapsed – three male workers survived the collapse.

Despite the prominence of excavation accidents and related injuries, it is not possible to determine the contribution thereof to the total number of fatalities and injuries in South Africa, and generally, for that matter internationally. However, according to the Health and Safety Executive (HSE) (2008) fatal accidents associated with excavations

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Smallwood, J J (2010) Excavation health and safety (H&S): a South African perspective. *In:* Egbu, C. (Ed) *Procs 26th Annual ARCOM Conference,* 6-8 September 2010, Leeds, UK, Association of Researchers in Construction Management, 233-241.

contributed 14% of reported fatalities due to demolition / collapse from April 1997 to March 2008 in the UK.

The April issue of SA Builder (Van Vuuren, 2009) reports that Colin de Kock, the Executive Director of the Gauteng Master Builders Association (GMBA) in South Africa, says many building contractors are still implementing low levels of H&S standards. Two months later, the Construction Industry Development Board (cidb) (2009) report entitled 'Construction Health and Safety in South Africa Status and Recommendations' reports that construction has the third highest fatality rate and the ninth highest permanent disability rate per 100 000 full-time equivalent workers out of twenty-three industries.

The frequency of excavation accidents and the number of related fatalities and injuries engendered the research reported on in this paper. Accordingly, the research investigated the: importance of H&S to respondents' organizations and to all contractors; extent to which excavation interventions are taken; performance of the construction industry relative to various excavation aspects; extent to which aspects constitute barriers to H&S, and extent to which interventions could contribute to an improvement in H&S.

REVIEW OF THE LITERATURE

Excavation H&S

Hughes and Ferret (2007) contend that many excavations collapse without warning resulting in serious fatalities, and such accidents occur in shallow working areas. Excavation operations are mostly dependent on soil characteristics. Soil properties include weight, density, modulus of elasticity, internal resistance, internal friction, cohesion, and volume changes from various causes that in turn affect bulk materials such as grains, granular materials, sand, and clay, which forms a slope (angle of repose) along their sides when they are piled up (Brauer, 2006). According to Kwong (2001), between 1990 and 1999, eight fatalities associated with trench excavations were recorded in Hong Kong. Most of the ninety-seven accidents that led to the death of eight workers were caused by trench collapses and trench-induced slope failures due to inadequate contract specifications for trench excavations and / or non-compliance with specified works requirements.

In addition, improper drainage that leads to the accumulation of water, which reduces strength of shoring, inadequate barriers around excavations, and improper access and egress facilities may result in accidents and possible fatalities (Brauer, 2006). Therefore, during excavations the following hazards must be noted and addressed appropriately (Hughes and Ferrett, 2007).

- collapse of the sides;
- materials falling on workers in the excavations;
- falls of people and / or vehicles into the excavation;
- workers being struck by plant;
- specialist equipment such as pneumatic drills;
- hazardous substances particularly near the site of current or former industrial processes;
- influx of ground or surface water and entrapment in silt or mud;
- proximity of stored materials, waste materials or plant;
- proximity of adjacent building or structures and their stability;
- contact with underground services;

- access and egress to the excavation;
- fumes, lack of oxygen and other health hazards such as manual handling, electricity, noise and vibration.

It follows that control mechanisms must be in place whenever excavation operations are taking place. The precautionary and control measures suggested by Hughes and Ferret (2007) include.

- at all stages of the excavation, a competent person must supervise the work and workers must be given clear instructions regarding working safely in the excavation;
- the sides of the excavation must be prevented from collapsing, either by battering digging them at a safe angle or by shoring them up with timber, sheeting, a proprietary support system, and not storing spoil material near the top of the excavation;
- workers should wear appropriate personal protect equipment (PPE);
- if the excavation is greater than 2m, a substantial barrier, consisting of guardrails and toe boards should be provided around the working areas;
- vehicles should be kept as far away as possible using warning signs and barriers;
- adequate lighting should be provided at nights;
- buried services should be located and appropriately handled, and
- safe access and egress should be provided to and from the excavation.

Careful approach to excavation operation alone is not a prerequisite for an incident / or accident free operation on construction sites. According to Behm (2005), reduction or elimination of the frequency of construction injuries and fatalities that occur due to falls from height can be achieved through the utilization of the design for construction H&S concept. In other words, a holistic approach to excavation H&S is required for continuous improvement, that is, designers, contractors, and workers involvement is required for safe excavation operations. It follows that excavation H&S requires the contributions of both workers and management in order to address human errors that may lead to fatalities.

Legislation

The South African Construction Regulations (Republic of South Africa, 2003) require a range of interventions relative to clients, designers, and contractors.

Clients are required to provide the principal contractor with an H&S specification and any information that may affect H&S, ensure that principal contractors have made adequate allowance for H&S, and discuss the contents and approve the H&S plan. Designers are required to provide the client with all relevant information about the design, which will affect the pricing of the works, inform the contractor of any known or anticipated dangers or hazards, provide the contractor with a geo-science technical report, and the methods and sequence of construction, and modify the design where dangerous procedures would be necessary, or substitute hazardous materials.

Contractors are required to: ensure excavation work is supervised by a competent person who has been appointed in writing, and evaluate, as far as is reasonably practicable, the stability of the ground before commencing excavation work. They are also required to: take suitable and sufficient steps to prevent, as far as is reasonably practicable, any person from being buried or trapped; not require or permit any person to work in an excavation which has not been adequately shored or braced – provided that shoring or bracing may not be necessary; ensure that the shoring or bracing is designed and constructed in such a manner rendering it strong enough to support the sides of the excavation, and ascertain as far as is reasonably practicable the location and nature of electricity, water, gas or other similar services.

Although the Construction Regulations indicate what should be done, they do not provide guidance on how to assess excavation risks. Furthermore, there is no South African excavation H&S standard or guidelines available as in Australia, Canada, New Zealand, the UK, and the USA (Myer, 2008).

Barriers to excavation H&S

296 Summaries of OSHA fatality investigations in the USA for the period 1997-2001 (Arboleda and Abraham, 2004 in Plog, Materna, Vannoy, and Gillen, 2006) determined that in 94% of cave-ins, no protective systems were in place.

Based upon 44 case files from OSHA inspections of fatal trench collapses in the USA during the period 1997-99 (Deatherage *et al.*, 2004 in Plog, Materna, Vannoy, and Gillen, 2006) were attributable to: failure to provide trench protection (66%); lack of daily inspections by competent person (52%), and no training provided (52%). Other contributing conditions were: spoil pile within 610mm of edge (41%), and rain / standing water (34%).

In 2003, 53 trenching and excavation fatalities were reported to OSHA in the USA (Pachico, 2004). 62 % of the deceased had received no trench safety training, and 50% of them had worked for their employer less than one year. Additional statistics from the fatality case files show that 75% of the reported trench-related deaths were caused by trench cave-ins where no protective devices or practices were used.

Plog, Materna, Vannoy, and Gillen (2006) conducted 34 interviews in the USA to identify barriers to excavation H&S. The five categories of barriers include attitude, lack of training, insufficient enforcement, costs, and general. Relative to attitude, they identified casual attitude on the part of employers and workers, that workers believe a cave-in will not happen to them and are consequently willing to enter an unprotected trench, and that workers also believe that a cave-in can be outrun. Lack of training includes lack of training per se, lack of appropriate training for competent persons and workers, lack of training in preferred language, and the inexperience and ignorance of contractors regarding trenching hazards. Insufficient enforcement relates to failure of the OSHA inspectorate to ensure compliance. Costs in the form of the cost of trenching equipment – transportation, installation, and storage are excessive, and then competitive bidding, which results in the marginalization of adequate budgeting for excavation H&S. General includes: overly complicated regulations; lack of certification or a training standard for competent-person training providers, and workers' compensation insurance systems for not providing adequate financial incentives for employers to create exemplary H&S programmes, and also for not holding employers financially responsible for unsafe conditions resulting in serious injury or death, for instance, through substantially higher premiums.

According to Lew and Thompson (1997) poor trenching practices include: no plan; not ordering the necessary materials; untrained workers; untrained 'competent' person; trenching ahead of supports; working outside or supports or trench box, and installing supports from the bottom.

Improving excavation H&S

The interviews conducted in the USA by Plog, Materna, Vannoy, and Gillen (2006) to identify barriers to excavation H&S, also indentified the interventions to achieve excavation H&S. There are three categories of interventions, namely training and outreach, regulatory action, and technology improvements. Training and outreach includes: training of management, supervisors, and workers; addressing the OSHA excavation standard; focusing on the reasons for using protective equipment, and providing information regarding trench shielding methods. Regulatory action includes: increasing OSHA fines; increasing enforcement of the OSHA multi-employer citation policy; mandating certification of competent person trainers; prosecuting wilful offenders; making protective systems a bid item per lineal foot, and linking revocation of contractor licenses to OSHA trenching violations. Technology improvements include developing lighter-weight shielding that would help reduce the cost of transporting and installing

The role of H&S culture in H&S performance has been documented by Krause (1993) who postulated the upstream → downstream sequence. Culture occurs upstream of management system, which occurs upstream of exposure, which occurs upstream of incidents. In terms of culture relative to excavation H&S, Lew and Thompson (1997) advocate: total commitment to trench H&S and the elimination of trench deaths; the belief that trench cave-ins are not accidental; the belief that trench cave-ins are preventable; team work to evolve sensible solutions, and appointment of a competent person. Lew and Thompson (1997) also advocate certain design, procurement, and construction interventions: the provision of geo-technical information; pre-tender site inspections; the provision of pre-tender trench H&S plans and H&S plans; the review of pre-tender trench H&S plans and H&S plans; pre-construction discussions and approval of trench H&S plans and H&S plans and review of financial provision for trench H&S; trench H&S inspections, and the revision of trench H&S plans and H&S plans.

RESEARCH

Methodology and sample stratum

The sample stratum consisted of 150 delegates attending six excavation H&S seminars in various centres in South Africa. Therefore, the sample stratum can be deemed to be a captive sample. The questionnaire consisted of eight close-ended questions, and seventy sub-questions, followed by a question requesting comments in general. To avoid the possible influence of delegates, delegates were required to complete the questionnaires before the commencement of the seminar. Furthermore, the respondents are likely to constitute the more committed in terms of H&S given that they were sponsored by their organizations to attend a specialist seminar in the form of excavation H&S. However, this is likely to have resulted in findings that can be deemed reliable.

Findings

Table 1 indicates the extent to which thirteen interventions are taken. It is notable that all the interventions have MSs above the midpoint score of 3.00, which indicates that in general they can be deemed to be taken. It is notable that none of the documents / interventions have mean scores $> 4.20 \leq 5.00$, which equates to a frequency between often to always / always. However, the top ten of the twelve interventions have MSs $> 3.40 \leq 4.20$, which indicates that the interventions can be deemed to be taken between sometimes to often / often. The remaining three interventions, which have MSs > 2.60

Table 1: The extent to which interventions are taken

Intervention	Response (%)							
	Unsure	**Never**	**Rarely**	**Sometimes**	**Often**	**Always**	**MS**	**Rank**
Barricading	1.3	2.7	4.7	12.8	31.5	47.0	4.17	1
Inclusion of excavation section in the H&S plan	8.2	2.0	5.4	16.3	24.5	43.5	4.11	2
Inclusion of excavation section in the H&S specification	7.5	2.7	6.1	17.7	21.8	44.2	4.07	3
Adequate access	2.0	1.4	8.8	22.3	26.4	39.2	3.95	4
Location of services prior to project	4.0	2.0	12.1	17.4	23.5	40.9	3.93	5
Contractor inspections as per the Construction Regulations	5.4	4.1	10.8	20.3	25.0	34.5	3.79	6
Adequate support of services	4.1	2.0	11.6	24.5	25.9	32.0	3.77	7
Excavation toolbox talks	4.7	6.0	12.0	17.3	27.3	32.7	3.72	8
Goe-technical report	14.2	6.8	17.6	18.2	18.2	25.0	3.43	9
Shoring when required	6.8	5.4	17.7	24.5	22.4	23.1	3.43	10
Appointment of a certified excavation competent person	5.3	16.7	16.7	15.3	11.3	34.7	3.32	11
Review of financial provision for excavation H&S	14.7	12.0	27.3	12.0	14.7	19.3	3.02	12
Scientific design of shoring	12.8	18.9	24.3	15.5	12.2	16.2	2.80	13

≤ 3.40 can be deemed to be taken between rarely to sometimes / sometimes. Given that scientific design of shoring is a pre-requisite for assuring excavation H&S, particularly deep excavations, it is notable that it is ranked last.

Table 2 presents the rating of the South African construction industry relative to thirteen excavation H&S aspects. It is notable that five of the thirteen aspects have MSs ≤ 3.00, which indicates that relative to these aspects the South African construction industry can be deemed to be rated below average. Notable aspects include: geo-technical reports, the provision of which is a requirement in terms of the.

Construction Regulations; training and education, which are important in terms of managing, supervising, and undertaking excavations, design of shoring which is a requirement, particularly with respect to deep excavations, and culture, which occurs upstream of management system, exposure, and incidents. It is also notable that only barricading has a MS > 3.40 ≤ 4.20, which indicates it can be deemed to be rated between average to good / good. Given that the MSs of the remaining twelve aspects are > 2.60 ≤ 3.40, the aspects can be deemed to be rated between poor to average / average.

Respondents were required to rate the South African construction industry in terms of excavation H&S. The resultant MS of 2.93 equates to a rating of poor to average / average.

Table 3 indicates the extent to which aspects constitute barriers to excavation H&S. All ten of the aspects have MSs > 3.00, and thus can be deemed to constitute barriers to excavation H&S. Time pressure is frequently cited as a barrier to H&S in general. The cost of equipment is added to by storage, and transport costs. Insufficient enforcement is often cited as a reason for poor H&S performance in general. Supervisor attitude and management attitude are important as it relates to culture, and if inappropriate, negatively affects excavation H&S. Inadequate supervision is a barrier as excavations require constant monitoring. Ignorance, in the form of perceptions such as 'collapses can be outrun', result in unsafe conditions and acts. Planning is critical relative to construction in general, but certainly excavation H&S, therefore inadequate planning constitutes a barrier. Lack of training is a barrier as workers need to be aware of the related hazards and risks, and be empowered to work in a healthy and safe manner. Worker attitude also relates to culture, and can be linked to ignorance.

Table 2: Rating of the South African construction industry relative to various excavation H&S aspects

Aspect	**Response (%)**						**MS**	**Rank**
	Unsure	**Very poor ……………………………Very good**						
		1	**2**	**3**	**4**	**5**		
Barricading	2.0	2.7	14.8	31.5	30.2	18.8	3.49	1
Contractor inspections	4.7	4.7	14.9	35.8	25.7	14.2	3.31	2
'Managing' existing services	3.4	1.4	19.0	36.7	29.9	9.5	3.28	3
Access	3.4	3.4	21.1	35.4	25.9	10.9	3.20	4
Pre-planning	4.9	3.5	25.7	31.9	19.4	14.6	3.17	5
Technology	11.6	6.8	20.5	31.5	17.1	12.3	3.09	6
Awareness	2.1	2.8	30.6	33.3	21.5	9.7	3.05	7
Enforcement of legislation	6.0	12.1	20.1	25.5	25.5	10.7	3.03	8
Geo-technical reports	12.4	10.3	23.4	23.4	19.3	11.0	2.97	9
Training	2.1	9.6	32.2	35.6	11.6	8.9	2.78	10
Education	2.0	12.2	28.4	36.5	12.2	8.8	2.77	11
Design of shoring	12.8	13.5	28.4	22.3	12.2	10.8	2.75	12
Culture	11.0	7.5	32.2	34.9	10.3	4.1	2.68	13

Table 4 indicates the extent to which fourteen interventions could contribute to an improvement in excavation H&S in terms of percentage responses to a scale of 1 (minor) to 5 (major) and a MS between 1.00 and 5.00. It is notable that all the MSs are > 3.00, which indicates that in general all the interventions can be deemed to be able.

Table 3: Extent to which aspects constitute barriers to excavation H&S

Aspect	**Response (%)**						**MS**	**Rank**
	Unsure	**Minor …………………………………… Major**						
		1	**2**	**3**	**4**	**5**		
Time pressure	2.0	0.7	9.4	21.5	24.8	41.6	3.99	1
Costs	7.5	2.7	12.9	21.1	29.9	25.9	3.68	3
Insufficient enforcement	1.4	3.4	9.5	25.7	36.5	23.6	3.68	2
Supervisor attitude	1.4	2.7	11.5	30.4	31.8	22.3	3.60	4
Management attitude	4.7	3.4	12.2	23.6	37.8	18.2	3.58	5
Inadequate supervision	2.0	4.7	12.8	28.2	28.9	23.5	3.55	6
Ignorance	3.4	6.8	17.7	17.7	29.3	25.2	3.50	7
Inadequate planning	3.4	4.8	12.2	29.3	31.3	19.0	3.49	8
Lack of training	1.4	6.8	19.0	21.8	23.8	27.2	3.46	9
Worker attitude	0.7	5.4	23.5	28.9	26.8	14.8	3.22	10

to contribute to an improvement in excavation H&S. Ten of the fourteen interventions have MSs > 4.20 ≤ 5.00, which indicates that the extent to which the interventions could contribute to an improvement in excavation H&S is between near major to major / major. These include: excavation H&S training; H&S training; certified excavation competent persons; increased enforcement; excavation H&S guidelines;

optimum supervision, pre-planning, and H&S culture; scientific design of shoring, and tertiary excavation H&S education. It is notable that although lack of training was ranked ninth in terms of the extent to which ten aspects constitute barriers to excavation H&S, excavation H&S training and H&S training are ranked first and second respectively in terms of the extent to which interventions could contribute to an improvement in excavation H&S.

Table 5: Extent to which interventions could contribute to an improvement in excavation H&S

	Response (%)							
		Minor				Major		
Interventions	**Unsure**	**1**	**2**	**3**	**4**	**5**	**MS**	**Rank**
Excavation H&S training	0.7	0.0	3.4	8.2	23.8	63.9	4.49	1
H&S training	0.7	0.0	1.3	10.7	30.0	57.3	4.44	2
Certified excavation competent persons	1.4	0.0	3.4	11.6	25.2	58.5	4.41	3
Increased enforcement	1.4	0.0	2.7	10.1	31.1	54.7	4.40	4
Excavation H&S guidelines	1.3	0.0	2.7	12.8	26.8	56.4	4.39	5
Optimum supervision	0.7	0.7	4.0	10.7	32.7	51.3	4.31	6
Optimum pre-planning	2.7	0.7	2.7	12.2	33.1	48.6	4.30	7
Optimum H&S culture	6.1	0.7	1.4	15.0	32.0	44.9	4.27	8
Scientific design of shoring	9.3	1.3	2.0	12.0	32.7	42.7	4.25	9
Tertiary excavation H&S education	2.0	2.0	3.4	15.5	27.7	49.3	4.21	10
Focus on financial provision for excavation H&S during bidding	5.4	2.7	3.4	14.9	27.0	46.6	4.18	1
Enhanced technology	10.1	0.7	4.7	13.5	30.4	40.5	4.17	12
Tertiary H&S education	2.7	2.1	4.1	21.9	29.5	39.7	4.04	13
Optimum project duration	10.9	2.7	2.7	17.0	35.4	31.3	4.01	14

CONCLUSIONS

In general, the South African construction industry is rated marginally below average in terms of excavation H&S overall. However, in terms of certain excavation related aspects, it is rated below average, notably critical aspects such as culture, education, training, design of shoring, and although marginally so, geo-technical reports.

Therefore, it can be concluded that an excavation related environment that is conducive to the occurrence of incidents is being engendered by the respective stakeholders involved with construction, in particular, contractors.

The extent to which various aspects constitute a barrier to excavation H&S amplifies the role of all project stakeholders in excavation H&S. Time pressure and costs implicates clients, project managers, designers, and quantity surveyors. Insufficient enforcement implicates the H&S inspectorate. Supervisor, management, and worker attitude, inadequate supervision, inadequate planning, and lack of training implicate contractors. Furthermore, the degree of concurrence with the statement ‘Excavation H&S requires a multi-stakeholder effort’ reinforces this conclusion. However, these findings result in further conclusions, namely that there is a lack of understanding and appreciation for what is required to realize compliance relative to excavation H&S,

there is a lack of leadership in the industry across all project stakeholders, and that the underlying reason is a lack of awareness and knowledge.

The extent to which interventions could contribute to an improvement in excavation H&S underscores the low rating of the South African construction industry relative to excavation H&S overall, and in terms of various excavation H&S related aspects. Therefore, it can be concluded that all stakeholders can contribute to an improvement, provided that they have the requisite leadership and that they are empowered to do so.

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