

# The Role of a Design Engineer in Safety of Building Projects

by

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at Stellenbosch University*

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## ABSTRACT

One of the causes for money to be wasted on construction sites is accidents. The reason is that an accident on site is an unplanned event typically relating to the loss of production or the loss of life. Many industry stakeholders and role players have focused on construction health and safety and to improve this area of concern; however, construction health and safety are not significantly improving. Construction still continues to contribute a large number of fatalities and injuries relative to other industry sectors. During the construction phase, poor construction health and safety performance is attributable to a lack of management commitment, inadequate supervision, and a lack of health and safety training and - systems. Health and safety systems do not only include excellent health and safety management on site, but rather an integrated approach on health and safety issues from the conceptual design phase by all stakeholders participating. This integrated approach includes the design done by the engineer.

The inspiration behind this research is the question of whether South African Engineers design buildings safe for construction. The lack of knowledge by engineers with regard to construction processes, the lack of health and safety enforcement in the engineering offices and construction sites, and whether engineers adhere to safe design principles is the subject of investigation in this research.

Therefore, this research aims to investigate the role of the design engineer in the safety of building projects. Specifically, it investigates to what extent the design engineer can contribute to site safety, and to what extent this is actually taking place. The Construction Regulations states the engineer can be appointed to act on behalf of a client and should share any information that might affect the health and safety of construction employees with the contractor.

By means of a literature study, the investigation of case studies and the investigation of questionnaires to which a percentage of South African engineers responded, this research identified the information that should be shared by the design engineer with the contractor. The information can be shared by indicating hazardous activities or - locations on the actual drawings. Information can also be shared by specifying and reminding the contractor of certain health and safety hazards in the health and safety specifications of the building project.

Although the Construction Regulations state that the safety hazards associated with most construction processes are the responsibility of the contractor, it will be beneficial for the safety of the employees if the engineer also consults the contractor on the hazards identified by him or her during the early design stages. Early collaboration between the engineer and contractor is also

beneficial for the safety of construction employees. The result is an integrated approach towards safety hazard identification and mitigation.

Having adequate knowledge with regard to construction processes allows the engineer to be aware of possible safety hazards. This will result in the correct information to be shared with the contractor and incorporated into the early design phases of the project to ensure a healthy and safe working environment.

The study shows that a percentage of South African engineers have a lack of site experience, a lack of safety training, a lack of knowledge with regard to the content of the Construction Regulations, and a lack of knowledge with regard to construction processes. These shortcomings can be detrimental to site safety.

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I trust that the thesis poses as a basis for more research to be done regarding employee safety on construction sites.

## LIST OF CONTENTS

<b>DECLARATION</b> .....	Error! Bookmark not defined.
<b>ABSTRACT</b> .....	<b>i</b>
<b>ACKNOWLEDGEMENTS</b> .....	<b>iv</b>
<b>LIST OF CONTENTS</b> .....	<b>v</b>
<b>LIST OF FIGURES</b> .....	<b>xii</b>
<b>LIST OF TABLES</b> .....	<b>xv</b>
<b>CHAPTER 1: GENERAL INTRODUCTION</b> .....	<b>1</b>
1.1 Introduction to Design .....	1
1.2 Identifying the Engineer as the Designer.....	2
1.2.1 Different procurement strategies associated with building construction.....	2
1.2.2 Contracting strategy associated with building construction .....	4
1.3 Design Reasonable Practicable .....	5
1.3.1 Risk assessment .....	6
1.3.2 The knowledge of the engineer about hazards and risks .....	6
1.4 Problem Statement.....	7
1.5 Scope of Investigation.....	8
1.6 Research Objectives.....	9
1.7 Research Hypotheses.....	9
1.8 Thesis Structure .....	10
<b>CHAPTER 2: RESEARCH METHODOLOGY</b> .....	<b>12</b>
2.1 Introduction on Research Methodology.....	12
2.2 Research Methodology Classification .....	12
2.2.1 Group 1: Descriptive - vs. Analytical Research.....	12
2.2.2 Group 2: Applied – vs. Fundamental Research.....	13

2.2.3	Group 3: Quantitative - vs. Qualitative Research .....	13
2.2.4	Group 4: Conceptual - vs. Empirical Research .....	13
2.3	Research Instruments .....	14
2.3.1	Questionnaires .....	14
2.3.2	Content Analysis .....	14
2.3.3	Observations .....	14
2.4	Theory Applied in this research .....	15
2.5	Objectives of Literature Study .....	16
2.6	Objectives of Case Studies .....	16
2.7	Objectives of Questionnaires .....	16
<b>CHAPTER 3: DESIGNING FOR SAFETY - LITERATURE STUDY .....</b>		<b>17</b>
3.1	Overview of Construction Health and Safety in South Africa .....	17
3.1.1	Statistics of construction site injuries in South Africa .....	17
3.1.2	International comparison of accident rates .....	19
3.2	Legislative Framework for Construction Health and Safety in South Africa .....	20
3.2.1	Primary legislation in South Africa .....	21
3.2.2	Unique characteristics and impacts of the Construction Regulations .....	21
3.2.3	Responsibilities according to the Construction Regulations .....	23
3.2.4	Secondary legislation in South Africa .....	24
3.3	Construction Site Hazards for Buildings .....	26
3.3.1	Demolition .....	26
3.3.2	Electrical works .....	27
3.3.3	Ergonomics .....	28
3.3.4	Excavation .....	28
3.3.5	Hazardous substances .....	29
3.3.6	Maintenance .....	30
3.3.7	Manual handling .....	31

3.3.8	Plant and equipment.....	31
3.3.9	Refurbishment .....	32
3.3.10	Steelwork .....	33
3.3.11	Utilities .....	33
3.3.12	Work done on roofs .....	34
3.3.13	Construction site hazards - conclusion .....	34
3.4	Proposed Safe Design Process .....	35
3.4.1	Discuss the project and project scope .....	36
3.4.2	Identify design team .....	36
3.4.3	Determine the means of communication.....	36
3.4.4	Prepare a risk identification and mitigation register .....	36
3.4.5	Provide an initial report to the client and contractor.....	38
3.4.6	Amend and finalise the design.....	39
3.4.7	Provide a final report to the client and contractor.....	39
3.4.8	Evaluation of the design.....	39
3.4.9	Benefits of a safe design process .....	39
3.5	Efficient Knowledge Exchange to Improve Constructability.....	39
3.5.1	Constructability during design .....	40
3.5.2	Constructability principles for design .....	41
3.5.3	Difference in constructability values .....	42
3.5.4	General information exchanged between the engineer and contractor.....	45
3.6	Summary of Literature Study.....	46
<b>CHAPTER 4: CONSTRUCTION SITE SAFETY – CASE STUDIES.....</b>		<b>51</b>
4.1	Reasons for selecting International Case Studies .....	51
4.2	Approach taken for Investigation of Case Studies.....	52
4.3	List of Primary Case Studies Investigated .....	53



4.4	Case Study 1: Labourer succumbs after falling from an elevated work platform during construction .....	53
4.4.1	Background .....	53
4.4.2	Case Study 1 Analysis .....	55
4.4.3	Lessons learned from Case Study 1 .....	56
4.5	Case Study 2: Construction employee succumbs after falling from a collapsed precast concrete slab.....	56
4.5.1	Background .....	56
4.5.2	Case Study 2 analysis .....	59
4.5.3	Lessons learned from Case Study 2 .....	62
4.6	Case Study 3: Construction employee struck by falling steel roof truss.....	62
4.6.1	Background .....	63
4.6.2	Case Study 3 analysis .....	64
4.6.3	Lessons learned from Case Study 3 .....	65
4.7	Case Study 4: Construction employee electrocuted when an extended ladder contacted an overhead power line .....	66
4.7.1	Background .....	66
4.7.2	Case Study 4 analysis .....	67
4.7.3	Lessons learned from Case Study 4 .....	68
4.8	Case Study 5: Demolition employee suffered a fatal accident from falling through a roof opening .....	68
4.8.1	Background .....	69
4.8.2	Case Study 5 analysis .....	69
4.8.3	Lessons learned from Case Study 5 .....	70
4.9	Case Study 6: Operator of equipment succumbed due to chimney falling on hydraulic excavator during demolition.....	70
4.9.1	Background .....	70
4.9.2	Case Study 6 analysis .....	71

4.9.3	Lessons learned from Case Study 6 .....	72
4.10	Case Study 7: Construction employee falls through insulation to concrete floor .....	72
4.10.1	Background .....	72
4.10.2	Case Study 7 analysis .....	73
4.10.3	Lessons learned from Case Study 7 .....	74
4.11	Case Study 8: Construction employee struck by falling wall formwork .....	75
4.11.1	Background .....	75
4.11.2	Case Study 8 Analysis .....	78
4.11.3	Lessons learned from Case Study 8 .....	80
4.12	Additional Case Studies.....	80
4.12.1	Summary of additional case studies .....	81
4.13	Case Studies: Lessons Learned and Conclusion .....	82
4.13.1	Lessons learned from primary case studies .....	82
4.13.2	Lessons learned from additional case studies .....	86
4.13.3	Contents included in a health and safety plan.....	87
4.13.4	Construction safety hazard prevention through design .....	89
4.13.5	Final thought .....	91
<b>CHAPTER 5: CONSTRUCTION SITE SAFETY - QUESTIONNAIRES .....</b>		<b>92</b>
5.1	Questionnaire Design.....	92
5.1.1	Reasons for deciding on electronic questionnaire.....	92
5.1.2	Technology used for electronic questionnaire design and distribution .....	93
5.2	Objectives of Questionnaire .....	94
5.2.1	Part 1: Personal Information.....	94
5.2.2	Part 2: Construction Employee Safety and Site Hazards .....	95
5.2.3	Part 3: Lessons Learned from Case Studies .....	96
5.2.4	Part 4: Information Exchanged between Engineer and Contractor .....	97
5.2.5	Part 5: Safe Design Process .....	97

5.3	Questionnaire Results .....	98
5.3.1	Part 1 Results: Personal Information (Columns B – K) .....	98
5.3.2	Part 2 Results: Construction Employee Safety and Site Hazards (Columns L – AA)....	103
5.3.3	Part 3 Results: Lessons Learned from Case Studies (Columns AB – AY) .....	125
5.3.4	Part 4: Information Exchanged between Engineer and Contractor (Columns AZ – BE) ... .....	130
5.3.5	Part 5: Safe Design process (Column BF) .....	132
5.4	Results from Questionnaires on Construction Site Safety - Conclusion .....	134
<b>CHAPTER 6: RECOMMENDED SAFE DESIGN PROCESS .....</b>		<b>135</b>
6.1	Introduction .....	135
6.2	Detailed Steps .....	135
6.2.1	Step 1: Conceptual design and hazard identification .....	136
6.2.2	Step 2: Provide a first report to the client .....	137
6.2.3	Step 3: Incorporate constructability principles into the design.....	138
6.2.4	Step 4: Incorporate safety into the design.....	139
6.2.5	Step 5: Provide the contractor with the health and safety specifications of the building project .....	141
6.2.6	Step 6: Provide final report to client.....	146
<b>CHAPTER 7: FINAL CONCLUSIONS .....</b>		<b>147</b>
7.1	Summary of Key Results and Findings .....	147
7.1.1	Designing for safety - literature study .....	147
7.1.2	Case studies on construction site safety.....	148
7.1.3	Questionnaires on construction site safety .....	149
7.2	General Conclusions.....	150
7.3	Future Research .....	153
<b>REFERENCES .....</b>		<b>153</b>
<b>APPENDIX A: INVITATION LETTER FOR QUESTIONNAIRE.....</b>		<b>157</b>

<b>APPENDIX B: COVER LETTER FOR QUESTIONNAIRE.....</b>	<b>159</b>
<b>APPENDIX C: QUESTIONNAIRE.....</b>	<b>161</b>
<b>APPENDIX D: QUESTIONNAIRE RESULTS SPREADSHEET .....</b>	<b>169</b>
<b>APPENDIX E: RESULTS TO PART 3 OF QUESTIONNAIRE .....</b>	<b>182</b>
<b>APPENDIX F: RESULTS TO PART 4 OF QUESTIONNAIRE .....</b>	<b>195</b>

## LIST OF FIGURES

Figure 1: A graph presenting the number of construction site injuries in South Africa from 2004 to 2008 (Smallwood, et al., 2009). .....	18
Figure 2: A graph presenting the comparison of occupational accident rates of different regions in the world (Smallwood, et al., 2009).....	20
Figure 3: Different views by South African engineers and contractors with regard to constructability values (Kuo, 2012).....	44
Figure 4: Investigation Model used to analyse case studies.....	52
Figure 5: The condominium that was constructed (Higgins, 2004) .....	54
Figure 6: The position of the victim before the fall (A) and the position of the victim after the fall (B) (Higgins, 2004) .....	54
Figure 7: The steel framework and the concrete members that were placed on the steel beams (Higgins, 2004) .....	57
Figure 8: Plan view showing precast concrete floor slabs positioned on steel beams (Higgins, 2004)	58
Figure 9: Plan view of the initially failed slab and adjacent slabs on the steel beams (Higgins, 2004)	59
Figure 10: CAT 920 loader forklift that was used for transportation of the steel roof trusses (Higgins, 2004) .....	63
Figure 11: The location of the accident (Higgins, 2004) .....	64
Figure 12: The tines of the forklift with two holes burned near the ends (Higgins, 2004).....	64
Figure 13: The location of the stairwell on the 30th floor (Work Safe Compensation Board of British Columbia, 2010).....	76
Figure 14: The position of the loading blocks on the wall of the stairwell (Work Safe Compensation Board of British Columbia, 2010).....	76
Figure 15: The loading blocks that were used and the duplex spikes that were used to connect the load blocks to the stairwell wall. (Work Safe Compensation Board of British Columbia, 2010).....	77
Figure 16: The position of a 1.4 ton wall form on top of the loading block (Work Safe Compensation Board of British Columbia, 2010).....	77
Figure 17: The number of duplex spikes used to reattach the north end loading block to the concrete wall (Work Safe Compensation Board of British Columbia, 2010) .....	78

Figure 18: An illustration of the Construction Hazard Prevention through Design (CHPtD) process (Gambatese, et al., 2008).....	90
Figure 19: Response to statement: In your experience, employees on construction sites have problems in communicating with their employers/supervisors.....	102
Figure 20: Response to statement: You know how to improve the safety of construction sites.....	102
Figure 21: A graph that presents the opinion of a percentage of South African engineers with regard to the main reason for construction site accidents in general .....	104
Figure 22: A graph that presents the opinion of a percentage of South African engineers with regard to the main reason for construction site accidents with regard to the shortcomings of contractors.....	105
Figure 23: A graph that presents the opinion of a percentage of South African engineers with regard to the main reason for construction site accidents with regard to the shortcomings of employees .....	106
Figure 24: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with demolition.....	108
Figure 25: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with electrical works .....	109
Figure 26: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with ergonomics .....	111
Figure 27: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with excavations .....	112
Figure 28: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with hazardous substances.....	114
Figure 29: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with maintenance .....	115
Figure 30: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with manual handling .....	116
Figure 31: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with plant and equipment .....	118
Figure 32: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with refurbishment .....	119

Figure 33: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with steelwork ..... 120

Figure 34: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with utilities ..... 122

Figure 35: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with work performed on roofs .. 123

Figure 36: The average of the effect an engineer has on safety for each construction activity ..... 124

## LIST OF TABLES

Table 1: Construction site injuries from 2004 until 2008 (excluding vehicle accidents) (Smallwood, et al., 2009). .....	18
Table 2: A comparison of the occupational accident rates between different regions in the world (Smallwood, et al., 2009). .....	19
Table 3: Possible safety hazards for the construction of buildings (WorkCover NSW, 2009) .....	37
Table 4: Results from Part 1 of the questionnaire (Years of Experience).....	99



## CHAPTER 1: GENERAL INTRODUCTION

Employees, contractors and people using a building expect it to be safe with regard to their own health, safety, and welfare. Probably the most cost-effective and practical approach is to avoid introducing a hazard to the building as early as during the design stage. Safe design may be defined as the strategy that aims to prevent injuries and disease, as early as possible during the planning and design stages, to those working on site and to those using the facility after construction have been completed.

Safe design starts in the office of the consulting engineer (Brown, et al., 2007). **The consulting engineer is referred to as the engineer throughout this research.** By referring to construction processes and procedures, Jerling (2009) makes the following statement concerning design knowledge of the engineer:

*“The designs provided by engineers are commonly seen as unsafe designs due to a lack of knowledge of construction processes and the risks associated with it.”*

This research will investigate the above mentioned statement with focus on South African engineers and the main objective is to identify the roles of engineers to ensure or improve the safety of construction employees. This means to identify the causes for an unsafe design, i.e. which safety areas of concern to consider during the design and construction phase and what the engineer can do to prevent or minimise construction site accidents.

It is important to note that the research is **not** about structural integrity of the final product, but rather about safety during construction execution.

Chapter 1 presents a discussion of the problem that needs to be addressed throughout this research. The discussion includes the objectives by focusing on two hypotheses that will be aimed to be proved. For the duration of this research, certain questions will be answered by means of different research techniques. These techniques are discussed in Chapter 2.

### 1.1 Introduction to Design

When referring to construction projects, especially buildings, the term “design” is commonly defined as the activity done prior to the actual construction of the building (Caple, 2010). This activity generally includes the creation of a plan or drawing to present the appearance, functions or workings of a building. Therefore, it is a creative process that includes the integration of the physical qualities of a product with aesthetic considerations.

It is important to note that the definition of design does not only refer to the preparation of drawings or the specifications of the end result but also includes different matters that relate to the execution of a project (Gambatese, 2000). Therefore, the participants during the design phase of a building do not only include the designer or architect but also include the designers for proprietary products, designers for temporary works, and the client.

Design, with regard to a building, includes the design of the whole or part of the structure as well as any changes that have to be made to the original design. Generally the outputs associated with the design of buildings include construction details, construction information, and specifications relating to the structure. The details and information can be produced in hard copy or electronic format.

## **1.2 Identifying the Engineer as the Designer**

For the purpose of this research, it is important to identify when the design of a building is the responsibility of the engineer. The responsibility may depend on the choice of procurement strategy or contract strategy. These choices are influenced by the type or size of a project or the preferences of the client (Davis, 2008).

### **1.2.1 Different procurement strategies associated with building construction**

The procurement strategy (or procurement system) is an organised system that includes the manner in which the different participants in a construction project will be appointed. It is also during the procurement phase when the different responsibilities and authorities are assigned to all participants and the different elements of the construction of a project are defined. Procurement strategies are generally classified as (Davis, 2008):

- Conventional procurement;
- Design-and-Construct procurement;
- Management procurement.

#### **Conventional procurement**

For the conventional (separated) procurement system, the client accepts that the design and the construction of the building will be performed by different entities. The engineer is solely responsible for the design and cost control of the project, while the contractor is responsible for the construction of the actual works (Davis, 2008). The contractor is appointed by means of competitive tendering with complete information supplied to the contractor prior to tendering. Davis (2008) mentioned that this procurement strategy should be used in situations where the program allows sufficient time, the design of the engineer is warranted, the client choose to appoint contractors and engineers separately, and when a balance of risk is placed between the client and the contractor.

### **Design-and-Construct procurement**

In the case of a Design-and-Construct (integrated) procurement strategy, the contractor usually accepts responsibility for all or a fraction of the design. However, it is important that the extent of design liability should be stated clearly in the contract (Davis, 2008). Therefore, the design done by the contractor should be approved by the client and once the design is approved, the contractor is responsible for the construction of the building and the coordination between design and construction.

However, the contractor usually employs his/her own design engineer. Being in his/her employment, the two parties can much easier discuss safety and other constructability issues.

In cases when the building should be functional rather than prestigious or when the design of the building is not complex, this procurement strategy would be a wise choice. Other reasons for choosing this type of procurement strategy would be if the scope of the project is likely to change as it proceeds or if the project programme can be accelerated by overlapping design and construction activities (Davis, 2008).

### **Management procurement**

When referring to management procurement, two forms of procurement strategies exist. These include Management Contracting and Design-and-Manage (Davis, 2008).

For Management Contracting, the client will appoint an independent professional team, which generally includes the engineer and a management contractor. According to Davis (2008), the management contractor would be responsible to provide advice to the professional team during the pre-construction phase. During construction, the management contractor will be responsible for the construction of the actual works. This form of procurement allows for design changes during construction as the drawings and details can be adjusted and finalised as construction proceeds.

For a Design-and-Manage procurement strategy, the management contractor is paid a fee and is responsible for the construction of the works but also for the design team. The engineer is referred to as the project designer or -manager and also as the client's agent (Davis, 2008).

For the three different procurement strategies mentioned above and that are associated with the construction of buildings, the engineer is part of a design team. Therefore, the engineer is responsible, to some extent, for design. However, contract data also commonly state which party is responsible for the design. Therefore, the choice of contract form is also important.

### 1.2.2 Contracting strategy associated with building construction

A construction contract can be defined as an agreement by one party (usually called the contractor) to undertake and carry out works for another party (commonly referred to as the client). This agreement may involve design, fabrication, erection, alteration, repair, or demolition of structures (Singh, 2009). Various standard forms of contract are available today for construction projects and the choice of contract to be used generally depends on the type and size of a project. Therefore, it is important for engineers, contractors and clients to know the differences between these contracts to choose the standard form of contract that best fits the project.

Founded in 1972, the Joint Building Contracts Committee (JBCC) is supported by the large professional and contracting bodies in the building industry in South Africa. The essential bodies that form the JBCC are (Joint Building Contracts Committee Inc, 2000):

- Association of Construction Project Managers.
- Association of South African Quantity Surveyors.
- Building Industries Federation of South Africa.
- South African Association of Consulting Engineers.
- South African Institute of Architects.
- South African Property Owners Association.
- Specialist Engineering Contractors Committee.

The concept behind the JBCC was to formulate a set of standardized contractual documents which will help to support an effective and well-organised building process. Therefore, the JBCC documents are compiled to represent the consensus view of the Joint Building Contracts Committee of good practice and an equitable distribution of contractual risk. The document is intended to provide a clear, balanced, and enforceable set of procedures, rights, and obligations, which when competently managed and administered, protect the client, contractor, and sub-contractor alike. The Series 2000 covers all aspects for most types of building projects (Construction Industry Development Board (CIDB), 2005).

According to CIDB (2005), the Principal Building Agreement is the basis of the JBCC Series 2000 document range. The agreement is compiled by nine sections with the first section defining all the primary elements and phrases that regularly occur throughout the document. The final section is a schedule of all variables required to complete the Agreement (Joint Building Contracts Committee Inc, 2000). This agreement includes standard provisions to cater for the requirements commonly associated with “national” contracts. The JBCC Series 2000 Principal Building Agreement is therefore the most commonly used form of contract for the construction of buildings in South Africa.

Clause 4.0 of the Principal Building Agreement discusses the matter of design responsibilities. It clearly states in Clause 4.1 that the contractor shall not be responsible for the design of the works other than the Contractor's or his subcontractors' temporary works (Joint Building Contracts Committee Inc, 2000). This is an indication that the design of the actual building, excluding the temporary works, is the responsibility of the engineer or the client. Clause 5.1 states that the Principal Agent, as stated in the contract data, has full authority and obligation to act in terms of the agreement. According to Clause 3.7 of the Principal Building Agreement, the Principal Agent shall provide the number of copies of drawings, unpriced Bill of Quantities, and documents as stated in the contract data at no cost to the contractor (Joint Building Contracts Committee Inc, 2000). Therefore, it is clear from the latter that the design of the permanent structure is the responsibility of the professional team under the JBCC contract.

### **1.3 Design Reasonable Practicable**

During the design phase, the engineer is responsible to meet certain design requirements. These requirements contribute to a design being safe and reasonable practicable. The requirements of a design to be reasonably practicable are discussed in this section.

The engineer should understand the methods of how a building can be constructed, maintained, decommissioned, and demolished safely (WSH Council, 2009). Therefore, the engineer should investigate the design and study the risks to those working on site, the public, and people using the facility in the future.

The WSH Council (2009) states that an important duty of the engineer as designer is to assess the design in a manner as to review the health and safety risks the design creates and to eliminate the hazards as far as reasonably practicable. The term, *reasonable practicable*, is a commonly used term when referring to the design of basically any form of infrastructure. Therefore it is important to understand the term and to be aware of what it entails.

To determine whether a design is *reasonable practicable* is to consider all relevant matters until a balance is achieved between constructability and the requirements of the client. The balance should provide the highest level of protection, against construction hazards, that is both possible and reasonable in practice (Safe Work Australia, 2011). Some matters may be relevant to what can be done, i.e. adjusting the design to the immediate environment. Other matters may be relevant to what is reasonable to do, i.e. designing according to certain standards. However, according to Safe Work Australia (2011), some matters must be taken into account when the design of a building is to be reasonably practicable. These matters include:

- The likelihood of the hazard or risk occurring.
- Degree of harm if the hazard or risk occurs.
- The knowledge of the engineer about the hazard or risk and methods to minimise or eliminate it.

### **1.3.1 Risk assessment**

Prior and during the design phase, the engineer should perform a risk assessment to determine the likelihood of hazards to occur and the risks these hazards present. The greater the likelihood of a risk, the greater is the significance of it (Safe Work Australia, 2011). Therefore, if the risk is more likely to occur then it will be reasonable to expect more to be done to eliminate or minimise that specific risk.

The significance of safety risks is usually calculated by multiplying the likelihood of the risk and the degree of harm it may cause to employees.

The degree of harm that a risk will cause should be identified. The greatness of the degree of harm will state to what extent attention will be given to the specific risk. Therefore, the greater the degree of harm, the greater is the attention provided to the risk (Safe Work Australia, 2011).

### **1.3.2 The knowledge of the engineer about hazards and risks**

This is commonly referred to as the *state of knowledge* of the engineer and is seen as an area of concern in the construction industry according to Safe Work Australia (2011). The designs provided by engineers are often seen as unsafe designs in terms of execution due to a lack of knowledge of construction processes and the risks associated with it (Jerling, 2009). However, an Engineer may gain knowledge in various ways, for example by:

- Consulting their employees, colleagues and other people in the same industry.
- Undertaking risk assessments.
- Reviewing historical data and analysing previous incidents.
- Considering regulations and Codes of Practice.

It is seemed as reasonably practicable for an engineer to take steps in a proactive way to identify hazards or risks before the occurrence of injury, death, or illness to the employees or the people surrounding the immediate environment. Therefore, the knowledge of how the hazard or risk may occur or the degree of harm it may cause is essential to the engineer.

The effective exchange of knowledge between the engineer and the contractor is also an important requirement for a safe and reasonable practicable design. However, knowledge exchange is discussed in detail in Chapter 3.5.

## 1.4 Problem Statement

Accidents and injuries on construction sites are causes for contractors to struggle financially. The reason is that an accident on site is an unplanned event typically relating to the loss of production or the loss of life (CIDB, 2010). Many industry stakeholders and role players have focused on construction health and safety and to improve this area of concern; however, construction health and safety are not significantly improving. Construction still continues to contribute a large number of fatalities and injuries relative to other industry sectors (Smallwood, et al., 2009).

According to Venter (2009), there were 162 fatalities in the construction industry between the period of 2007 and 2008. This is much higher in comparison with 79 in 2006, 81 in 2005 and 54 in 2004. However, the reason for the increase in fatalities is not due to a lack in health and safety legislation in South Africa, rather to a lack in the enforcement of adequate health and safety systems (Venter, 2009). However, since 2008 the fatalities have halved, but there is still no reason why these accidents should happen on site (Enslin, 2011).

During the construction phase, poor construction health and safety performance is attributable to a lack of management commitment, inadequate supervision, and a lack of health and safety training (Smallwood, et al., 2009). A lack of employee involvement and work pressures may also contribute to poor performance.

However, health and safety systems do not only include excellent health and safety management on site, but also an integrated approach on health and safety issues from all stakeholders participating. This integrated approach includes the design done by the engineer.

The inspiration behind this research is the uncertainty of whether South African engineers design buildings safe for construction execution. The uncertainty extends to whether the engineers comply with safe design principles in South Africa. These principles include:

- Life-Cycle approach: Safe designing techniques should be applied to every phase in the life cycle of a building or structure.
- Risk management procedure during design phase: Safe design techniques should include risk management by systematically identifying, assessing, and controlling hazards.
- Knowledge and capability: Safe design requires construction knowledge and capability which should either be demonstrated or accessed by any person influencing the design.

- Information transfer: Safe design relies on information being transferred effectively between participating parties by means of effective documentation and communication.

The lack of knowledge of construction processes, the lack of health and safety enforcement in the engineering offices, and whether engineers adhere to safe design principles is the subject of investigation in this study.

## 1.5 Scope of Investigation

A construction project involves a number of participants. These participants may include the client, the consulting engineer, the contractor, the subcontractors, and the architect. However, this research is limited to focus on the consulting engineer. The consulting engineer is responsible for some parts of the design of the project and as mentioned before, the consulting engineer is referred to as the engineer in this research. Therefore, the engineer is the term used for the person responsible for the design throughout this research. The engineer responsible for temporary works is indicated as the *temporary works engineer* at certain sections of this research.

Note that reference made to the Construction Regulations throughout the research refers to the Construction Regulations that were promulgated in 2003 in South Africa (Department of Labour, 2003).

The Civil Engineering industry consists of many disciplines that amongst others include structures, earthworks, road construction, water resources engineering, and coastal engineering. However, this research focuses on the effect design engineers have on construction employee health and safety in building projects. Since the JBCC Principal Building Agreement are commonly used in South Africa for building construction (Joint Building Contracts Committee Inc, 2000), this research will only focus on this standard form of contract as there will be numerous references to some clauses in the JBCC Principal Building Agreement.

The research methodology consisted of a literature study, the investigation of case studies and a questionnaire that presents certain questions, related to construction site safety, being asked to South African engineers. The questionnaires were sent to 25 South African engineers of which 23 of the engineers responded. The latter, seen in light of the average years of experience of the respondents as consulting engineers, resulted in the responses to be declared as credible and trustworthy. Since 23 engineers is small in comparison with all the engineers in South Africa, the responses resulted in conclusions that can be made with regard to the knowledge of a **percentage** of South African engineers on construction site safety and construction methods



It is important to note that the questionnaires were only sent to engineers and not contractors. The reasons are:

- The research aims to identify the role only the engineer can play to contribute towards a safe construction site.
- The research also aims to identify the knowledge of South African engineers on construction safety and on methods to improve it.
- The responsibilities of the contractor are already stated in the Construction Regulations.

Further research should include the responsibilities of the contractor, apart from what is stated in the Construction Regulations, in order to improve safety on construction sites.

## **1.6 Research Objectives**

This research has the following objectives:

- a. To understand the role of the engineer with regard to the safety of employees on construction sites of buildings.
- b. To identify the safety hazards associated with the construction activities that are performed for the construction of a building.
- c. To identify the role of the engineer with regard to construction site safety and to investigate the opinion of South African engineers with regard to role of the engineer.
- d. To identify the effect of engineers on the safety of employees with regard to the safety hazards associated with the construction processes that are used during the construction of a building.
- e. To identify whether safety training takes place on construction sites.

## **1.7 Research Hypotheses**

This research will test the following hypotheses:

Hypothesis 1: South African engineers have a lack of experience in the processes that are used during the construction phase of a project.

Hypothesis 2: Engineers can play a role in improving the safety of construction employees on building sites, i.e. construction site safety is not solely the responsibility of the contractor.

## 1.8 Thesis Structure

- Chapter 1 of this research presents the literature study to identify scenarios where the engineer will be responsible for the design of the building. The research problem, the scope of investigation, the research hypotheses, and - objectives were stated.
- Chapter 2 presents a discussion of the research instruments used for this research, i.e. a discussion of the literature study, case studies, and questionnaires. It also includes a discussion on the various research methodologies that can be used for a thesis. Chapter 2 also presents the objectives of each of the chosen research instruments.
- Chapter 3 includes the literature study to investigate safety in designs done. It includes an overview of construction health and safety statistics and the current legislative framework in South Africa. Chapter 3 also includes twelve construction activities that present possible health and safety hazards for employees. Furthermore, it presents a proposed safe design process and a discussion on the importance of efficient knowledge exchange between project participants to improve constructability.
- Chapter 4 presents the investigation of case studies on construction site safety. It includes the discussion on the approach taken to analyse each case study and the reasons for investigating international case studies. The investigation of the case studies resulted in valuable lessons that were learned with regard to the role of the engineer to possibly improve health and safety on construction sites. These lessons are also included in Chapter 4.
- Chapter 5 presents the discussion of the design of the questionnaire and the results obtained. It includes a discussion and analysis of the results for each of the five parts of the questionnaire.
- Recommendations are presented in Chapter 6. It presents a safe design process that recommends the steps to be taken by the engineer to contribute towards healthy and safe construction sites.
- Chapter 7 presents the final conclusions. It includes the key results and findings obtained from each of the research instruments used for this research.
- Appendix A presents the invitation letter that was sent to possible respondents for the questionnaire.
- Appendix B presents the cover letter that was sent to those South African engineers that did agree to participate in answering the questionnaire.
- Appendix C presents the actual questionnaire in the form it was sent to the respondents.

- Appendix D includes the spreadsheets that show the results obtained from the questionnaire.
- Appendix E includes the graphs that present the results to Part 3 of the questionnaire.
- Appendix F includes the graphs that show the results to Part 4 of the questionnaire.

## CHAPTER 2: RESEARCH METHODOLOGY

Chapter 2 includes discussions on research methodology in general and the research instruments that were used for this research. Furthermore, the objectives of each research instrument are discussed with reference to analysing construction employee safety of building projects as function of design specifications.

### 2.1 Introduction on Research Methodology

Sedgley (2007) defines research as a process that is systematic, methodical and ethical to investigate ways to solve practical problems and to increase knowledge on a topic.

Therefore, research is a contribution to existing knowledge, with regard to a specific topic. It is the pursuit of truth by means of study, observation, comparison, and experiment. Research methodology is a systematic process consisting of identifying the problem, formulating a hypothesis, collecting the facts or data, analysing the facts or data, and reaching certain conclusions either in the form of solutions towards the concerned problem or in certain generalisations for some theoretical formulation (Wilkinson & Birmingham, 2003).

### 2.2 Research Methodology Classification

Research methodology can be classified in various forms. Sedgley (2007) classifies research methodology in 4 groups, with each group containing two opposing research methods. The four groups, which will be discussed in this section, are the following:

- Group 1: Descriptive vs. Analytical
- Group 2: Applied vs. Fundamental
- Group 3: Quantitative vs. Qualitative
- Group 4: Conceptual vs. Empirical

The methods that were used for the research are discussed in Section 2.4.

#### 2.2.1 Group 1: Descriptive - vs. Analytical Research

Descriptive research is a process that includes fact finding investigation. The purpose of descriptive research is to identify the state of certain matters as it exists at present. The researcher has no control over the variables; he can only report what has happened or what is happening. The most common methods of research utilized in descriptive research are surveys or questionnaires (Sedgley, 2007).

Opposed to descriptive research, analytical research includes the use of facts or information already available and the analysis of it to result in an assessment of the material.

### **2.2.2 Group 2: Applied – vs. Fundamental Research**

Applied (or action) research aims to identify a solution for a problem facing a society or an industrial/business organisation. Fundamental research is mainly concerned with generalisations and with the formulation of a theory (Sedgley, 2007).

Research concerning some natural phenomenon or relating to pure mathematics are examples of fundamental research. Similarly, research studies, concerning human behaviour carried on with a view to make generalisations about human behaviour, are also examples of fundamental research, but research aimed at certain conclusions (a solution) facing a real social or business problem is an example of applied research.

Therefore, the main aim of applied research is to discover a solution for some pressing practical problem. Fundamental research is directed towards finding information that has a broad base of applications and therefore, adds to the already existing organized body of scientific knowledge (Sedgley, 2007).

### **2.2.3 Group 3: Quantitative - vs. Qualitative Research**

The aim of quantitative research is to collect and analyse numerical data by focusing on measuring the scale, range, frequency etc. of phenomena. Quantitative research is usually highly detailed and structured with the results being easily organised and presented statistically (Jerling, 2009).

Sedgley (2007) mentions qualitative research is more subjective in nature than quantitative research. Qualitative research includes the examination and reflection on the less tangible aspects of a research subject, e.g. values, attitudes, or perceptions. The results obtained from a qualitative research approach are often difficult to interpret and can also be challenged more easily.

### **2.2.4 Group 4: Conceptual - vs. Empirical Research**

Conceptual research is a process related to abstract ideas or theory and is often used by philosophers to develop new concepts or to reinterpret existing ones.

Empirical research relies on experience or observation alone. The latter is a data-based research method resulting in conclusions which are capable of being verified by observation or experiment.

## 2.3 Research Instruments

Research instruments are simply devices for obtaining information relevant to a specific research project, and there are numerous alternatives from which to choose (Jerling, 2009). The following research instruments were identified for this research and are discussed in this section:

- Questionnaires;
- Content analysis;
- Observations.

### 2.3.1 Questionnaires

Questionnaires are commonly used research instruments as they provide cheap and effective ways of collecting data in a structured and manageable form (Wilkinson & Birmingham, 2003).

However, questionnaires can be difficult to design and analyse and the questions posed can be misleading and ambiguous. A problem behind questionnaires is also that it often needs to be targeted at a specific group with response to the questionnaires not being guaranteed. Therefore, questionnaires can create hours, days, or weeks of work in analysis (Wilkinson & Birmingham, 2003).

However, a well-planned and well-executed questionnaire campaign can result in valued data to be produced in a format ready for analysis and interpretation.

Questionnaires take many different forms and styles (Barnes, 2001). On the one end, face-to-face interviews are a possibility where the researcher asks questions and is verbally answered by the respondent. Between the face-to-face interview and the electronic questionnaire, several other forms of questionnaires are possible. These include, amongst others, telephone interviews or postal questionnaires (Barnes, 2001).

### 2.3.2 Content Analysis

Content analysis includes the investigation of information that was collected and applying significance or meaning to it (Wilkinson & Birmingham, 2003). It is a broad area of research that includes both quantitative and qualitative approaches to analysis. Content analysis can also be used as a powerful research tool to determine sound inferences concerning the attitude of a speaker or writer.

### 2.3.3 Observations

Observation is a research instrument defined by Wilkinson & Birmingham (2003) as research characterised by a prolonged period of intense social interaction between the researcher and the subjects during which data is systematically collected.

Social researchers are interested in people and, in particular, the ways in which people act in, interpret, and understand the complex world around them. The latter may refer to the classroom, the hospital, the factory floor, the head office, or the local government department. How people see and understand their surroundings will no doubt play a part in the ways in which they behave, they act and interact with others, and in the ways their actions are perceived by others. Observation is a handy tool for researchers in this regard. It allows researchers to understand much more about complex real world situations than they can discover simply by asking questions of those who experience them (no matter how probing the questions may be), and by looking only at what is said about them in questionnaires and interviews (Wilkinson & Birmingham, 2003).

This may be due to interviewees and questionnaire respondents often being reluctant to impart everything they know, perhaps feeling it would be improper or insensitive to do so, or because they consider some things to be insignificant or irrelevant. It is more likely the case that they are unable to provide information about certain events or activities, if asked outright, because they occur so regularly or appear so unremarkable and mundane that they are hardly aware of them at all.

## **2.4 Theory Applied in this research**

Following the identification of the problem statement (refer to Chapter 1.4) and the formulation of the hypotheses (refer to Chapter 1.7), the research methods and instruments to collect data and information for this research was identified.

In Chapter 3, a literature study on the subject of safe design with regard to the responsibilities of engineers is presented. As the literature study investigates information and data currently available with regard to the topic of this research, Chapter 3 can be classified as an analytical -, applied -, qualitative -, and quantitative research method. The use of a literature study is also a content analysis research instrument as mentioned earlier in Chapter 2.3.2.

Chapter 4 of this research includes the investigation of eight primary international case studies and several additional case studies. These case studies include construction site accidents that can be related to poor design decisions or techniques, a lack of construction knowledge, or a lack of involvement by the engineer. With regard to the classification of research methodologies, Chapter 4 can be classified as an analytical -, applied -, and empirical research method. Two research instruments, i.e. content analysis and observations, are used in Chapter 4.

Furthermore, Chapter 5 includes the design and distribution of a questionnaire based on the results obtained from Chapters 3 and 4. These questionnaires were distributed to 25 South African

engineers. Therefore, Chapter 5 can be classified as a descriptive -, fundamental -, quantitative -, and qualitative research method.

## 2.5 Objectives of Literature Study

The primary objectives of the literature study in Chapter 3 is to investigate information that is currently available with regard to the safety of construction employees on site and the responsibilities of the engineer with regard to construction employee safety. The literature study aims to identify the current state of construction site accidents in South Africa by investigating statistical data, it aims to identify the characteristics of a safe design approach, and it aims to identify all construction site hazards that can be connected to the construction of buildings.

## 2.6 Objectives of Case Studies

Although this research is primarily focused on the impact of South African engineers on the safety of construction sites, discussing and analysing international case studies are also relevant. The reasons for making use of international case studies are the following:

- In collaboration with Chapter 3, international case studies help to identify construction site hazards that need to be taken into account by the engineer from the start of the project. Therefore, these case studies help to identify any hazards that are not mentioned in Chapter 3, or it is used to confirm that the hazards identified in Chapter 3 are legitimate.
- The use of international case studies also helps to identify the information that the engineer needs to share with the contractor.
- International case studies assist in identifying construction processes and techniques that are relevant for the engineer to be aware of during the design phase.
- Few case studies on construction site accidents in South Africa were found.

The information gathered through case studies contributed towards the successful development of questionnaires.

## 2.7 Objectives of Questionnaires

The main objective of the questionnaire is to use the research results obtained in Chapters 3 and 4 and to obtain the opinion of South African engineers on certain safety related matters. The chosen respondents were not limited to a certain number of years of experience.

The questionnaire consists of five parts (refer to Appendix C) with each part consisting of various questions based on previous research results.



## **CHAPTER 3: DESIGNING FOR SAFETY - LITERATURE STUDY**

Safety on construction sites must be considered carefully (CIDB, 2010). The term “safety” is defined by CIDB (2010) as a state in which the risk of harm or damage to a person is limited to an acceptable level.

The following chapter aims to identify and define acceptable safety practices on construction sites by presenting a theoretical view of safety concerns throughout the life-cycle of a building project. Chapter 3 provides an overview of health and safety in the South African construction industry for a period between 2004 and 2008. It explores construction accident rates and statistics.

Furthermore, a proposed safe design process is identified by discussing the various steps that need to be taken to ensure a safe design. This chapter identifies health and safety hazards that the engineer should be aware of from the conceptual design stage of the building.

The importance of an efficient collaboration between all project participants is investigated. The investigation identifies the importance of a design to also be constructible by identifying the constructability principles that need to be introduced during the conceptual planning, design, procurement, and construction phases. Finally, this chapter identifies the primary and secondary South African legislation that has an impact on construction health and safety. Furthermore, it discusses the impact of the Construction Regulations on construction health and safety in South Africa.

A literature study was used to gather information for this chapter.

### **3.1 Overview of Construction Health and Safety in South Africa**

Construction health and safety has been the focus of attention for many stakeholders and role players in South Africa. Although it is acknowledged that many professional societies, industry associations, and contracting companies have made significant efforts to help improve health and safety within South Africa’s construction industry, the overall construction health and safety is not improving significantly (Smallwood, et al., 2009).

Section 3.1 discusses the safety statistics of the construction industry of South Africa and compares it with statistics of other countries and other occupations.

#### **3.1.1 Statistics of construction site injuries in South Africa**

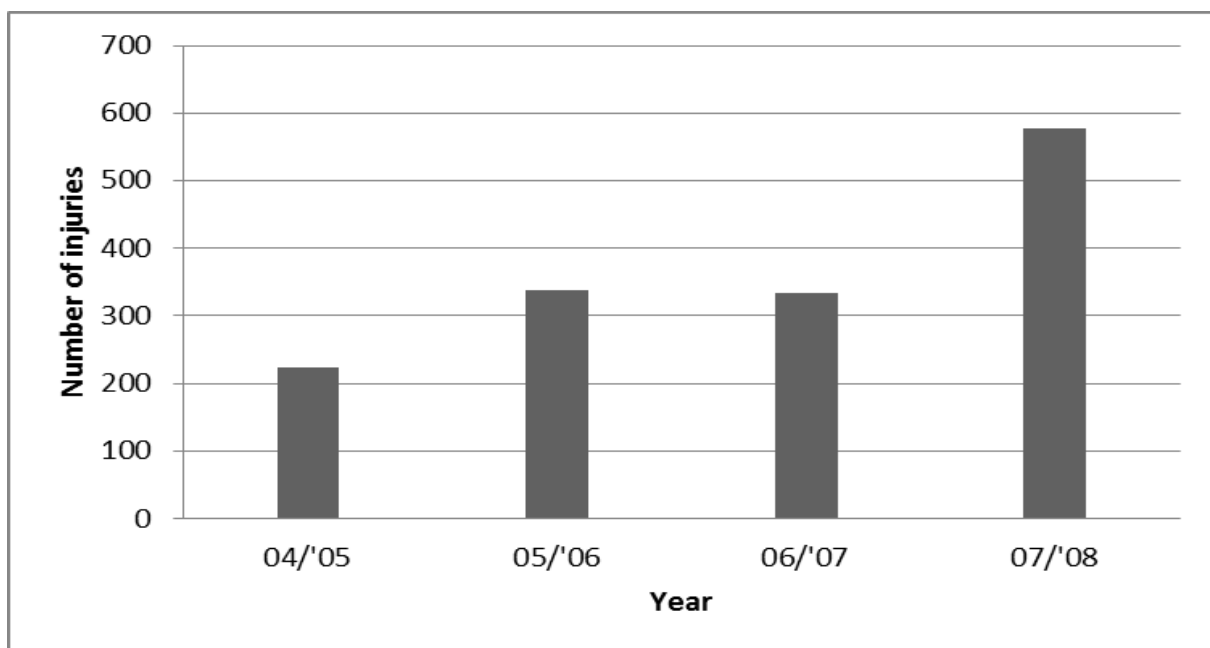
An assessment based on statistics is seen as a good starting point towards an overview of construction health and safety within an industry (Smallwood, et al., 2009).

According to the Compensation for Occupational Injuries and Disease Act No. 130 of 1993 (COID Act), all construction industry employers are required to be registered with either the Compensation Commissioner (housed within the Department of Labour, DoL) or the Federated Employers' Mutual Assurance Company Limited, FEMA. They are required to report occupational injuries within seven days after such injuries occurred.

Table 1 and Figure 1 provide statistics regarding construction site injuries obtained by the Department of Labour for the period from 2004 until 2008:

**Table 1: Construction site injuries from 2004 until 2008 (excluding vehicle accidents) (Smallwood, et al., 2009).**

	2004/05	2005/06	2006/07	2007/08
Fatal	54	81	79	162
Non-fatal	159	250	245	396
Non-casualty	11	7	10	20
Total	224	338	334	578
Total construction site injuries (2004 to 2008)			1474	



**Figure 1: A graph presenting the number of construction site injuries in South Africa from 2004 to 2008 (Smallwood, et al., 2009).**

As presented by Table 1, the number of fatalities increased from 2004 to 2008. Similar to this, the total number of injuries on construction sites also increased during this time period. According to Venter (2009), the reason for the increase in injuries is not due to a lack of health and safety

legislation in South Africa, but rather to the enforcement of adequate health and safety systems within the construction industry.

As mentioned in Chapter 1, adequate health and safety systems do not only include excellent health and safety management on site, but rather an integrated approach on health and safety issues from all stakeholders participating. This integrated approach includes the design done by the engineer if:

- The procurement strategy is the Conventional strategy, Design-and-Construct strategy, or the Design-and-Manage strategy.
- The contracting strategy is the Principal Building Agreement of the JBCC Series 2000 document range.

### 3.1.2 International comparison of accident rates

The comparison of the occupational accident rates between different regions in the world shows noteworthy results as presented by Table 2 and Figure 2 (Smallwood, et al., 2009).

The accident rates in Asia and surrounding islands, as well as in Sub-Saharan Africa, which primarily consist of developing countries, are significantly higher than that of Established Market Economies, which consist of developed countries. Table 2 shows that South Africa has an accident rate of approximately 14 600 accidents per 100 000 employees (14.6%). Although the accident rate in South Africa is slightly less than in Asia and Sub-Saharan Africa, it is still higher than in developed countries.

**Table 2: A comparison of the occupational accident rates between different regions in the world (Smallwood, et al., 2009).**

Region	Accident Rate (per 100 000 employees)
Asia and surrounding islands (excluding China and India)	16434
Sub-Saharan Africa	16012
South Africa	14626
Middle Eastern Crescent	14218
Latin America and Caribbean	13192
Former Socialistic Economies	9864
Singapore	7452
Established Market Economies	3240

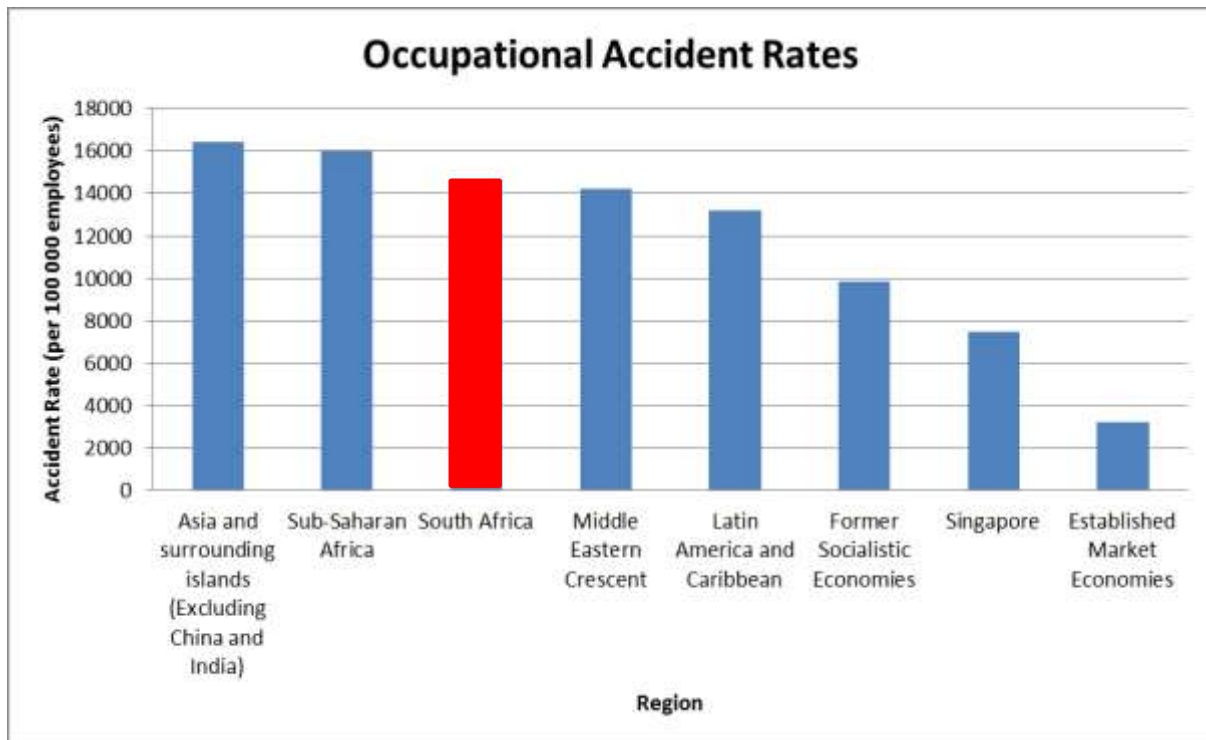


Figure 2: A graph presenting the comparison of occupational accident rates of different regions in the world (Smallwood, et al., 2009).

The construction industry contributes a total of 1077 accidents per 100 000 employees towards the total occupational accident rate of South Africa with 14626 accidents per 100 000 employees (Smallwood, et al., 2009). Therefore, the South African construction industry contributes a large number of accidents towards South Africa's occupational accident rate. Although many stakeholders and role players in South Africa have focused on improving construction health and safety in South Africa, it is still an area of concern as no significant improvement has been made (Venter, 2009). Designing for safety may be the starting point to reduce the accidents occurring on construction sites.

### 3.2 Legislative Framework for Construction Health and Safety in South Africa

As presented by Table 1, a total of 1474 construction site injuries were recorded for the period from 2004 to 2008. According to Smallwood et al. (2009), a poor health and safety performance in the construction industry all over the world was also recorded. This resulted in health and safety regulations to be subjected to major revisions and modifications during the last three decades.

Smallwood et al. (2009) makes the following statement with regard to health and safety legislation:

*“The primary objective of any Health and Safety legislation is the prevention of accidents with their consequences in terms of injury, disablement and fatality, and health within the work environment.”*

This objective can be achieved by having good legislation that is supported by effective and sensible enforcement (Smallwood, et al., 2009).

This section identifies the primary and secondary South African legislation that has an impact on construction health and safety. Furthermore, it discusses the impact of the Construction Regulations on construction health and safety in South Africa.

### **3.2.1 Primary legislation in South Africa**

According to Smallwood et al. (2009) and ECSA (2012), the primary legislative acts that have an impact on construction health and safety in South Africa are:

- Occupational Health and Safety Act No.85 of 1993.
- The Occupational Injuries and Diseases Act No. 130 of 1993.

A number of regulations are spread under the Occupational Health and Safety Act that also have an impact on construction health and safety. One of these regulations is the Construction Regulations that was promulgated in July 2003 (Smallwood, et al., 2009).

The Construction Regulations can be seen as a document that defines the legal duties for the safe operation of South African construction sites. The legal duties are specifically placed on clients, engineers, and contractors and assist these parties in their approach to health and safety. The Construction Regulations are applied throughout the life-cycle of a construction project i.e. from the inception phase to the final demolition and removal phase.

Other legislation, called secondary legislation, also has an impact on health and safety in the South African construction industry. The secondary legislation is discussed in Section 3.2.4.

### **3.2.2 Unique characteristics and impacts of the Construction Regulations**

The Occupational Health and Safety legislation in South Africa, in particularly the Construction Regulations, possess a number of unique characteristics that impact health and safety in the South African construction industry (Smallwood, et al., 2009). The following characteristics are identified (Smallwood, et al., 2009), (Engineering Council of South Africa (ECSA), 2012), (Department of Labour, 2003):

- 1) The responsibility for construction health and safety is redistributed away from the contractor. The contractor was solely responsible for health and safety on construction sites in the past. However, the Construction Regulations, since 2003, include all participants in the construction process from the client through to the final end-user.
- 2) The Construction Regulations convince project participants that health and safety management is a requirement that needs to be included into the planning and design of all construction projects.
- 3) The importance of identifying construction hazards, the assessment of construction hazards, and the elimination of risks are highlighted. The Construction Regulations emphasises that health and safety risks on construction sites should be avoided, or at least be reduced.
- 4) The Construction Regulations emphasise the importance of considering health and safety concerns throughout the entire life-cycle of the construction project. Therefore, from the inception phase until the final demolition phase, including operation, utilisation, and maintenance periods.
- 5) The Construction Regulations mention the formulation of compulsory health and safety specifications and plans that act as instruments to facilitate the exchange and communication of health and safety concerns between project participants.
- 6) The Construction Regulations define a health and safety file that is compulsory to be compiled by the contractor and should be handed to the engineer upon completion of the building.

The characteristics of the Construction Regulations prove the importance of this research as it acknowledges the roles of each project participant, especially the engineer, with regard to health and safety. Previously, engineers were not required to consider health and safety concerns (Smallwood, et al., 2009). However, they are now required to avoid foreseeable risks as a duty for all construction projects. The Engineering Council of South Africa (2012) states that if the client requires the engineer to undertake duties falling under the Occupational Health and Safety Act No.85 of 1993, on behalf of the client, the engineer should:

- Arrange, formally and in writing, for the contractor to provide documentary evidence of compliance with all the requirements of the Occupational Health and Safety Act.
- Perform the duties of the client, as his appointed agent, as contemplated in the Construction Regulations to the Occupational Health and Safety Act.

Smallwood et al. (2009) makes the following statement with regard to the impact of the Construction Regulations on health and safety within the South African construction industry:

*“The Construction Regulations are perceived to have had a wide spread impact, and in particular increased health and safety awareness and increased consideration by project managers and general contractors.”*

However, the results of research done by Smallwood et al. (2009) indicate that there has not been an increase in consideration of health and safety by engineers.

### **3.2.3 Responsibilities according to the Construction Regulations**

As mentioned before, the Construction Regulations acknowledge the responsibilities of each party with regard to construction site safety. According to the Construction Regulations, Clause 4.5, the client may appoint an agent that acts on his or her behalf and where such an appointment is made, the responsibilities provided in the Construction Regulations will apply to the agent appointed. For this research, the appointed agent is the engineer whom is responsible for the design of the project as well.

Importantly, Clause 4.1(b) of the Construction Regulations state that the engineer, appointed as the client’s agent, should provide the contractor with any information that might affect the health and safety of any person performing construction work (Department of Labour, 2003).

Therefore, it will be beneficial for the engineer to be aware of the possible construction safety hazards associated with buildings. Although the Construction Regulations state in Clause 7.1 that each contractor should undertake a risk assessment prior to the actual construction to identify the possible safety hazards, the engineer can assist the contractor in this process by identifying the possible hazards early on during the design phase. If the engineer is aware of the possible hazards, the design can be modified to make the construction process safer.

The engineer should also provide the contractor with health and safety specifications for the construction work (Department of Labour, 2003). Based on the latter, the contractor should provide and demonstrate to the engineer a suitable and sufficiently documented health and safety plan that shall be applied from the date of commencement and throughout the duration of the construction process (Department of Labour, 2003).

Within the health and safety plan, the contractor can be required to provide information on safety hazards. This information may include (for example):

- Proof that the contractor did undertake a risk assessment.
- Proof that the contractor’s employees are provided with adequate safety training.
- The employees are provided with the necessary safety equipment.
- The employees are informed on the possible construction safety hazards.

- The contractor tested his or her equipment to proof that it will perform tasks efficiently and safely.

An investigation of the contents of a health and safety plan was done and is discussed in Section 4.13.3 of this research.

The Construction Regulations acknowledges the prevention of safety hazards associated with certain construction activities to be the responsibility of the contractor. Some of these activities are the following:

- Demolition;
- Excavation;
- Work done on roofs;
- Hazardous substances;
- Plant and equipment;
- Electrical works.

Even though the contractor is acknowledged by the Construction Regulations as the primary responsibility party, the engineer is required, under the Construction Regulations, to provide the contractor with any information that might affect the health and safety of the construction employees. Due to the latter, the engineer is also responsible. The engineer can assist the contractor in identifying and mitigating the hazards associated with hazardous construction activities.

According to Smallwood, et al. (2009), the prevention of a safety hazard is always better than mitigating it. Therefore, the knowledge of the engineer with regard to construction safety should be adequate to incorporate safety awareness during the early stages of design.

Possible construction safety hazards that are associated with various construction activities are discussed in Section 3.3.

### **3.2.4 Secondary legislation in South Africa**

Other legislation also has an impact on health and safety within the construction industry of South Africa (Engineering Council of South Africa (ECSA), 2012). This legislation (secondary legislation) has a direct or indirect reference to health and safety. The following secondary legislation is identified (Smallwood, et al., 2009), (Engineering Council of South Africa (ECSA), 2012):

- 1) Basic Conditions of Employment Act No. 75 of 1997 – This act aims to emphasise the right to fair labour practices as referred to in the Constitution. It makes the following references to health and safety, specifically the health and safety of construction employees:



- a. Clauses 13.1 and 13.3 state that the maximum allowed hours of work may be prescribed by the Minister of Labour on grounds of health and safety.
  - b. Clauses 17.3 (a-c) state that contractors are required to inform all employees of any health and safety hazards and allow the employees to undergo medical examinations concerning those hazards.
- 2) Labour Relations Act No. 66 of 1995 – The Labour Relations Act identifies the right of every employee to work environments that are fair as advocated in Section 14 of the Constitution. This act also recognises the participation by employees during decision-making in the workplace. Therefore, these provisions implicate that contractors should provide working environments that do not threaten the health and safety of the employees. It is compulsory for contractors to notify each employee of any risks that might affect their working environment, which include their health and safety. The Labour Relations Act also identifies the importance of training and education with regard to health and safety.
- 3) The National Building Regulations and Standards Act No.103 of 1977 – This act addresses a range of health and safety issues relative to both the public and employees. The following issues are identified:
- a. Part E of the National Building Regulations and Standards Act No.103 of 1977 discusses demolition work. Amongst others, Part E discusses safety during demolition, safeguarding of basements and the prevention of dangerous demolition methods.
  - b. Part F, site operations, also addresses a range of health and safety concerns. Amongst others, Part F addresses the protection of the public, control of dust and noise, unstable soil conditions, sanitary facilities, waste material on site and the cleaning of the site.
  - c. Part G discusses, inter alia, the general stability requirements during excavation processes.
  - d. Part H addresses, amongst others, unstable foundations.

Therefore, secondary legislation with regard to the health and safety of employees on construction sites in South Africa is present. While these acts are silent with respect to explicit reference to health and safety, they imply that health and safety are to be considered to create and sustain pleasant, professional and efficient working relationships between contractors and employees.

### 3.3 Construction Site Hazards for Buildings

As an engineer responsible to design a building, it is important to be aware of the different construction site hazards in order to contribute towards a safe working environment for those working on site. The awareness of these hazards ensures that the engineer eliminates it during the design stage or includes it in the health and safety specifications. A total of 12 hazardous construction processes or subjects of concern, which may be affected by the design, are identified (WorkCover NSW, 2009), (Zou, et al., 2007), (Jones, 2009), (Gilbertson & Arup, 2007), (Kogi & Serbitzer, 1992):

- Demolition;
- Electrical works;
- Ergonomics;
- Excavation;
- Hazardous substances;
- Maintenance;
- Manual handling;
- Plant and equipment;
- Refurbishment;
- Steelwork;
- Utilities;
- Work done on roofs.

The above mentioned processes will be discussed in the following paragraphs. The discussions will be primarily focused on the responsibilities of the engineer with respect to the hazards associated with each process. It is important to note that these responsibilities include what the engineer **can possibly do** during the design phase and throughout the life-cycle of the project, or what the engineer **can possibly include** in the health and safety specifications.

#### 3.3.1 Demolition

The demolition of a building often involves (WorkCover NSW, 2009):

- The risk of employees falling due to work done at severe heights.
- The risk arising from the actual demolition or collapse of the building (employees being struck or buried by falling material).
- Employees being exposed to hazardous substances, such as dust.
- Employees being exposed to noise during demolition.

Engineers can monitor that employees working at heights are equipped with the necessary safety equipment by including it in the health and safety specifications of the project (Jones, 2009). Engineers can also pass relevant information, such as surveys, historical drawings, and service records on to the demolition contractor (WorkCover NSW, 2009).

The risk of collapse is an important aspect associated with the demolition of buildings. The engineer can consider the dangers involved in working on buildings at or near the point of collapse by providing the contractor with information on load paths that include (WorkCover NSW, 2009):

- The critical loading conditions that may cause collapse.
- Critical load-bearing elements that should not be removed without supporting arrangements (columns under supporting beams, floor beams, members providing lateral restraint to compression members).
- Pre-stressed concrete elements which contain considerable tension.

The engineer can also be responsible to consider risks arising from temporary situations. These situations are for example the creation of retaining walls and excavations when basements and foundations are removed or destabilising a structure when demolishing an adjoining structure (WorkCover NSW, 2009).

Gilbertson & Arup (2007) states that the engineer is responsible to identify hazardous material that is present during the demolition process or remains on the site. It will be beneficial for the safety of the project if the engineer also identifies the critical sequences that need to be followed during demolition and communicate it with the demolition contractor. Alongside structural instability, any pre-tensioned or post-tensioned components of the building can be identified by the engineer and be brought to the attention of the demolition contractor.

Therefore, the engineer can be responsible to incorporate relevant information in the design and share the information with the demolition contractor that will potentially prevent accidents during demolition.

### **3.3.2 Electrical works**

WorkCover NSW (2009) states that the main causes for electrical hazards are contact made with overhead power lines and underground cables. Furthermore, installing, repairing, and maintaining electrical installations are also common causes.

During the design phase, the engineer can specify that overhead power lines be disconnected, re-routed, covered or be underground before construction starts (WorkCover NSW, 2009). This will avoid contact between the power lines and cranes, mobile plant, scaffolding, and other tall

equipment. However, in situations where it is not possible to disconnect and re-route the power lines, the engineer can adjust the design to fit the layout of the power lines. Therefore, access roads, material dumping sites, and unloading areas can be located away from overhead power lines.

During electrical installations, the engineer can minimise the need for electricians to work in cramped or restricted work areas during construction or maintenance. The engineer can consider the location of, access to, egress from, and space in the switch room in the design (WorkCover NSW, 2009). For example, the engineer can design adequate working space when the switchboard doors are opened and extra space for the manual handling of aids, such as trolleys.

Engineers can also aim to minimise the length of large cables by considering the location of the switch room. If possible, the engineer can advise the contractor that cables should always be laid “top down”, as gravity can assist in the laying of the cables, rather than moving them from the “bottom up”. The engineer can also specify that the contractor should consider using mechanical cable pulling machinery, if possible, to avoid manual handling risks (WorkCover NSW, 2009).

To summarise, the engineer can indicate the location of underground electrical cables and overhead power lines. The design can also be a logical approach with regard to electrical works i.e. adequate space can be provided for the electrical sub-contractor to perform efficiently.

### **3.3.3 Ergonomics**

Ergonomics are generally defined as a discipline focused on making products and tasks comfortable for the user and the person performing the task. Therefore, during the design phase of a building, the engineer can take the capabilities and limitations of the contractors and employees into account (WorkCover NSW, 2009). With regard to the actual construction of the building, the engineer can consider the tasks the contractors and their employees would carry out on site (Jones, 2009). Therefore, they can consider how the design and layout of the construction site will affect those working on it.

An example of an ergonomic consideration is for the engineer to avoid designing construction and maintenance activities that require work to be done in restricted areas or areas with difficult access. They should also aim to avoid designs that would require repetitive or prolonged movements to complete jobs.

### **3.3.4 Excavation**

A number of safety risks are associated with excavation (WorkCover NSW, 2009), (Zou, et al., 2007):

- The collapse of the excavation.
- Objects or employees falling into an excavation.

- Employees exposed to hazardous substances during the excavation process, for example the exposure to carbon monoxide from plant driven by an internal combustion engine or by digging into contaminated material.
- Damage done to underground services, for example power cables, water or sewer pipes, or gas pipes.

The aim for the engineer can be to design the excavation process in such a manner that it provides a safe working environment for the employees on site (WorkCover NSW, 2009). The latter means that the engineer can identify those hazards associated with excavation and inform the contractor of it. This, however, includes designing alternative processes to avoid excavation in certain circumstances (WorkCover NSW, 2009).

The engineer can indicate the location of existing underground services that include electrical cables, gas pipes, and sewer - and water pipes. The exact location is provided to the contractor by means of service plans. The engineer may also be able to adjust the position of the building or its temporary works to avoid contact with underground services (WorkCover NSW, 2009). In scenarios where the position of the building or its temporary works cannot be adjusted, the engineer can indicate that underground services are relocated. Therefore, it will be beneficial for the safety of the employees if engineer is aware of site conditions and construction processes that will enable him or her to adjust the design to fit the circumstances.

The engineer can play a part during excavation to prevent collapse of the excavation or objects and employees falling into it. The same as for a number of other construction site hazards, the responsibility of the engineer is not to avoid risks during the actual excavation process, rather during the design process. For the actual excavation process, the contractor is responsible to ensure the safety of the excavated and surrounding area (Department of Labour, 2003). However, the design can still include information that will assist the contractor to ensure a safe working environment. This information includes the specification and allowance of sufficient space for the sloping and benching of excavations. The design can indicate that excavations are performed away from static loads (such as buildings, wall, and immobile plant) or dynamic loads (such as traffic and excavation equipment) (WorkCover NSW, 2009). The design can also avoid employees to work near deep trenches to prevent them from falling into the excavation (Department of Labour, 2003).

### **3.3.5 Hazardous substances**

The choice of substances to be used during the construction of a building can be adjusted by the engineer (WorkCover NSW, 2009). The engineer can reduce the risks created by hazardous

substances by specifying that less hazardous alternatives are used. Hazardous substances may be present in (WorkCover NSW, 2009), (Gilbertson & Arup, 2007):

- Concrete (cement, plasticisers, accelerants, and retarders);
- Masonry (cleaners, sealants, and insulation);
- Surface coatings (spray painting);
- Steelwork (paints, rust-proofing, grout, and welding fumes);
- Timberwork (paints, preservatives, and flame retardants);
- Adhesives.

Throughout the construction process, employees are exposed to hazardous substances that are the result of a certain construction activity. For example, during demolition, large amounts of dust are present that are hazardous to the health of those working on site.

The total prevention of dust seems like an impossible task to perform on a construction site. The engineer cannot, through design, prevent dust created by demolition or strong winds. In these cases, the engineer can monitor that employees are equipped with the necessary safety equipment (Zou, et al., 2007). Therefore, the engineer can require from the contractor to include the usage of safety equipment in his or her health and safety plan. However, dust is also created by other construction processes such as cutting. For processes like this, the amount of dust created can be managed by eliminating the use of these processes and by recommending alternative methods to the contractor (WorkCover NSW, 2009).

During demolition and refurbishment, the removal of asbestos may be required. The materials that asbestos consist of presents major health risks to those employees working on site (WorkCover NSW, 2009). The role of the engineer in this case can be to monitor that only licensed asbestos removal contractors carry out the removal of asbestos.

Asbestos may be present in the following material (WorkCover NSW, 2009):

- Ceiling tiles;
- Asbestos cement building tiles (corrugated and flat sheets, pipes and gutters);
- Fire doors;
- Wall and ceiling sheeting in wet areas (bathrooms).

### **3.3.6 Maintenance**

The engineer can improve the safety of maintenance - and cleaning employees, by incorporating safe access to roofs, plant rooms and windows in the design (WorkCover NSW, 2009) (Safe Work Australia, 2011).

As mentioned before, preventing a risk is easier than mitigating it after it occurred (Safe Work Australia, 2011) (Smallwood, et al., 2009). Therefore, the engineer can avoid unsafe access by designing plant rooms reasonably and sensibly. For example, serviceable plant and pipes can be designed at ground level, rather than roofs or other heights.

The engineer can ensure that permanent safe access is provided as part of the building. This include designing stairs or walkways with guardrails, externally by providing a building maintenance unit or other access system for window cleaning, or internally by providing balconies or suitable reversible windows (WorkCover NSW, 2009).

The engineer can also specify materials with high durability and low maintenance requirements in the design. This will increase the periods between maintenance activities.

### **3.3.7 Manual handling**

Kogi & Serbitzer (1992) mentions manual handling is one of the most significant causes of workplace injuries across all industry sectors.

Building materials that may be manually handled by employees include concrete blocks or cladding and temporary structures, such as scaffolding. These materials are often specified by the engineer during the design phase and may have a serious impact on the safety of employees moving and installing them (WorkCover NSW, 2009). The engineer can eliminate the need for manual handling of heavy components by specifying lighter products that meet the design criteria. The location of the delivery point for materials can be indicated at a convenient location to shorten manual hauls (WorkCover NSW, 2009), (Zou, et al., 2007).

However, large pre-fabricated building components should be lifted by a crane to reduce ergonomic issues as discussed in Section 3.3.3.

### **3.3.8 Plant and equipment**

According to the JBCC Principal Building Agreement (2000), Clause 19.3; the contractor shall be responsible to provide, maintain and remove, on completion, all plant, equipment and scaffolding. With regard to construction safety that is affected by plant and equipment, the contractor is mainly the responsible party (Department of Labour, 2003). However, the engineer can still play a part during the design phase as it may result in the safety of the construction site to increase.

The engineer can improve safety and efficiency by allowing for the use of temporary works equipment and scaffolding by monitoring that level surfaces and sufficient room are present on the construction site (WorkCover NSW, 2009).

The engineer can also monitor that sufficient room and good foundations are provided for the movement of cranes. Good foundations mean to avoid poor or uneven ground (WorkCover NSW, 2009).

The responsibility of the engineer in this case is only to point out possible hazards to the contractor. Therefore, for safety hazards associated with plant and equipment, the engineer may be viewed as a safety assistant to the contractor. The engineer can monitor that the contractor includes proof in the health and safety plan that he or she is aware of the hazards associated with plant and equipment and that all machinery are reliable.

### **3.3.9 Refurbishment**

According to Kogi & Serbitzer (1992), refurbishment is an important and hazardous aspect of the renovation process of a building.

Refurbishment often includes strengthening the structure of the building, replacing windows and floors, stripping or replacing cladding, or total rewiring (WorkCover NSW, 2009). Therefore, the design process for refurbishment is more or less the same as for construction or demolition. This implies that hazards caused by refurbishment are similar to those associated with construction and demolition work. Hazards under refurbishment include (WorkCover NSW, 2009) (Behm, 2006):

- Structural collapse.
- Employees exposed to hazardous substances.
- Employees falling from heights.
- Employees working in confined spaces.

Once the construction of the building has been completed, hazards may be more difficult to control where the premises remain occupied by the public during refurbishment. Therefore, the engineer may be able to detail the works in a way to minimise the risk of public access to areas where work is to be carried out.

Although this research is primarily focused on the safety hazards for construction employees, it is still important to ensure the safety of the public and those employees responsible for refurbishment after the completion of the building. Therefore, it will be beneficial for the safety of employees if the engineer, designing for refurbishment, is aware of the following structural information (WorkCover NSW, 2009), (Jones, 2009):

- The age of the building that will provide information on the building and design techniques employed during its construction.



- The strength of the building which will identify how structural additions should be supported by the additional structure.
- The actual condition of the building which will identify possible weaknesses of the structure.
- The materials used will also provide information on the strength and condition of the building.

### **3.3.10 Steelwork**

Steelwork often requires work to be done at heights on incomplete structures and often involves the use of machines (WorkCover NSW, 2009).

The provisions for steelwork that are mentioned below are generally the responsibility of the steel fabricator. However, the engineer can be able to improve the safety of steelwork erection by monitoring that the provisions are carried out and that the design allows for and enables it. The following provisions are identified:

- The engineer can monitor that the patterns of bolt holes are as uniform as possible throughout the frame for easy insertion of bolts.
- The engineer can also monitor that pre-attached seating cleats are provided on columns at joints with beams. This will ensure that the ends of the beams are stationary while bolts are inserted.
- The engineer can ensure that safe access stairs form part of the original structure to avoid the use of loose ladders and beams for access.
- The engineer can also specify that holes be drilled into columns during fabrication. This will allow steel erectors to use the columns as anchors for fall-arrest systems.

However, an engineer responsible for the design of steelwork will benefit from construction site experience. As such, it will be beneficial for the safety of employees if the engineer is aware of construction processes for the erection of steelwork as there is often a risk of instability and collapse. The engineer can also be aware and monitor that temporary bracing is used for vulnerable steel members (WorkCover NSW, 2009).

### **3.3.11 Utilities**

Clause 4.0 of the Principal Building Agreement discusses the matter of design responsibilities. It clearly states in Clause 4.1 that the contractor shall not be responsible for the design of the works other than the contractor's or his subcontractors' temporary works (Joint Building Contracts Committee Inc., 2000). Therefore, the design of the actual building, excluding the temporary works, is the responsibility of the engineer.

The design of utilities, such as electricity, gas, water and telecommunications is usually carried out by specialist subcontractors or their appointed engineers (Kogi & Serbitzer, 1992). According to the JBCC Principal Building Agreement (2000), the contractor is responsible for the design of the subcontractor's temporary works. Therefore, the responsibility for the design of the utilities often rests with the specialist subcontractor.

However, the engineer can still be responsible to design provisions in the building for the installation of utilities. The provisions include ensuring adequate space for ducts and equipment for subcontractors to work from safe positions (WorkCover NSW, 2009).

### **3.3.12 Work done on roofs**

Work done on roofs is seen as hazardous to employees due to severe heights. Also, fragile materials are often involved. The risk of falling from edges or through fragile or incomplete roofing surfaces is a possibility (Jones, 2009). With regard to the design of roofs, the engineer can consider the following matters and include it in the health and safety specifications of the building project (WorkCover NSW, 2009):

- The use of fall prevention equipment (guardrails and guardrail attachments at the perimeter).
- Measures to prevent falls through the roof, such as roof member spacing and safety nets. This matter is primarily the responsibility of the contractor. However, the engineer can assist the contractor by bringing this matter to his or her attention.
- Providing anchorage points for a fall arrest system (refer to Section 3.3.10).
- The strength of the roof members to which guardrails are attached or which act as an anchorage point for a fall arrest system.
- Provisions for safe access to or through the roof space.

The use of fragile materials presents a significant hazard to construction employees, and an even greater hazard to maintenance employees, who may be unaware of their fragile nature (WorkCover NSW, 2009). The engineer can improve the safety of employees in this case by specifying that fragile materials are not used on roofs. Apart from avoiding fragile materials, the engineer can also specify a safety net to be installed during construction (Jones, 2009).

### **3.3.13 Construction site hazards - conclusion**

For the construction site safety hazards mentioned above, the engineer can play a role to increase the safety of those working on site. However, for some of the hazards, the responsibility of the

engineer is limited to the identification of the hazard and to pointing it out to the contractor or sub-contractor. Therefore, for some hazards the engineer acts as an assistant to the responsible party.

An engineer will benefit from construction site experience. This will improve his or her knowledge of construction processes and it can then be incorporated into the design.

Since the engineer can be responsible to identify and point out the various hazards to the contractor, the two parties should be in close collaboration. This will ensure that the possible hazards and the best possible manner in which hazards can be mitigated are identified. A close collaboration can be achieved by the effective transfer of knowledge between the engineer and the contractor. Knowledge transfer between the two parties is discussed in Section 3.5.

### 3.4 Proposed Safe Design Process

As mentioned in Chapter 1, contractors and employees expect their workplace to be a safe environment with regard to their own safety, health and welfare. A cost-effective and practical approach towards safe design of construction sites is to avoid introducing a hazard to the construction site by eliminating it during the concept development phase.

Caple (2010) defines safe design as follows:

*“Safe design is the integration of hazard identification and risk assessment methods early in the design process to eliminate or minimise the risks of injury throughout the life of the product being designed.”*

Therefore, an engineer should adopt a safe design approach that considers the safety of those responsible for the construction, maintenance, cleaning, repairing, and demolishing of a building. **A safe design approach is a process in which safe design principles, risk management, consultation, and reporting are taken early into account to minimise the risk for accidents on construction sites** (WorkCover NSW, 2009). However, it is the construction knowledge and experience of the engineer that is important to adjust the process to suit the particular requirements and restrictions of the project.

Eliminating a hazard during the concept development phase is the start of an effective safe design approach as it provides the best opportunity to make fundamental decisions since much of the design is still to be determined (CIDB, 2010).

According to WorkCover NSW (2009), an effective safe design approach consists of eight steps taken in a certain order. These steps are listed below and discussed in the following sections:

1. Discuss the project and project scope.

2. Identify design team.
3. Determine means of communication.
4. Prepare a risk identification and mitigation register.
5. Provide an initial report to the client.
6. Modify and finalise the initial design.
7. Provide a final report to the client and contractor.
8. Evaluation of the design.

### **3.4.1 Discuss the project and project scope**

An important aspect of a safe design procedure is the effective transfer of knowledge and communication between those involved in the project. To comply with the latter, a strong and collaborative relationship between the participants is necessary to ensure the effective exchange of information (WorkCover NSW, 2009) (CIDB, 2010).

A safe design process starts when the client discusses the requirements of the building with the engineer and provides preliminary information about certain hazards that should be considered during the design process.

### **3.4.2 Identify design team**

As soon as the engineer has been appointed for the design of a building, the client in collaboration with the engineer should decide on an appropriate design team. The expertise of a diverse group of designers will ensure that more hazards are identified during the design phase of a project.

### **3.4.3 Determine the means of communication**

After the design team has been identified, the engineer should determine convenient and effective means of communication within the team. According to WorkCover NSW (2009), the size of a project is commonly used to determine the method of communication.

For large projects, a formal workshop that is led by a skilled facilitator is recommended. However, if it proves impractical to gather the design team in one place, a well-planned survey can be used to gather information (WorkCover NSW, 2009). For smaller projects, a consultation process may be as simple as a series of phone calls between participants seeking clarification on identified risks.

### **3.4.4 Prepare a risk identification and mitigation register**

In consultation with the design team, the engineer should lead a preliminary risk analysis. The aim is to identify certain hazards that may cause risks prior to the detailed design. These risks should be

recorded in a risk and mitigation register that is used to identify the probability of a risk to occur and the impact that risk will have on the project.

The knowledge of different construction site risks is important for the engineer as designer. By being aware of the risks, the engineer is able to tune his design during the early stages to avoid the risks. Different building construction site hazards were discussed in more detail in Section 3.3. However, Table 3 below presents 12 safety hazards for the construction site that may be affected by the design of buildings.

**Table 3: Possible safety hazards for the construction of buildings (WorkCover NSW, 2009)**

<b>Safety hazard</b>	<b>Considerations of hazard</b>
Access and egress	The access and egress requirements that includes the position and number of emergency exit points, emergency procedures, obstructions, and lighting.
Building material	Risks relating to the material used to construct the building, e.g. Material flammability or emissions of toxic fumes.
Building profile	Construction risks relating to the shape and complexity of the building profile.
Confined spaces	Risks relating to work done in enclosed spaces, including the release of toxic fumes and the lack of ventilation.
Construction method and equipment	Risks relating to the position of construction plant and materials, the use of scaffolding, the movement and operation of equipment, and the sequence and timing of works.
Demolition	Risks relating to the demolition of the building, including premature collapse and the emission of hazardous materials during demolition.
Electrical wiring and equipment	Risks relating to electrical works, including overhead and underground cables, switch-boxes and electrical equipment.

Design hazard	Considerations of hazard
Environmental conditions	Risks relating to weather conditions e.g. rain, floods, and high winds.
Excavation	Risks relating to excavation done near to or during construction, including the stability of the structure and using plant and machinery near an excavation.
Heights and depths	Risks relating to working at heights, including falls and objects being dropped.
Movement of materials, plant and vehicles	Risks relating to the safe movement of materials, plant and vehicles that include the space required for their safe movement, ramps, slopes, and distances of movement.
Structural strength and stability	The permanent and temporary loads borne by the structure itself, as well as the reliability of temporary structures.

By making use of a risk and mitigation register, the design team aims to identify the above mentioned hazards, their probability of occurrence, and possible consequences. Finally, the risks should be ranked according to the severity of each.

If the contractor has been appointed, it is during this phase that the engineer should be in close collaboration with the contractor who provides his or her construction knowledge to the engineer to ensure maximum risk identification and mitigation (Mroszczyk, 2005).

### 3.4.5 Provide an initial report to the client and contractor

The engineer should provide the client and contractor (if appointed already) with an initial report to enable a decision on design options. This report should include:

- A record of the identified construction site risks.
- An assessment of these risks for the client and contractor to understand their relative importance and prioritise control measures.
- How these risks can occur.

- An explanation of design measures that partially control the risks.
- Any additional information that could help contractors to eliminate or control the risks.

#### **3.4.6 Amend and finalise the design**

On the basis of the information provided in the initial report, the client may agree on modifications to be made to the design.

#### **3.4.7 Provide a final report to the client and contractor**

Once the modifications have been made to the design, a final report should be provided to the client and contractor (if appointed already). This report will include the same information as in Section 3.4.5; however, the final report would include fewer risks as the design had been modified to ensure their elimination. The final report is also used to identify any residual risks (risks that have not been completely eliminated or controlled during the design of the building or structure).

#### **3.4.8 Evaluation of the design**

Finally, the design should be reviewed as new information may have been brought to the attention of anyone in the design team that may affect the original design decisions.

#### **3.4.9 Benefits of a safe design process**

The use of a safe design process ensures that safe design principles are used which will result in improved safety and reduced risk and injury to those working on site (Mroszczyk, 2005). An unsafe design (a design that does not efficiently eliminate or minimise health and safety risks) contributes to a significant loss in project costs due to production downtime, higher insurance premiums, and the costs associated with possible litigation. Therefore, it is more economical to eliminate possible construction site hazards during the design stage than to control them after the building has been constructed.

A safer design can also reduce the costs of subsequent safety measures. For example, the use of wall mounted lighting on balconies, rather than ceiling mounted lighting, reduces the need for maintenance staff to work at heights. As well as reducing costs, a safe design process can help simplify the risk control process; providing a greater ability to predict and manage hazards (WorkCover NSW, 2009).

### **3.5 Efficient Knowledge Exchange to Improve Constructability**

Cheng (2009) states the construction industry is viewed as a project-based industry where knowledge is distributed between different construction projects and participants. Due to the

complex nature of construction projects that include a number of challenges, knowledge will seldom be shared or reused correctly if it is not transferred effectively and acquired correctly.

According to the JBCC Principal Building Agreement (2000), Clause 15.8, the engineer and the contractor shall hold regular meetings related to the progress of the works and to discuss any other matters relating to the project. However, sufficient collaboration between the engineer and the contractor may sometimes be absent during the conceptual design, or the detailed design phase. Therefore, it is important for engineers to have sufficient experience and knowledge of construction processes to produce designs that are suitably constructible (Kuo, 2012).

According to Kuo (2012), problems associated with design management practices relate to a poor understanding of constructability and the sharing of constructability knowledge between participants.

Section 3.4 aims to identify the importance of keeping constructability in mind during the design phase. Therefore, this section will discuss the importance of constructability and what it entails. The different constructability principles that need to be considered by the engineer during the design phase are identified. This section discusses a study done by Kuo (2012) that shows the different views of engineers and contractors with regard to constructability values. Finally, general information is identified that needs to be exchanged between the engineer and contractor to ensure a safe design and construction environment.

### **3.5.1 Constructability during design**

Constructability entails the incorporation of construction knowledge during the design phase of a building. One of the subsets of the overall project constructability is safety constructability (Gambatese, 2000).

Gambatese (2000) defines safety constructability as a process in which construction site safety is addressed during the design phase. Studies have shown that construction site safety is generally not included in the design due to a lack of involvement in safety by the engineer (Gambatese, 2000). The lack of involvement can be attributed to the lack of construction knowledge, lack of safety education, lack of experience of the engineer, and an attempt by the engineer to minimise liability exposure.

Kuo (2012) investigated several studies that discussed the matter of engineers being unfamiliar with construction processes. These studies revealed the following (Kuo, 2012):

- Engineers often do not consider the impact of construction constraints.



- There is a lack of communication between engineers and contractors that lead to designs being unsafe, difficult and expensive to build.
- A lack of construction experience in the design team and the absence of tools to assist designers in addressing constructability.
- Engineers fail to consider how a contractor will implement the design and this may result in problems, delays, and disputes during the construction process.

Therefore, it is evident that a lack of construction and constructability knowledge in the engineering offices is present. Gambatese (2000) states a lack of construction and constructability knowledge contributes towards a lack of involvement in safety by engineers. Kuo (2012) also states that there is no comprehensive explicit definition for constructability knowledge and an uncertainty is present of what exactly needs to be shared with the contractor. Therefore, the key constructability principles that need to be taken into account by the engineer during design is important to be identified.

### **3.5.2 Constructability principles for design**

Constructability is seen as a system for achieving the best possible integration of construction knowledge during the construction process. It allows various project and environmental constraints to be balanced to achieve maximisation of project goals and building performance (Griffith & Sidwell, 1997). The introduction of constructability principles during the conceptual planning, design, procurement, and construction phase can ensure the total building process to be successful with regard to time, cost and safety.

Kuo (2012), Griffith & Sidwell (1997), Jergeas & Van der Put (2001), and El Hourani (2008) studied the important constructability principles that need to be considered by all project participants for the project to be successful. However, this research focuses on those constructability principles that need to be considered by the engineer during the design stages of the project to improve construction employee safety. The following principles are identified (Kuo, 2012), (El Hourani, 2008), (Jergeas & Van der Put, 2001):

- 1) Simplicity - The engineer as designer should attempt to produce details at the most simplistic level that fits the requirements of the building.
- 2) Level of tolerance – The engineer should recognise that different materials and components that are used on site have different composition. Therefore, these materials and components require different jointing methods. A practical level of tolerances for the materials and components should be adopted. Knowledge of site conditions and different construction methods is essential for the engineer in this case. The level of tolerance can also be applied in close collaboration with ergonomics, as discussed in Section 3.3.3, as the

engineer should also be aware of the capabilities of the employees on site during the design phase.

- 3) Proper scheduling – The engineer should also aim to produce proper construction scheduling during the design phase to ensure smooth construction progress. A detailed and carefully planned schedule will allow for a systematic construction process. Proper scheduling also includes the manner in which similar buildings are built, i.e. if the project includes a series of buildings to be built, the engineer should employ a similar sequence of operations for all buildings. This will ensure efficiency and familiarity with construction processes and will lead to safer construction conditions.
- 4) No damage to finished elements – The building and construction processes should be designed in a manner where damage to finished elements of the building is avoided. Therefore, the design should ensure work to be carried out safely for the construction employees and also for the building itself. This will reduce the need for construction employees to repair damage elements and will lead to construction time to be reduced that minimises construction employee safety risks.
- 5) Standardization – Engineers should design building to be constructed by using standardized construction elements and components. The use of these elements will reduce costs, construction time, and the safety risks that are associated with customized elements.
- 6) Accessibility - The design should promote easy access to construction materials and equipment for construction employees.
- 7) Integrated approach between participants – The entire team of the building project should be allowed to participate at any level throughout the project life-cycle. Early project planning and discussions should be held to avoid interferences between the design and construction process. Therefore, the engineer and the contractor should communicate and exchange information from the beginning of the project to ensure a design that suits the construction methods of the contractor. However, Kuo (2012) mentions there is a sense of uncertainty of what type of information should be communicated and shared between the engineer and contractor.

This research aims to identify the specific information that needs to be exchanged between the engineer and contractor that will lead to a safer and more constructible working environment.

### **3.5.3 Difference in constructability values**

Even if engineers and contractors make an effort to communicate with each other during the life-cycle of a building project, problems with communication still persist and this might be due to a

difference in the values by the two parties (Emmitt, et al., 2005). However, an aim of any construction project should be to identify the differences between the engineer and the contractor and to develop a solution that is acceptable to both parties. Emmitt et al. (2005) states all project participants should engage in a dialogue to investigate and then confirm a set of values that forms the basis of the project.

Research done by Kuo (2012), investigated the views of both the engineers and contractors of South Africa with regard to constructability values. Both parties were asked to rate the constructability values below in descending order of importance. The following values were tested (Kuo, 2012):

- 1) Contractor's resources should be allowed economic use.
- 2) Design requirements should be enabled to be visualised and co-ordinated by those working on site.
- 3) Contractors should be allowed to develop and adopt alternative construction details.
- 4) Contractors should be allowed to overcome restrictive site conditions.
- 5) The design should enable standardisation of construction materials and components.
- 6) The design should allow for a freedom of choice between prefabricated and onsite works.
- 7) Simplification of construction details should be enabled in case of non-repetitive construction elements.
- 8) A more flexible construction design should minimize the impact on the project due to adverse weather conditions.
- 9) The design should be done in a manner that safe construction sequences on site are achieved.

Figure 3 presents the importance of each constructability value as rated by South African engineers and contractors. Note that the numbers in front of each constructability value listed above should be used as reference to identify the constructability values in the graphs presented by Figure 3.

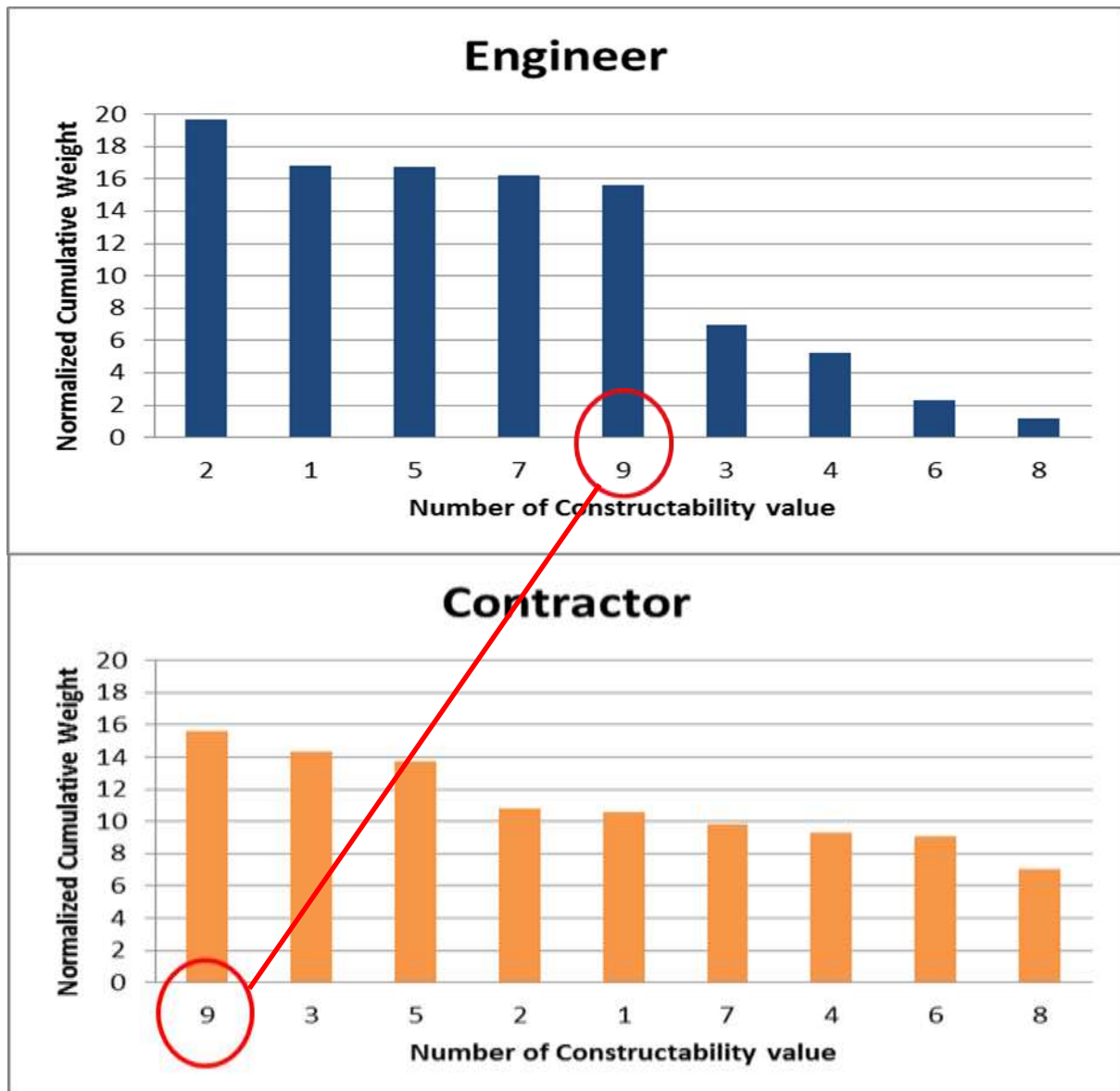


Figure 3: Different views by South African engineers and contractors with regard to constructability values (Kuo, 2012).

It is important to note that the normalized cumulative weight as shown in Figure 3 does not represent a degree of importance of each constructability value. It rather shows the relative importance of each constructability value to the other values.

It is clear from Figure 3 that a difference between South African engineers and South African contractors do exist with regard to constructability values. Important for this research, contractors voted safety of construction sites to be the most important value in comparison with engineers who voted construction safety to be the fifth most important (refer to number 9 on the X-axes in Figure 3). This is an indication of the lack of involvement in construction safety by South African engineers.

As already mentioned, the engineers and contractors should come to a consensus about the values for a project that will be the start of an integrated approach throughout the project life-cycle. An integrated approach for a building project should enable work to be done more efficiently by both parties, leading to a more desirable working environment. In order to develop integration between the engineer and contractor that will lead to safer working environments, the two parties should share important information.

#### **3.5.4 General information exchanged between the engineer and contractor**

As mentioned before, integration between all participants for a construction project is necessary to improve the constructability of the project that will lead to a safer working environment. The successful exchange of information between the engineer and the contractor is one way to ensure integration between them.

However, the problem still persists in the form of the type of information that should be shared between the engineer and contractor. This research aims to identify the information, in specific detail, that the engineer needs to share with the contractor.

The Construction Regulations include the responsibilities of the client to ensure his or her compliance with the Occupational Health and Safety Act (1993). However, according to the Principle Building Agreement (2000), the engineer can be appointed as an agent for the client. Therefore, the responsibilities for the client in the Construction Regulations may also be applicable to the engineer. These responsibilities are seen as a general approach to what the engineer should do during a construction project and no specific details are provided. The responsibilities can also be seen as the work that needs to be done by the client and provided to the contractor. Therefore, it is a general view of the type of information that the engineer should share with the contractor.

According to the Construction Regulations, the following information needs to be shared by the engineer to improve safety on the construction site:

- 1) The engineer should share the health and safety specifications for the construction work with the appointed contractor, or any other contractor who is making a bid for the project.
- 2) Information which might affect the health and safety of any employee carrying out construction work.
- 3) The engineer should also undertake periodic audits, at least once a month, and share the results of the audits to ensure that the contractor's health and safety plan is implemented and maintained on the construction site.

- 4) The engineer should stop the contractor from executing any construction work which is not in accordance to the health and safety plan of the contractor. Therefore, any construction work that poses a threat to the health and safety of the construction employees.
- 5) Sufficient health and safety information needs to be shared with the contractor to ensure that the work is executed safely where changes are brought about.

As mentioned in Section 3.3.13, the identification of construction site hazards by the engineer is important and should be pointed out to the contractor.

The five types of information that are mentioned above are just a general view of what the engineer should share with the contractor. For example, number 2 states that information that might affect the health and safety of an employee on site should be shared with the contractor by the engineer. The problem is that there is an uncertainty of what that specific information should be. Therefore, this research aims, by means of case studies and questionnaires, to identify the specific information that needs to be shared by the engineer in order to contribute towards a safer working environment.

### **3.6 Summary of Literature Study**

The literature study aims to explore existing and related research on designing for safety with focus being on the responsibilities of the engineer, as designer, throughout the life-cycle of the building project. Safety can be defined in many ways; however, this research adopted the following definition of safety from CIDB (2010):

*“Safety is a state in which the risk of harm or damage to a person is limited to an acceptable level.”*

The research is set out to identify what is acceptably safe, with regard to the work done by the engineer as designer. However, the research also emphasises the importance of health and safety on construction sites to be an integrated approach from start to finish by all project participants.

The need for an integrated approach and safe designs in the South African construction industry can be related to the large contribution it makes towards the occupational accident rate in South Africa. The total of construction accidents in South Africa, whether it is fatal, non-fatal or non-casualty, increased for the period from 2004 to 2008. The reason for the increase is not due to a lack of health and safety legislation in South Africa, but rather the enforcement of adequate health and safety systems within the construction industry. Inter alia, an adequate health and safety system includes a safe design process.

A safe design process is the integration of hazard identification and risk assessment methods early in the design process to eliminate or minimise the risks of injury throughout the life of the product being designed. Therefore, the engineer should adopt a safe design approach that considers the safety of those working on the construction site somewhere during the life-cycle of the project. Knowledge of construction processes and experience are important to the engineer when designing a building, as the engineer will be able to adjust the design process to fit the particular requirements and restrictions of the project. An effective safe design approach eliminates possible hazards during the concept development phase or minimises the risks that may occur from a specific hazard. A safe design approach, as recommended by WorkCover NSW (2009), consists of the following in steps:

1. Discuss the project and project scope.
2. Identify design team.
3. Determine means of communication.
4. Prepare a risk identification and mitigation register.
5. Provide an initial report to the client.
6. Modify and finalise the initial design.
7. Provide a final report to the client and contractor.
8. Evaluation of the design.

As a designer, the engineer should be aware of any construction hazards that may endanger the health and safety of the employees working on site. Depending on the hazard, the engineer plays either a direct or indirect role in contributing towards a safe working environment. This research identifies 12 hazardous construction processes or subjects of concern that the design has a direct or indirect impact on. The following processes are identified:

- Demolition;
- Electrical works;
- Ergonomics;
- Excavation;
- Hazardous substances;
- Maintenance;
- Manual handling;
- Plant and equipment;
- Refurbishment;
- Steelwork;
- Utilities;

- Work done on roofs.

For the construction processes mentioned above and the safety hazards associated with each, the engineer can increase the safety of those working on site. However, for some of the processes, the responsibility of the engineer is limited to the identification of the hazard and to pointing it out to the contractor or sub-contractor. Therefore, for some hazards the engineer acts as an assistant to the responsible party.

An engineer will benefit from site experience as this will improve his knowledge of construction processes and it can then be incorporated into the design.

Since the engineer can be responsible to identify and point out the various hazards to the contractor, the two parties should be in close collaboration. This will ensure that the possible hazards and the best possible manner in which hazards can be mitigated are identified. A close collaboration can be achieved by the effective transfer of knowledge between the engineer and the contractor.

Constructability includes the incorporation of construction knowledge during the design phase of a building. Therefore, effective construction knowledge transfer between the engineer and contractor ensures the constructability of the building to increase. One subset of the overall project constructability is safety constructability that is defined as the incorporation of construction site safety concerns during the design phase. Again, the importance of an engineer being familiar with construction processes, having construction site experience, and identifying construction site hazards is emphasised. However, a study done by Kuo (2012) revealed that there is a lack of construction and constructability knowledge in some of the engineering offices of South Africa and the lack of knowledge contributes to a lack of involvement in safety by engineers.

Alongside the identification of construction site hazards, a safe design approach will also be achieved if the engineer considers constructability principles. The introduction of constructability principles during the conceptual planning -, design -, procurement -, and construction phase can ensure the total building process to be successful with regard to time, cost and safety. Kuo (2012), Griffith & Sidwell (1997), Jergeas & Van der Put (2001), and El Hourani (2008) studied the important constructability principles that need to be considered by all project participants for the project to be successful. However, this research focuses on those constructability principles that need to be considered by the engineer during the design stages of the project to improve construction employee safety. The following principles are identified:

- Simplicity;
- Level of tolerance;



- Proper scheduling;
- No damage to finished elements;
- Standardization;
- Accessibility;
- Integration between project participants.

The literature study also identifies the primary and secondary legislation in South Africa that has an impact on construction health and safety. The primary legislation is identified to be the Occupational Health and Safety Act No.85 of 1993, and the Occupational Injuries and Disease Act No.130 of 1993. One of the regulations that are distributed under the Occupational Safety and Health Act is the Construction Regulations that was promulgated in July 2003 (Smallwood, et al., 2009).

The Construction Regulations can be seen as a document that defines the legal duties for the safe operation of South African construction sites. The legal duties are specifically placed on clients, designers, and contractors and assist these parties in their approach to health and safety. The Construction Regulations are applied throughout the life-cycle of a construction project i.e. from the inception phase to the final demolition and removal phase.

The Construction Regulations possess the unique characteristics that entitle it to have an impact on the health and safety in the South African construction industry. The following characteristics are identified:

- 1) The responsibility for construction health and safety is redistributed away from the contractor. The contractor was solely responsible for health and safety on construction sites in the past. However, the Construction Regulations, since 2003, include all participants in the construction process from the client through to the final end-user.
- 2) The Construction Regulations convince project participants that health and safety management is a requirement that needs to be included into the planning and design of all construction projects.
- 3) The importance of construction hazards identification, construction hazards assessment and the elimination of risks are highlighted. The Construction Regulations emphasises that health and safety risks on construction sites should be avoided, or at least be reduced.
- 4) Emphasis is placed on the importance of considering health and safety concerns throughout the entire life-cycle of the construction project. Therefore, from the inception phase until the final demolition phase, including operation, utilisation and maintenance periods.

- 5) The Construction Regulations mention the formulation of compulsory health and safety specifications and plans that act as instruments to facilitate the exchange and communication of health and safety concerns between project participants.
- 6) The Construction Regulations define a health and safety file that is compulsory to be compiled by the contractor and should be handed to the client upon completion of the building.

The characteristics of the Construction Regulations prove the importance of this research as it acknowledges the roles of each project participant, especially the engineer, with regard to health and safety. Previously, engineers as designers were not required to consider health and safety concerns. However, they are now required to avoid foreseeable risks as a duty for all construction projects.

## CHAPTER 4: CONSTRUCTION SITE SAFETY – CASE STUDIES

This chapter addresses site safety in a practical manner by investigating eight case studies that provide information on accidents during the construction or demolition of buildings. This chapter also focuses on the lessons that can be learned from the investigations. These lessons are limited to what the engineer could have done prior and during construction or demolition to prevent the accident. The eight case studies that were thoroughly investigated are listed in Section 4.3.

Each case study is investigated by using the investigation model that is presented by Figure 4. All case studies are international construction projects and the reasons for choosing only international case studies are mentioned in Section 4.1.

Several additional case studies were analysed and also provided lessons that can be learned with regard to safety on construction sites. However, these additional case studies do not only include building projects, but provide lessons from other civil engineering disciplines that can be connected to the construction and demolition activities of buildings.

### 4.1 Reasons for selecting International Case Studies

Although this research is primarily focused on the impact of South African engineers on the safety of construction sites, discussing and analysing international case studies are also relevant. The reasons for making use of international case studies are the following:

- In collaboration with Chapter 3, international case studies help to identify construction site hazards that need to be taken into account by the engineer from the start of the project. Therefore, these case studies help to identify any hazards that are not mentioned in Chapter 3, or it is used to confirm that the hazards identified in Chapter 3 are legitimate.
- The use of international case studies also helps to identify the information that needs to be shared with the contractor by the engineer as it was uncertain in Chapter 3 what the information should include.
- International case studies assist in identifying construction processes and techniques that are relevant for the engineer to be aware of during the design phase. Few documented case studies on construction site accidents in South Africa were found.

The information gathered from the above mentioned reasons will contribute towards the successful development of questionnaires that will be discussed in Chapter 5. Research done by Tien (2011), Krishnamurthy (2007), Hide, et al., Behm (2006), Higgins (2004), Ratay (2010), Yates & Lockley (2002), Work Safe Compensation Board (2010), the National Institute for Occupational Safety and

Health (2012), and Brown, et al. (2007) were consulted with regard to the actual cases and approaches taken to analyse these cases.

## 4.2 Approach taken for Investigation of Case Studies

To evaluate the case studies selected for review and analysis, a model is developed that aims to provide an analysis of possible links between construction site accidents and designing for safety. An investigation model developed by Behm (2006) was consulted during the development of the model used for this research. The model is developed to analyse the case studies to answer the following two questions:

- 1) *Did an incident occur?* Question 1 will be answered “Yes” if the structure failed during construction, and caused an injury or death to an employee, due to the structure being designed not to withstand construction activities, or if the structure prevented the employee from implementing a temporary safety device.
- 2) *Could any design modifications have been made by referring to the existing literature in Chapter 3?* This question will be answered “Yes” if it is possible that any design modifications could have been made that would have reduced the risk of injury or death to the employee, or would have facilitated the use of temporary safety measures.

The two questions mentioned above are aimed to be answered by analysing each case study using the model presented by Figure 4.

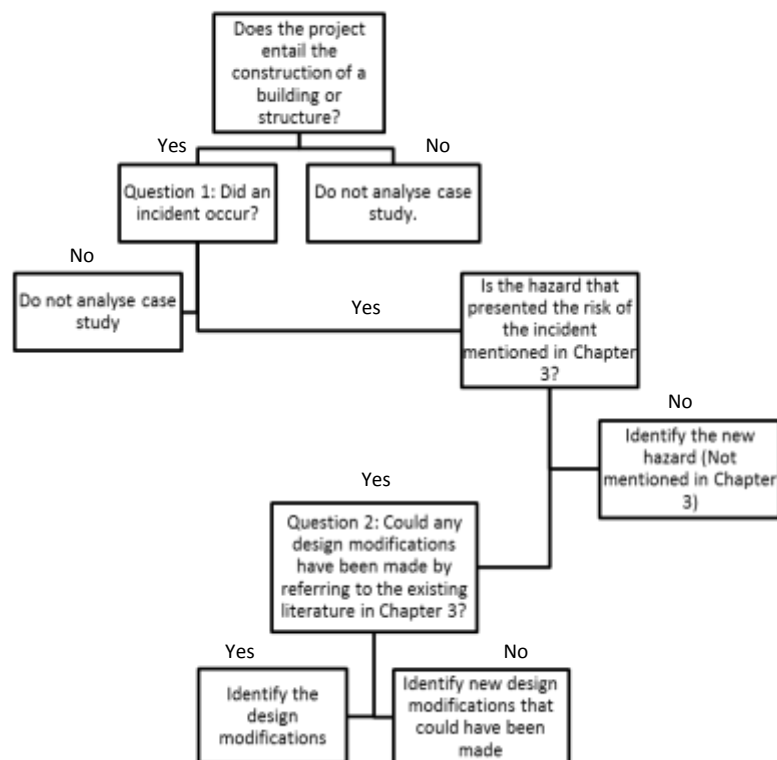


Figure 4: Investigation Model used to analyse case studies.

### 4.3 List of Primary Case Studies Investigated

The list below presents the case studies that are analysed in this chapter. The brackets indicate the hazardous construction processes or subjects of concern that are identified in each case study.

- Case Study 1: Labourer dies after falling from an elevated work platform during construction (Ergonomics, Work done on roofs).
- Case Study 2: Construction employee succumbs after falling from a collapsed precast concrete slab (Work done on roofs, Steelwork, Unsafe design).
- Case Study 3: Construction employee struck by falling steel roof beam (Plant and equipment).
- Case Study 4: Construction employee electrocuted when an extended ladder contacted an overhead power line (Electrical work, Hazardous substances, Plant and equipment).
- Case Study 5: Demolition employee suffered a fatal accident caused by falling through a roof opening (Demolition, Work done on roofs).
- Case Study 6: Operator of equipment succumbed due to chimney falling on hydraulic excavator during demolition (Demolition, unsafe design).
- Case Study 7: Construction employee falls through insulation to concrete floor (Work done on roofs).
- Case Study 8: Construction employee struck by falling wall formwork (Unsafe design).

### 4.4 Case Study 1: Labourer succumbs after falling from an elevated work platform during construction

This section includes the discussion of the background for Case Study 1 and the analysis of the incident or accident that occurred, focusing on possible causes for occurrence (National Institute for Occupational Safety and Health, 2012) (Higgins, 2004).

#### 4.4.1 Background

In South Carolina, a 16-year-old Hispanic construction labourer, that was part of a framing crew, succumbed on March 9, 2004, after falling from a 10 feet high work platform and striking his head against a concrete slab. After the fall occurred, the victim complained of a severe headache to his crew leader. However, he passed away later on the same day.

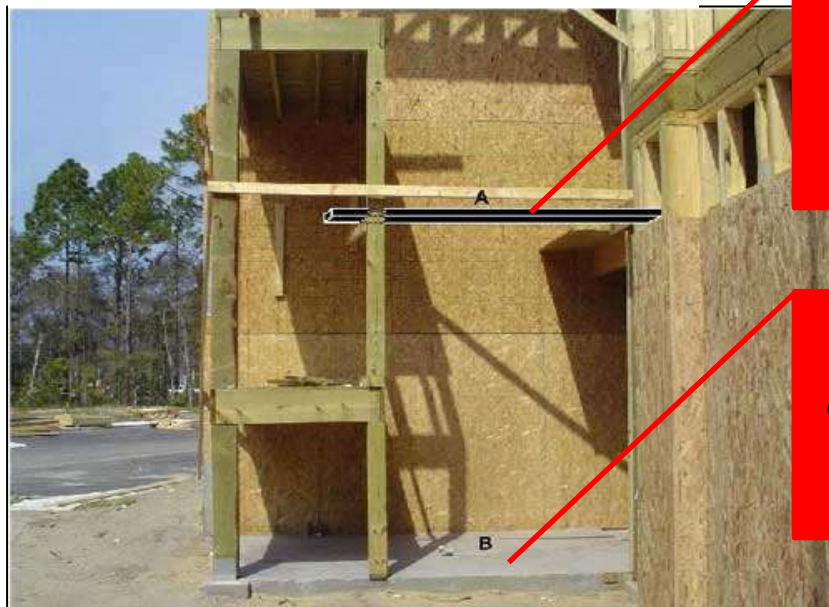
Figure 5 shows a photograph of the condominium that was constructed. Figure 6 shows a photograph of the condominium stairwell and balcony. The letter A indicates the victim's position before the fall occurred and the letter B presents the concrete slab that the victim fell onto.

The victim was paid by a crew leader who was employed by a concrete and framing subcontractor who had subcontracted with the general contractor to do the framing and concrete work for a new condominium development. The framing subcontractor had been in operation for 2 years and employed 5 office staff and a crew leader who, according to the subcontractor, spoke enough English to understand instructions. The crew leader was responsible for finding Hispanic labourers to perform framing and concrete work.



Location of where the incident occurred during the construction of the condominium

Figure 5: The condominium that was constructed (Higgins, 2004)



Work platform from where the labourer fell from.

The location of the concrete slab onto which the labourer fell.

Figure 6: The position of the victim before the fall (A) and the position of the victim after the fall (B) (Higgins, 2004)

The crew leader had 18 Hispanic employees performing framing work at the time of the incident. Neither the crew leader nor the subcontractor had obtained documentation of the victim's date of birth and it is not certain if they knew that the victim was under the age of 18.

#### **4.4.2 Case Study 1 Analysis**

The reason that the labourer fell from the work platform is uncertain. However, this research aims to identify possible causes that lead to the occurrence of this incident. In Chapter 3.3.12 of this research, the construction site hazard of work that is done on roofs is discussed. Although the labourer, in this case study, was working on a 10 feet high platform, the same criteria for working on roofs can be applied in this case as work was still performed at height.

Ergonomics is another construction site hazard that is identified for this case study. Ergonomics is generally defined as a discipline focused on making tasks comfortable for the person performing it. Therefore, the engineer should have informed the contractor to consider the capabilities and limitations of the employees during the design phase of the condominium. In this case, the area surrounding the location of the incident seems to be difficult to access (refer to Figures 5 and 6).

Although not a direct requirement of the Construction Regulations, the following design modifications could have been made by the engineer that may have prevented the accident:

- The engineer could have made provisions in the design for safe and easy access to the location where the work was required. In Chapter 3.5.2, safe accessibility is mentioned as a constructability principle that needs to be considered by the engineer during the design phase. Safe accessibility includes safe access to materials and equipment, and also to the locations where work needs to be performed.
- The material of the work platform may also have been fragile material and the labourer could have been unaware of the platform's fragile nature. The engineer can specify in his design that even work platforms, which are used at heights, should not consist of fragile materials that will endanger the safety of construction employees.
- The engineer can also monitor that elevated work platforms meet the safety requirements and that all construction employees are provided with fall protection when the potential for falls exists.

Contractors are responsible for providing their employees with appropriate means for safely performing their work at heights, and for providing adequate fall protection and hazard awareness training. However, the engineer can act as an assistant during these processes by monitoring it. Therefore, the design done by the engineer can define different types of scaffolds to be used when work is done at elevation. This will ensure that the selection of scaffold meets the specifications for a

safe design. Although not a direct requirement of the Construction Regulations, the engineer can also monitor that construction employees do undergo safety training related to hazards caused by work done on scaffolds.

According to the Construction Regulations, Clause 7.4, a contractor should ensure that all employees under his or her control are informed, instructed and trained by a competent person regarding any hazard related to work procedures before any work commence. Therefore, in the health and safety plan, the contractor can be required by the specifications of the engineer to include proof that all employees working on site received descent safety training.

#### **4.4.3 Lessons learned from Case Study 1**

The following lessons can be learned from Case Study 1:

- During the design phase, the engineer should advise the contractor to keep the capabilities and limitations of employees in mind, such as the age and language of employees.
- The engineer in collaboration with the contractor should ensure that all working and storage areas are easily and safely accessible.
- When work needs to be performed at heights, the engineer can specify that non-fragile materials be used as work platforms.
- The engineer can monitor that the contractor provide all employees with fall protection equipment when work is performed at height.
- The engineer can also monitor that the contractor provide all construction employees with safety training related to hazards caused by work done at heights.

#### **4.5 Case Study 2: Construction employee succumbs after falling from a collapsed precast concrete slab**

This section includes the discussion of the background for Case Study 2 and the analysis of the incident or accident that occurred, focusing on possible causes for occurrence (National Institute for Occupational Safety and Health, 2012) (New York State Department of Health, 2009) (Higgins, 2004).

##### **4.5.1 Background**

In February 2007, a construction employee (the victim) sustained fatal injuries during the construction of a ten-storey building in New York after falling three floors that followed the collapse of precast concrete floor slabs. The victim's employer had thirty years of experience in the precast concrete erection business and employed union employees.



Concrete floor slabs and wall panels were manufactured by a precast fabricator and transported to the construction site. The victim's company was responsible for the erection of the ten-story building that consists of steel columns and beams that would serve as the framework of the building. The concrete slabs and wall panels were placed on the steel structure as presented by Figure 7.



**Figure 7: The steel framework and the concrete members that were placed on the steel beams (Higgins, 2004)**

The concrete floor slabs were adjusted and manoeuvred to their final position by the victim's company and secured to the steel frame by means of grouting or welding.

The construction of the building was divided into three areas. Areas 1 and 2 had been completed by the time of the incident. In Area 3, where the incident occurred, the steel structure had been erected up to the ninth floor of the ten-story building. The precast concrete slabs had been erected up to the eighth floor, however, the concrete floor slabs had neither been grouted nor provided with additional welded support as grouting and welding had been postponed due to low temperatures.

On the day of the incident, the victim and a co-employee were assigned to adjust the concrete floor slabs into their final position for grouting and welding. The two construction employees started on the fifth floor in Area 3 from the North side of the building, moving South and aligning the floor slabs with pry bars. The dimensions of the concrete floor slabs were 7.92m x 2.53m x 0.2m and each weighed approximately seven tons. As presented by Figure 8, the longitudinal sides of the concrete floor slabs were orientated in the East and West directions and were supported by steel beams on their transverse sides.

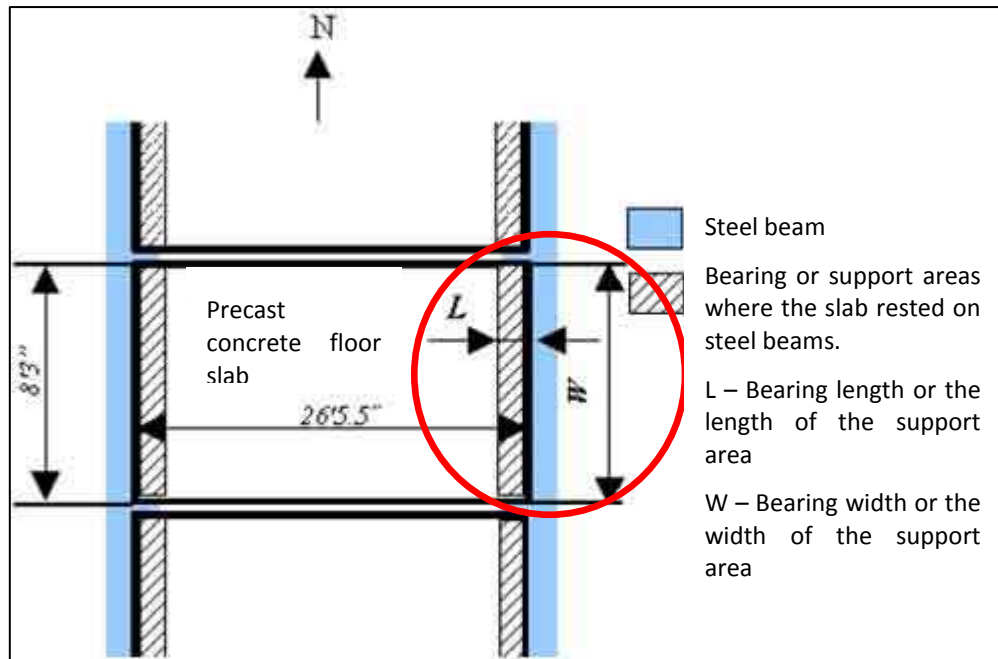


Figure 8: Plan view showing precast concrete floor slabs positioned on steel beams (Higgins, 2004)

In Figure 8, the red circle indicates the bearing length,  $L$ , and bearing width,  $W$ , that shows the support areas where a concrete floor slab was supported by the steel beams. The design specified that each floor slab should have a minimum bearing length of 70mm.

The victim and co-employee were busy aligning the third floor slab from the North side on the sixth floor. One of the slabs was in-between two steel columns (refer to Figure 9 on the next page). This resulted in the slab to be notched on both corners on the North side to fit the slab between the two steel columns. The longitudinal side of the slab on the north side was cantilevered and not supported by the steel beams. Figure 9 shows the plan layout of the failed concrete floor slab.

The red circle in Figure 9 shows the steel column that contributed to the concrete slab to be notched on the North corners. The grey area shows the section of the slab that was cantilevered due to no support provided by the steel beams. The star indicates the spot where the slab initially failed in concrete bearing. It is important to note that the design specified a bearing length of at least 70mm; however, a post incident investigation that was conducted determined that the bearing length of this specific slab was only 25mm.

The victim and a co-employee were aligning the slab by pushing it northward to close the gap between this slab and the adjacent slab on the north. The incident occurred when both employees walked on the slab in a northerly direction. The slab tilted as it cantilevered around its longitudinal axis to an almost vertical position. The victim fell from the sixth floor onto the fifth floor while the slab stayed wedged in between the steel beams. However, the wedged slab collapsed, causing slabs

on the three stories below to also fail. The victim fell through the gaps created by the initially failed slab and came to rest on the third floor.

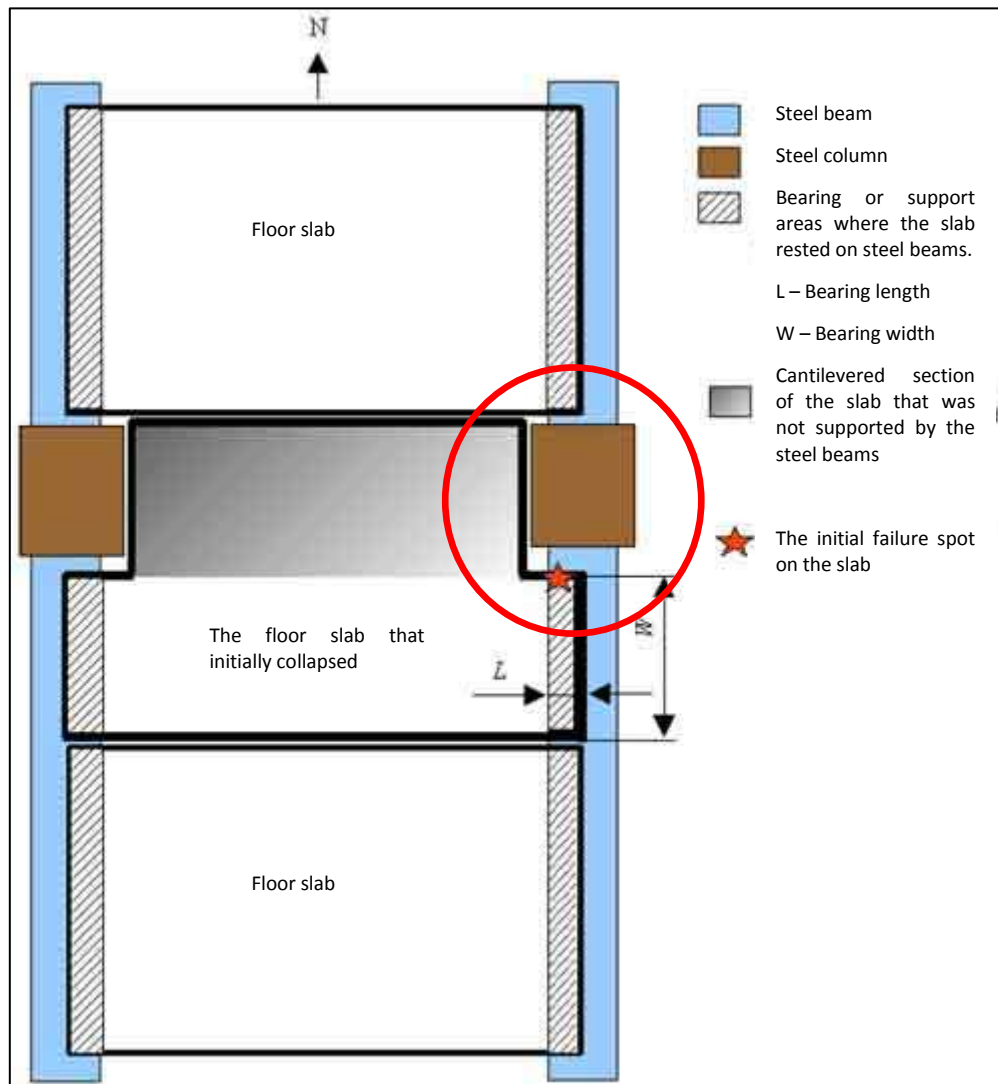


Figure 9: Plan view of the initially failed slab and adjacent slabs on the steel beams (Higgins, 2004)

#### 4.5.2 Case Study 2 analysis

When referring to the construction site hazards mentioned in Chapter 3.3, certain hazards are present in case study 2. As for most buildings, work was performed at height and it is the responsibility of the contractor to ensure that all employees are equipped with the necessary fall arrest equipment when working on slabs that are not permanently secured to the structural frame.

The engineer can enforce the use of personal fall arrest systems. In this case, both the victim and his co-employee did not have any safety equipment that could have prevented the victim from falling. However, the construction of the slab that failed was not performed near any edges of the building

and therefore, it seems almost unnecessary to equip the employees with equipment that would prevent them from falling. The latter is only the case if the design is safe and trustworthy.

The problem that developed on the sixth floor that caused the concrete slab to be notched should have been an indication that more focus should have been placed on the safety of the employees, rather than on the adjustment of the original design that was potentially unsafe.

Probably the main cause for this incident is the design that was unsafe. In Chapter 1 of this research, the requirements of a design to be reasonable practicable are discussed. To determine whether a design is *reasonable practicable* is to consider all relevant matters until a balance is achieved between constructability and the requirements of the client. The balance should provide the highest level of protection against construction hazards that is both possible and reasonable in practice (Safe Work Australia, 2011). Some matters may be relevant to what can be done, i.e. adjusting the design to the immediate environment. Other matters may be relevant to what is reasonable to do, i.e. designing according to certain standards. However, according to Safe Work Australia (2011), some matters must be taken into account when the design of a building is to be reasonably practicable. These matters include:

- The likelihood of the hazard or risk occurring.
- Degree of harm if the hazard or risk occurs.
- The knowledge of the engineer about the hazard or risk and his or her knowledge of methods to minimise or eliminate it.

The knowledge of construction methods and experience of the engineer is important in cases like this in order to adjust the design to the immediate environment in a correct, constructible, and safe manner.

The engineer should also monitor that suppliers comply with the structural dimensions and tolerances that are specified by the erection design. Before any precast slabs were erected, the contractor in collaboration with the engineer should have ensured that the vertical and horizontal alignment of the steel structure is correct. Quality control is important to be performed on site as it is essential for structural integrity and employee safety. For a precast concrete building, the steel structural frame is the primary structural support. Deflection of the structural frame can compromise the integrity of the building structure and create safety hazards, especially during the construction of multi-story buildings.

In this case, the vertical alignment of the columns had not been checked before the floor slabs were erected. The columns that had not been constructed sufficiently vertical caused the bearing length of the failed slab to decrease by 45mm. Therefore, it reduced the beam support for the precast slab

and compromised the structural integrity of the floor slabs. Regular meetings should have been held between the contractor and engineer where they could have discussed matters such as checking the vertical and horizontal alignment before erecting any precast slabs. In Chapter 3.4.4, general information that needs to be exchanged between the engineer and contractor is discussed. In this chapter, it is mentioned that the engineer should stop the contractor from executing any construction work which is not in accordance to the health and safety plan of the contractor. The latter includes any construction work that poses a threat to the health and safety of the employees.

According to the health and safety specifications for construction works as published by the Department of National Treasury (2012) and the Construction Regulations, the engineer should visit the construction site at regular intervals to conduct site inspections. Based upon such visits, he could contribute to improve the safety of the construction site. Therefore, regular meetings and construction site visits, where tolerances and quality were addressed by the engineer, may have prevented this accident.

The engineer should also monitor that employees are provided with training on the prevention of fall hazards associated with working on unsecured precast concrete slabs. The training should include the proper use of personal fall arrest systems when working on unsecured structural elements. Employees should also be informed to walk or work, if possible, on areas that are supported by the steel beams.

During construction site visits and meetings, the engineer should monitor that the precast concrete erectors secure the precast slabs to the steel structure frame as soon as the slabs have been placed into their final position. For conventional concrete, contractors pour the concrete on the construction site and the concrete is allowed to cure before the contractor can move on to the next floor. Therefore, each floor is constructed above a cured concrete floor that is structurally secured. In contrast, precast concrete slabs are manufactured by precast fabricators at a factory and transported to the construction site where they are placed and secured onto the structural frame. It is important for the contractor to ensure that these precast concrete slabs are secured to the steel structure as soon as possible.

Finally, the support strength and integrity of odd shaped or notched precast concrete members should be carefully evaluated. The cantilevering of the notched concrete slab in this case study may have been prevented by making use of special erection procedures such as supplemental fastening or reinforcement to compensate for the reduced beam support area. The engineer should analyse the drawings thoroughly and monitor that precast fabricators provide the necessary supplemental supports.

### 4.5.3 Lessons learned from Case Study 2

The following lessons can be learned from Case Study 2:

- Since Clause 4.1 of the Construction Regulations states that the engineer should provide the contractor with any information that might affect the health and safety of the construction employees, the engineer can specify and monitor that employees are equipped with fall arrest equipment when work is done on building elements that are not permanently secured to the steel structure.
- The design of a building should be reasonably practicable, i.e. to consider all relevant matters until a balance is achieved between constructability and the requirements of the client that provides the highest level of protection against construction hazards that are both possible and reasonable in practice.
- The experience and knowledge of the engineer on construction methods should be adequate for the engineer to adjust the design in a constructible and safe manner whenever modification to the design is needed.
- The engineer and contractor should have regular meetings to discuss all possible construction hazards and they should undertake a descent quality control of the construction site.
- The engineer should also require proof from the contractor that the construction employees had been provided with training on the prevention of fall hazards associated with working on or near unsecured building elements.
- During construction site visits and meetings, the engineer should monitor that precast concrete erectors secure the precast slabs to the steel structure frame as soon as the slabs are placed into their final position.
- The engineer should analyse the drawings thoroughly and monitor that precast fabricators provide necessary supplemental supports where needed.

### 4.6 Case Study 3: Construction employee struck by falling steel roof truss

This section includes the discussion of the background for Case Study 3 and the analysis of the incident or accident that occurred, focusing on possible causes for occurrence (National Institute for Occupational Safety and Health, 2012) (Nebraska State Fatality Assessment and Control Evaluation Department , 2005) (Higgins, 2004).

### 4.6.1 Background

A construction employee suffered a fatal accident in Nebraska in 2005 when a steel roof truss fell from a forklift's tines onto him. The company, for which the victim worked, constructs commercial facilities, such as concrete buildings, gymnasiums, auditoriums, etc. At the time of the incident, the company employed twenty employees. However, none of these employees received descent safety training as the company was lacking a written safety program. Employees on site only received "on-the-job" training that included informal conversations between them and their employers. Training with regard to operating forklifts was also lacking at this time. The employee that was operating the forklift at the time of the incident did not have any qualifications or certification.

As presented by Figure 10, the company made use of a CAT 920 loader forklift with each forklift tine possessing a lifting capacity of 5 tons. Each steel roof truss was 25m in length and 1.1m in height in the centre. The steel roof trusses decreased in height towards the ends. The trusses were transported in groups of three with a total weight of 4.96 tons.

The victim, together with two other employees, were responsible to move the steel trusses to an area where the trusses were joined together, using x-bracing, for use in a newly constructed gymnasium. The incident occurred as the forklift operator lowered the steel roof trusses and a single truss slipped off from the forklift's tines and struck the victim.

Figure 11 shows the position of the victim when he was struck by the end of a steel roof truss. The red circle in Figure 11 (next page) represents the location of the victim and the red arrow points towards two 100mm x 100mm wooden blocks that served as supports for the truss. However, the top wooden block had not been placed correctly in the centre of the bottom block and this forced the victim to move in under the steel trusses to replace the top wooden block.



Figure 10: CAT 920 loader forklift that was used for transportation of the steel roof trusses (Higgins, 2004)

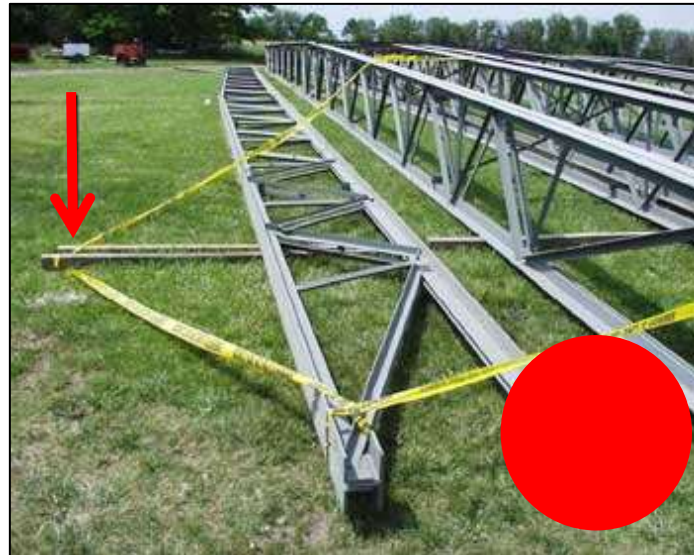


Figure 11: The location of the accident (Higgins, 2004)

It is important to notice that the incident forklift had two burned holes near the tip of each tine (refer to Figure 12). According to Cascade Corporation (2009), holes should be drilled into a forklift's tine and never be burned. The reason is that the tines of the forklift are heat treated. When a hole is burned, the heat treatment is lost in that specific area. This will result in the loading capacity of the tips to be compromised (Cascade Corporation, 2009).



Location of the two holes that was burned into the tines of the forklift

Figure 12: The tines of the forklift with two holes burned near the ends (Higgins, 2004)

#### 4.6.2 Case Study 3 analysis

With reference to the construction site subjects of concern mentioned in Chapter 3.3, construction plant and equipment played a role in this case study. According to the JBCC Principal Building Agreement (2000), Clause 19.3, the contractor shall be responsible to provide, maintain and remove



on completion all plant, equipment and scaffolding. With regard to construction safety that is affected by plant and equipment, the contractor is mainly the responsible party (Department of Labour, 2003). However, the engineer should still play a part during the design phase as it may result in the safety of the construction site to increase.

With reference to construction plant and equipment, the engineer can improve safety and efficiency by allowing for the use of temporary works equipment and scaffolding by monitoring that level surfaces and sufficient room around temporary work and equipment are present on the construction site for easy and safe access (WorkCover NSW, 2009). Furthermore, it would have been beneficial for the safety of this project if the engineer had informed the contractor that plant and equipment should be used that provide the adequate loading strength. The engineer can specify that the latter should be included in the health and safety plan of the contractor.

Certain factors, such as the length, weight and the terrain should always be taken into account when steel trusses are moved to the location where the trusses are joined together. Since holes had been burned into the tines of the forklift, the loading capacity of it was reduced and therefore, it seemed unsafe to use the specific forklift. If any of the factors mentioned above are considered to result in unsafe practice, alternative methods to transport the trusses should be used. In this case, a crane or a larger forklift with a wider span between the tines would have been a safer alternative.

The latter may be an indication why the steel truss slipped from the tines. However, a post incident investigation of this case study resulted in the conclusion that no exact causes can be determined that allowed the steel truss to slip off. However, it is the responsibility of the contractor to ensure that steel trusses are secured to the tines of the forklift by using chains. As for most cases, the engineer can assist the contractor by visiting and monitoring the construction site on a regular basis, communicating regularly with the contractor and enforcing quality standards with regard to construction plant and equipment, i.e. enforcing the use of plant and equipment that are adequate, reliable and which will perform the work safely.

A lack of safety training was also present on this specific construction site. Safety training should be a combination of formal instructions and practical training. Formal instructions include lectures, discussions, interactive computer learning and written material whilst practical training includes demonstrations performed by the safety trainer.

#### **4.6.3 Lessons learned from Case Study 3**

The following lessons can be learned from Case Study 3:

- The engineer can allow for the use of temporary works equipment and scaffolding by monitoring that level surfaces and sufficient room are present on the construction site for easy and safe access.
- During regular site visits and meetings with the contractor, the engineer can enforce a construction method statement included in the mandatory health and safety plan from the contractor that includes the use of plant and equipment that provide adequate loading strength.
- In the construction method statement, the contractor should indicate that the construction terrain, weight and length of the steel trusses are taken into account for transportation of the trusses.
- According to the Construction Regulations, Clause 7.4, a contractor should ensure that all employees under his or her control are informed, instructed and trained by a competent person regarding any hazard related to work procedures before any work commences. Therefore, in the health and safety plan, the contractor can be required by the specifications of the engineer to include proof that all employees working on site receive descent safety training. Therefore:
  - The engineer can enforce safety training programs with formal instructions that include lectures, discussions, interactive computer learning and written material.
  - The engineer can also enforce practical training that includes demonstrations performed by a safety trainer.

#### **4.7 Case Study 4: Construction employee electrocuted when an extended ladder contacted an overhead power line**

This section includes the discussion of the background for Case Study 4 and the analysis of the incident or accident that occurred, focusing on possible causes for occurrence (National Institute for Occupational Safety and Health, 2012) (Massachusetts State Fatality Assessment and Control Evaluation, 2006) (Higgins, 2004).

##### **4.7.1 Background**

In 2004, a Brazilian construction employee suffered a fatal accident due to electrocution when the ladder he was moving came into contact with overhead power lines. The employee worked for a company that primarily constructed roofs in residential areas and could only speak Portuguese and some Spanish.

The roofing company did not possess a written formal safety program that made employees aware of all possible hazards on a construction site. However, the contractor did own fall protection equipment that was available to employees working at heights. The contractor at the time of the incident communicated in Spanish which made it difficult for certain employees to understand him.

The morning of the incident, the employees constructed a roof for a house. In front of the house were electrical power lines running above the truck the equipment was transported in. The victim unloaded an extended ladder from the truck and it came in contact with a 7 620 volt energized power line and he suffered electrocution.

#### **4.7.2 Case Study 4 analysis**

In the design, the engineer should specify that conductive materials should not be used near energized power lines. Therefore, the engineer should also show on the drawings the locations of electrical services.

Engineers, contractors and employees should take caution when working in the proximity of energized power lines, such as using nonconductive ladders for this case study. With reference to the construction site hazards mentioned in Chapter 3.3, this case study considers hazards associated with three construction processes. The latter includes the use of plant and equipment, the presence of hazardous substances, and electrical works. The use of nonconductive ladders should have been specified in the design when construction is undertaken near overhead energized power lines. Nonconductive ladders include fiberglass and dry wooden ladders.

Therefore, the cause for this incident can be attributed to an unsafe design. It is important to note that the definition of design does not only refer to the preparation of drawings or the specifications of the end result but also include different matters that relate to the execution of a project. Therefore, the layout of the construction site, including the location of power lines is essential for the engineer to be aware of.

Design, in relation to a building, includes the design of the whole or part of the structure as well as any changes that have to be made to the original design. Generally the output associated with the design of buildings includes construction details, construction information and specifications relating to the structure. The engineer, in collaboration with the contractor, should undertake construction site surveys prior to the actual start of construction to identify potential hazards. This will allow the team to implement suitable control measures for these hazards.

The result of a construction site survey in this case, would have resulted in the power lines to be identified and placed on drawings. The construction team would then have been able to mark off

the area beneath the power lines since loading and unloading of construction equipment and materials should not take place beneath energized power lines.

Finally, the safety specifications provided by the engineer should require contractors to have a formal safety training program that includes the identification of possible construction site hazards and the avoidance of unsafe conditions. The latter, however, is only possible if the contractor identifies the languages spoken by the employees. Identifying the various languages will ensure that the comprehensive safety training program is presented in different languages for everyone to understand. The contractor should also ensure that special safety training is provided to those employees that possess low literacy skills.

Descent safety training should address the fact that loading and unloading of extended ladders should be avoided in certain areas.

#### **4.7.3 Lessons learned from Case Study 4**

The following lessons can be learned from Case Study 4:

- When work needs to be performed in the proximity of electrical power lines, the engineer can inform the contractor to use nonconductive materials and equipment by specifying it in the design.
- Loading and unloading of construction equipment and materials should not take place beneath energized power lines.
- During the design phase, the engineer should be aware of the layout of the construction site, especially the locations of power lines.
- The engineer, in collaboration with the contractor, should undertake construction site surveys prior to the actual start of construction to identify potential hazards.
- The engineer should monitor that contractors have a formal safety training program, presented in multiple languages, that includes the identification of possible construction site hazards and the avoidance of unsafe conditions (Department of Labour, 2003).

#### **4.8 Case Study 5: Demolition employee suffered a fatal accident from falling through a roof opening**

This section includes the discussion of the background for Case Study 5 and the analysis of the incident or accident that occurred, focusing on possible causes for occurrence (Higgins, 2004) (Massachusetts State Fatality Assessment and Control Evaluation, 2006).

### **4.8.1 Background**

A male demolition employee fell approximately 8m through a roof opening during demolition work that was performed manually at a school in Massachusetts. The victim, alongside four other employees of the same company, was manually dismantling tar, wooden planks and gravel from a flat rooftop to expose the steelwork underneath. The crew was exposed to the danger of falling through the roof as the openings became wider.

The crew made use of hand operated tools to cut the wooden planks to remove them with more ease. The victim and a fellow employee were using chainsaws to cut through the wooden planks in the proximity of several openings in the roof. Although the employees were focused on keeping the working surface clear of any slip or trip hazards, the victim fell through a 250mm x 250mm opening onto a heap of tar and debris.

### **4.8.2 Case Study 5 analysis**

Identifying demolition as one construction site hazard is valid. Demolition hazards present the risk of building elements falling onto employees, the inhaling of hazardous substances, being exposed to noise during demolition and the risk of employees falling from heights. In collaboration with demolition, work done on roofs is also a construction site hazard that can be identified in Case Study 5.

As for the construction of buildings, demolition should also be approached with a descent and safe design that identifies all possible hazards connected to demolition work. Prior to the actual demolition, the engineer in collaboration with the demolition contractor should engage in discussions and meetings to identify the hazards and methods to control it. The identified hazards and control measures should be communicated to all employees. With regard to the safety of employees, basic essential safety precautions should always be in place even before referring to rules and regulations.

The demolition company in Case Study 5, much like many other companies, had no formal written safety program in place. Besides the latter, the company did not appoint any person to act as a safety officer. According to Clause 4.4 of the Construction Regulations, an engineer should only appoint a contractor if he or she is reasonably satisfied that the contractor has the necessary competencies and resources to perform the work safely. Furthermore, Clause 6.1 of the Construction Regulations states that a contractor should appoint a full-time competent employee as the construction and safety supervisor.

Therefore, an engineer can enforce a contracting company to appoint an individual as a designated safety officer that would implement and develop a complete safety program. This safety program would generally include, but not be limited to, training of employees in fall hazard recognition and the use of personal fall arrest systems. Therefore, an engineer as designer can monitor that the contractor uses guardrail and toe board systems or harnesses whenever the risk is present of falling from or through a roof.

### **4.8.3 Lessons learned from Case Study 5**

The following lessons can be learned from Case Study 5:

- As for the construction of buildings, demolition should also be approached with a descent and safe design that identifies all possible hazards connected to demolition work.
- Prior to the actual demolition, the engineer in collaboration with the demolition contractor should engage in discussions and meetings to identify the hazards and methods to control it.
- The engineer can enforce a contracting company to appoint an individual as a designated safety officer that would implement and develop a complete safety program (Department of Labour, 2003).
- The engineer can monitor that the contractor uses guardrail and toe board systems or harnesses whenever the risk is present of falling from or through a roof.

## **4.9 Case Study 6: Operator of equipment succumbed due to chimney falling on hydraulic excavator during demolition**

This section presents the discussion of the background for Case Study 6 and the analysis of the incident or accident that occurred, focusing on possible causes for occurrence (National Institute for Occupational Safety and Health, 2012) (Tien, 2011).

### **4.9.1 Background**

During the demolition of a house in Virginia, an employee that worked as an equipment operator suffered a fatal accident when a chimney fell on a hydraulic excavator the victim was operating. The victim and a fellow employee completed 75% of the total demolition of the house. The remaining 25% included the demolition of a stone wall that also involved the demolition of a 9m high brick chimney.

Prior to any demolition work that was performed on the day; the victim and fellow employee had discussed the demolition of each part of the house in detail. They did, however, identify the possible

hazards that are connected to demolition work. Both employees inspected the chimney from ground level for defects and neither of them noticed any cracks in the bricks or mortar joints. Following the inspection, the victim who operated the hydraulic excavator, decided to push the chimney over to the south side as the excavator was positioned north of the chimney.

The victim started to demolish a portion of the stone wall that was connected to the west side of the chimney. This caused the chimney to sway towards and fall on the hydraulic excavator.

#### **4.9.2 Case Study 6 analysis**

The risk of building elements collapsing is an important aspect associated with the demolition of buildings. The engineer should always consider the dangers involved in working on buildings at or near the point of collapse. They should provide information to demolition contractors on load paths that include (WorkCover NSW, 2009):

- The critical loading conditions that may cause collapse.
- Critical load-bearing elements that should not be removed without supporting arrangements (columns under supporting beams, floor beams, members providing lateral restraint to compression members).
- Pre-stressed concrete elements which contain considerable tension.

Therefore, a thorough engineering survey should be done by the engineer and contractor before the demolition of any building or building elements. As for this case study, the two employees only discussed the condition of the brick chimney in an informal manner. A completed engineering survey performed by a competent person (engineer) would have determined the structural condition of the chimney in a more formal, mathematical and precise manner. An engineering survey would allow contractors and employees to identify the possibility of hazards better than a discussion between labourers. Potential hazards that can be identified for the demolition in Case Study 6 include collapse of building elements, inhaling hazardous substances and fires occurring. It is also important for the engineer to include ways of communicating with emergency rescue providers in the engineering survey.

Buildings consist of different materials. For this case study, a masonry chimney caused the incident to occur and it may be due to lack of knowledge on methods used for demolition of masonry structures by the victim. In this incident, a safer method would have been to demolish a part of the chimney first prior to demolishing any part of the house. Employees could also have been appointed to remove bricks from the top of the chimney manually. However, these employees should be assisted with the necessary fall protection equipment. The chimney could also have been manually

demolished from the inside of the house until it reached an adequate height for the hydraulic excavator to knock it down.

### 4.9.3 Lessons learned from Case Study 6

The following lessons can be learned from Case Study 6:

- The engineer should provide information to the demolition contractors on load paths that include:
  - The critical loading conditions that may cause collapse.
  - Critical load-bearing elements that should not be removed without supporting arrangements (columns under supporting beams, floor beams, members providing lateral restraint to compression members).
  - Pre-stressed concrete elements which contain considerable tension.
- A thorough engineering survey should be done by the engineer and contractor before the demolition of any building or building elements.
- The engineering survey should include manners in which contractors and employees can communicate with emergency rescue providers if necessary.
- The actual design for demolition activities should be carefully analysed to ensure that the safest possible demolition method is specified.

## 4.10 Case Study 7: Construction employee falls through insulation to concrete floor

This section includes the discussion of the background for Case Study 7 and the analysis of the incident or accident that occurred, focusing on possible causes for occurrence (WorkSafe Compensation Board of British Columbia, 2007).

### 4.10.1 Background

In 2007, the construction of a steel building in British Columbia entailed the placement of metal roof panels on top of a layer of blanket insulation by four employees. These four employees worked for a subcontractor, Coastal Steel Systems, which provided workmanship for the installation of doors, windows, hallway systems, framing, and roofing.

The four employees started with the preparation of the roof the morning of the incident by connecting power cords, installing ladders, and moving supplies and equipment. The height of the roof these employees worked on was 5.2m and no fall protection system was in place. Furthermore, the four employees spoke different languages and the understanding of the actual work that needed



to be done was vague. However, they understood the instructions to stay away from the edges and work as a team. The work that needed to be done on the roof included the following:

- The rolls of insulation should be layered across the horizontal steel beams.
- Metal roof panels that were stored on the roof should be carried to the areas needed.
- Installing the actual roof panels and fastening them to the horizontal beams.

At the time of the incident, two employees carried a metal roof panel from the storage area and started installing it next to a previous installed panel. The procedure of carrying the panels and installing was consistently followed by all four employees since the beginning of the roofing project. However, one employee fell through the blanket of insulation onto a concrete floor during the installation of a roof panel.

Fall protection equipment, such as harnesses, lanyards, and ropes were available to the employees working on site. Coastal Steel Systems also had a safety program in place that was compiled in 2005; however, the safety program did not include safety procedures that should be taken into account when work is done on roofs. Therefore, the employees were unaware of the safety equipment on site and the sub-contractor and contractor did not enforce any safety procedures.

#### **4.10.2 Case Study 7 analysis**

Several construction site hazards are identified in this case study. The reason for the employee to fall through the insulation can be due to the employee tripping on the protruding panel ribs and falling through the insulation. The employee could also have just step onto a weak area in the insulation that caused the fall to occur. However, work done on roofs as discussed in Chapter 3.3.12 is the main hazard identified in this case study.

A lack of supervision and monitoring is identified as a factor that led to the occurrence of the incident. The engineer assumed that the supervisory personnel on the construction site, in collaboration with the main contractor, were performing their safety duties and responsibilities at all times. At the time of the incident the engineer did not formally investigate the performance of the safety supervisors and the main contractor with regard to health and safety on the construction site. The engineer can monitor that the site supervisors and contractor provide evidence that regular construction site safety inspections are performed and that the employees on site undergo the necessary safety training, especially for work perform at heights (Department of Labour, 2003).

Safety procedures for work done on roofs should also be included in the safety program of a construction company.

For all projects that include work to be performed at heights, personal fall arrest systems should be in place. Personal fall arrest systems include safety equipment, such as harnesses, lanyards, and ropes that need to use by construction employees working at heights. In Case Study 7, the safety equipment was available; however the employees were unaware of it. The use of safety equipment can also be monitored by the engineer through regular visits to the construction site and through communication with site supervisors and contractors (Department of Labour, 2003).

The fact that safety equipment was present on site and not used can either be an indication that the contractor did not enforce the use of the equipment, or the employees did not understand the instructions due to language differences. In South Africa, as for many other countries, a variety of languages are spoken and it is therefore important for safety training to be provided in different languages for everyone to understand. The health and safety plan that can be required from the contractor should also include evidence that safety training is provided in different languages and that all employees are aware of safety equipment present on the construction site.

#### **4.10.3 Lessons learned from Case Study 7**

The following lessons can be learned from Case Study 7:

- Clause 6.1 of the Construction Regulations states that a contractor should appoint a full-time competent employee as the construction and safety supervisor. Based on the latter, the engineer can enforce adequate supervision and monitoring of safety procedures through specification.
- A formal health and safety plan compiled by a contracting company is necessary and should include all possible hazards connected to a construction site (Department of Labour, 2003).
- The formal safety program should also include safety procedures to manage construction site hazards.
- Personal fall arrest systems should always be provided to employees working at heights.
- Employees should be provided with adequate safety training in a language that they will understand.
- The safety training program and the use of fall arrest systems should be formally included in the safety method statement which the contractor provides to the engineer.

## 4.11 Case Study 8: Construction employee struck by falling wall formwork

This section includes the discussion of the background for Case Study 8 and the analysis of the incident or accident that occurred, focusing on possible causes for occurrence (Work Safe Compensation Board of British Columbia, 2010).

### 4.11.1 Background

The construction of a 32-story high-rise building in Vancouver, British Columbia, entailed the construction of wall forms performed by a company called HP Construction. The company was appointed to construct each wall form. However, these wall forms were modified by HP Construction in the sense that it included a work platform and tie rod holder without consulting any engineering drawings or taking into account the additional loads resulting from the modifications. A professional engineer conducted a wall form inspection at foundation level prior to the instalment of the formwork. The engineer issued a certificate after the inspection that stated the following:

*“The wall forms are in general conformance with the drawings and are ready for concrete pouring.”*

The wall forms were used to construct walls on higher levels of the building as well; however, the construction of walls on a higher level necessitated the erection method to change. The wall forms were erected using loading blocks that acted as a support for the wall form over stairs as level surfaces were not available. No engineering drawings were provided to the contractor that showed that the erection of wall forms should be done by using loading blocks and HP Construction did not consult the professional engineer for inspecting the erection method after it had changed.

On the day of the incident, the dividing walls of the stairwell on the 30<sup>th</sup> floor needed to be constructed (refer to Figure 13).

As no level surface was provided above the stairwell, the wall form was erected by first installing load blocks as presented in Figure 14. However, the method of installing the load blocks was based on the knowledge and experience of the carpenter in charge as no engineering drawings had been submitted that include the placement and installation of wall forms over stairwells.

The loading blocks were secured to the concrete wall by using three duplex spikes for each loading block. Figure 15 shows the manner in which the load blocks were connected.



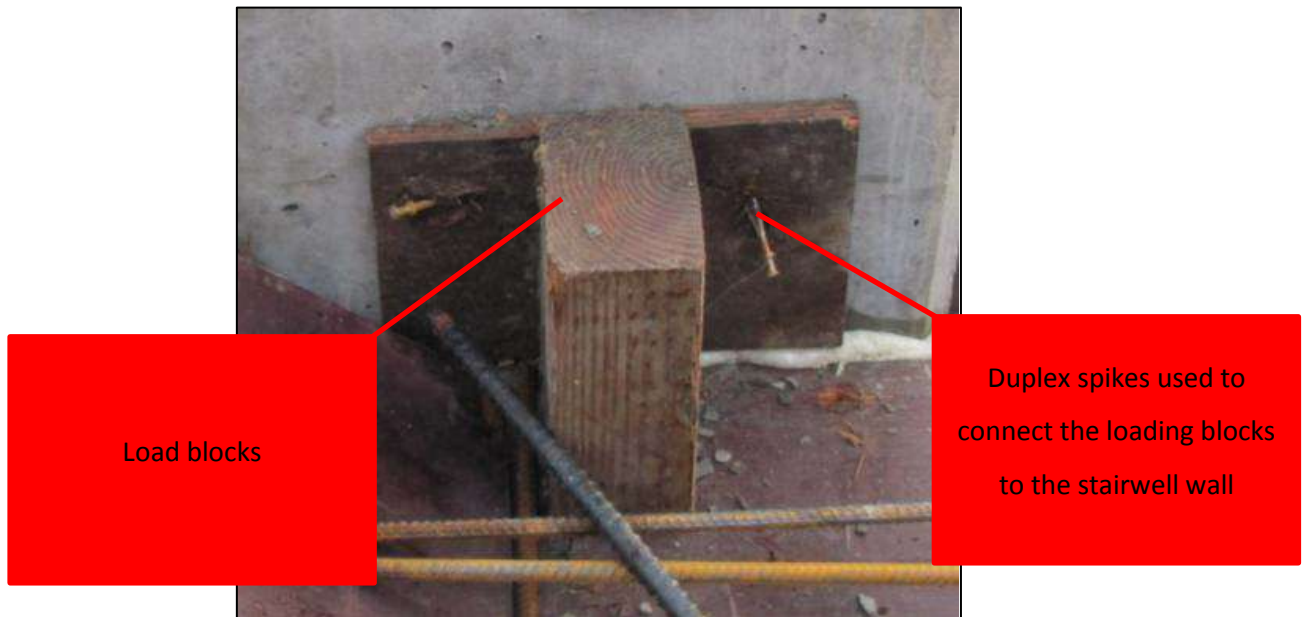
Location of stairwell

Figure 13: The location of the stairwell on the 30th floor (Work Safe Compensation Board of British Columbia, 2010)



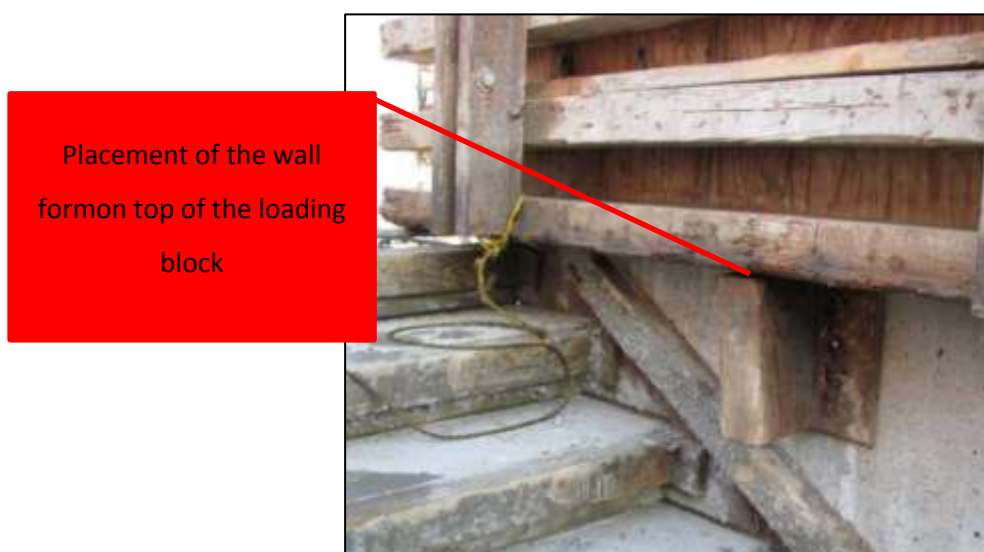
Location of load blocks

Figure 14: The position of the loading blocks on the wall of the stairwell (Work Safe Compensation Board of British Columbia, 2010)

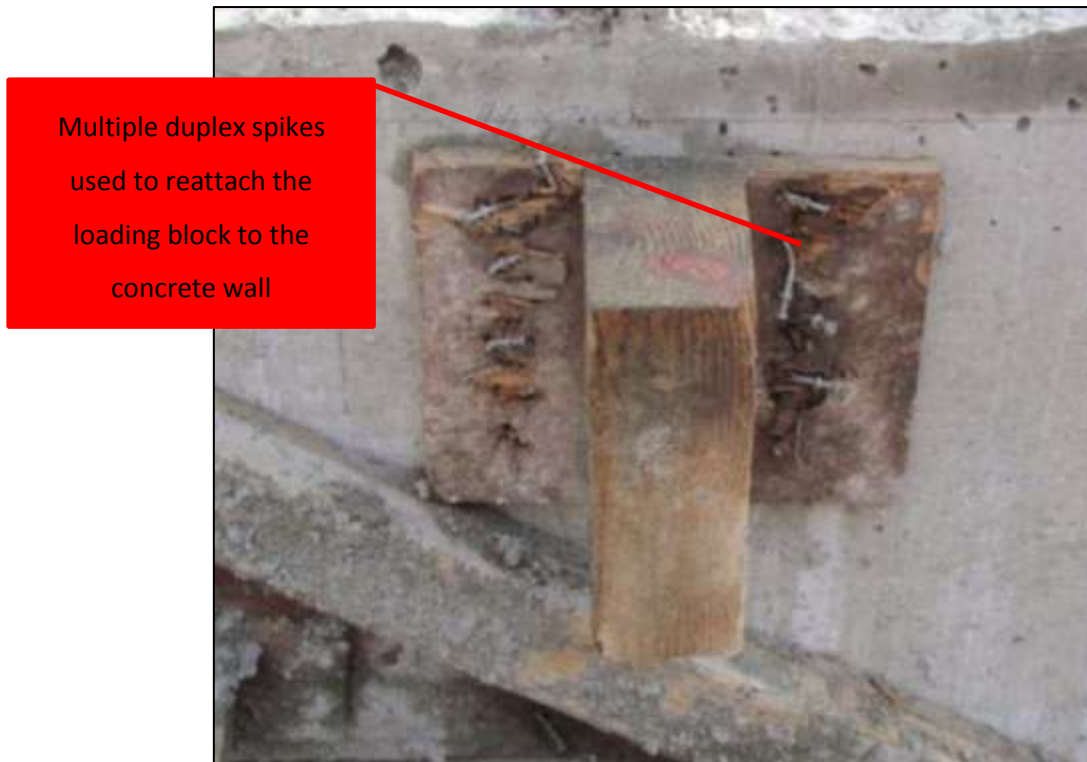


**Figure 15: The loading blocks that were used and the duplex spikes that were used to connect the load blocks to the stairwell wall. (Work Safe Compensation Board of British Columbia, 2010)**

With the load blocks in position, a 1.4 ton wall form was placed on top of the loading blocks as presented in Figure 16. The loading block on the north end started pulling away from the concrete wall when the wall form was placed on top of it. The carpenter in charge had the wall form lifted again by the crane and reattached the loading block by using more duplex spikes. Refer to Figure 17 for a photograph that shows the large number of duplex spikes that were used to attach the north end loading block to the concrete wall.



**Figure 16: The position of a 1.4 ton wall form on top of the loading block (Work Safe Compensation Board of British Columbia, 2010)**



**Figure 17: The number of duplex spikes used to reattach the north end loading block to the concrete wall (Work Safe Compensation Board of British Columbia, 2010)**

A diagonal form aligner support was fastened to both ends of the wall form. The top of the form aligner consisted of wood and at the bottom a metal turnbuckle was present. The top of the form aligner was nailed to the side of the wall form; however, the specific wall form had been used for several times, resulting in the sides of the wall form being in poor condition. The metal turnbuckle was attached to the deck and was used to adjust the wall form if it was needed.

After the specific wall form had been placed, rebar was hoisted into position and attached to the wall form with a second wall form being placed on the other side of the rebar. An employee climbed the walers of the wall form to help manoeuvre the rebar into position. The employee was approximately two-thirds up the way of the wall form when it broke away and fell onto another employee that stood nearby.

#### **4.11.2 Case Study 8 Analysis**

Since a few hazards that are mentioned in Chapter 3.3 of this research can be identified, this case study considers several other hazards.

First, there was a lack of site-specific engineered drawings. The engineered drawings that presented the erection of the wall form were only focused on the foundation level where level surfaces were always present. The erection of wall forms using loading blocks were not specified in the drawings.

Without consulting the engineer, HP Construction relied on the experience of carpenters for the erection of the wall form. This is an indication that there was a communication gap between the two parties. Apart from designing safe, the engineer should visit the construction site on a regular basis with the intention of communicating possible safety hazards, such as the incident in Case Study 8, with all other project participants. However, it will be beneficial for the health and safety of construction employees if the engineer is consulted during uncertain scenarios.

The absence of the erection method for the wall forms on unlevelled surfaces in the engineered drawings caused consecutive problems to occur. The span between the loading blocks were measured 4.2m; however, after the wall form had been placed into position, 1.2m of cantilever was measured on the north end and 0.6m on the south end. The drawings also did not include any information regarding how far the wall forms can be cantilevered to ensure stability. The engineered drawings specified the use of 90mm duplex spikes to attach the form aligners to the vertical steel strongbacks on the wall form; however, it was impossible to nail into the steel strongbacks. Again, HP Construction did not consult the engineer on an additional approved method to attach the form aligners. Instead, the employees of HP Construction used a modified method that had not been specified in the drawings and had not been submitted to the engineer.

At the time of the incident, the wall form had no bracing to prevent lateral movement at the base. The friction forces for each loading block, that was directly proportional to the reaction force on each loading block, were the only means that prevented lateral movement. Due to a larger cantilever on the north end of the wall form, a larger friction force developed on the north end loading block. In addition to the unequal loading of the wall form on the two loading blocks, the weight of the employee that climbed the walers resulted in the wall form to disconnect at the south end as the force on the south end was insufficient to stabilize the wall form. This resulted in the form aligner braces to disconnect on the south end due to the low quality of the wood.

In conclusion, the employees of HP Construction failed to consult the temporary works engineer on information not included in the design drawings. However, the temporary works engineer is responsible for designing erection methods for all levels of a multi-story building, not just for the foundation level. Proper drawings and communication between the engineer and HP Construction would have ensured that the design procedure and erection method was available to the employees.

According to the JBCC Principal Building Agreement (2000), the contractor is responsible for the design of the subcontractor's temporary works. Therefore, the engineer has little responsibility with regard to the design of the utilities.

However, it will still be beneficial, as mentioned in Clause 4.1(b) of the Construction Regulations, if the design engineer shares any information which might affect the health and safety of the employees on site. Therefore, during the mandatory site visits, the design engineer should aim to identify all safety hazards, including those he or she is not responsible for, and share it with the contractor.

#### **4.11.3 Lessons learned from Case Study 8**

The following lessons can be learned from Case Study 8:

- Efficient construction knowledge and adequate experience of the engineer, responsible for the design of a building, are important in order to contribute towards a safe construction process.
- The engineer and contractor should have regular meetings prior to any construction activity to discuss the actual construction method and safety hazards associated with it.
- All possible construction safety hazards should be communicated with employees on site.
- The contractor should always consult the engineer (design – and temporary works engineer) before modifying any construction methods specified on the engineered drawings.
- Regular communication and meetings between the engineer and contractor will also ensure that all necessary information is included in the final engineered drawings.

#### **4.12 Additional Case Studies**

Apart from the eight case studies that were investigated in this chapter, several additional case studies were investigated with focus on the lessons that can be learned from each. These additional case studies were not documented in this thesis as thoroughly as the eight case studies above. The reason is that the additional case studies encompass incidents on construction sites in various civil engineering disciplines, and are not limited to buildings. Although this chapter is primarily focused on investigating case studies for building construction sites, the lessons that are learned from other disciplines can be applied to building design, construction, and demolition.

Research done by the National Institute for Occupational Safety and Health (2012), Brown, et al. (2007), and the Work Safe Compensation Board of British Columbia (2010) were consulted with regard to additional case studies. Section 4.12.1 includes a summary of the additional case studies that were investigated. The summary includes a short description of each project and the incident that occurred; however, no formal analysis of each case study is done. The lessons learned from each are discussed in Section 4.13.2.



#### 4.12.1 Summary of additional case studies

In Vancouver, a three-story building was in the process of being demolished. The demolition process started at one corner of the building and continued until the final corner was left with two exterior walls. The demolition contractor decided to pull the floor joists to weaken the connection between the two exterior walls. This resulted in one exterior wall to fall outward onto a street where pedestrians and vehicles were present. The demolition contractor did not consult the engineer on a regular basis for the demolition project, because the demolition contractor believed that the potential hazards were adequately identified. Employees of the demolition company were unaware of specific requirements for engineering applicable to demolition. The employees relied on the fact that the project was similar to previous demolition projects, which had been completed successfully (Work Safe Compensation Board of British Columbia, 2010).

Another incident occurred near the Columbia River in Oregon during the construction of a large fish laboratory centre. The centre consists of an upper level area where most of the laboratory work is performed and a lower level for the collection of fish. The upper level was constructed by using steel frames as support for galvanized metal removable grating and mechanical and electrical equipment were also present on the upper level. The lower level was constructed approximately 9m below the upper level with no access available between the two levels at the time of the incident. As for many other construction incidents where work was performed at height, the employees working on the upper level were not protected by having a fall arrest system in place. The incident occurred when an employee stepped onto a section of the metal grating which had not been secured with fasteners, and fell 9m down onto the lower level (Work Safe Compensation Board of British Columbia, 2010).

During many maintenance procedures, safe and comfortable access is usually a concern. An example is a case study where a maintenance employee was instructed to replace circulator pumps in a boiler room where the pumps were located high up near the ceiling. In order for the employee to reach the pump, a ladder was used and the employee needed to work in between other piping to reach the circulator pump. The result was that the employee fell from the ladder to the ground, suffering an injury. The latter is a case study that can be discussed in collaboration with another incident where an employee fell through the attic of a commercial office building. An HVAC (Heating, Ventilation, and Air Conditioning) system had been installed in the attic and no floor or platform walkways were installed. The employees had to walk on the trusses to install the system and to maintain the system (Brown, et al., 2007).

Another incident occurred when a construction employee penetrated an embedded electrical conduit containing an energized 120-volt line while hand drilling into a concrete beam to install pipe hanger inserts. The conduit was 1 inch from the surface and the employee was not aware of any electrical lines in the concrete beam. The engineer could have required the contractor to include a construction method statement into his or her health and safety plan to investigate the method of installing the pipe hangers and whether any hazards, electrical lines in this case, will be present during the installation (Brown, et al., 2007).

Research done by the National Institute for Occupational Safety and Health (2012), Brown, et al. (2007), and the Work Safe Compensation Board of British Columbia (2010) were further investigated in a more informal and lightly manner than the previous cases. The aim was only to identify the lessons that can be learned from each. It is important to note that the research done by Brown, et al. (2007) was actually focused on construction projects, in various civil engineering disciplines, where the safety of employees was actually taken into account from the beginning of the project. The latter resulted in these projects to be successful with regard to cost, time, quality, and safety. Therefore, the lessons learned from these successful projects are important and are mentioned in Section 4.13.2.

### **4.13 Case Studies: Lessons Learned and Conclusion**

This section includes a combination of the lessons learned from the primary case studies that were analysed and the additional case studies. Furthermore, an approach that should be taken for the prevention of construction site hazards is discussed.

#### **4.13.1 Lessons learned from primary case studies**

Safety during the design phase was highlighted in the eight case studies that was analysed. The inclusion of safety considerations during the design phase, by the engineer, ensures that safe construction activities and safe post-construction operation of the building are possible. The absence of integrating safety considerations into design aspects are consistently featured in these case studies. These aspects include identifying safety hazards at the design stage, developing mitigation strategies and continuously reviewing designs. In most cases, collaboration between the engineer and contractor was absent and therefore, the identification of safety hazards, mitigation strategies and design reviews were not done effectively.

For some instances, the contractor is solely the responsible party (Department of Labour, 2003). However, the Construction Regulations state in Clause 4.1(b) that the engineer should provide the contractor with any information that will affect the health and safety of construction employees. The

latter includes any information that might improve the safety of the construction site, regardless of who is the responsible party.

As stated in the Construction Regulations, Clause 5.1, the contractor is required to provide the engineer with a formal safety plan that is based on the health and safety specifications documented by the engineer for each project. The engineer is also required to undergo regular site visits to address tolerances and quality (Department of Labour, 2003). Therefore, the opportunities for the engineer to inform the contractor of safety hazards are available. Although the contractor is primarily seen as the responsible party, the input from the engineer will always be beneficial for the safety of the employees. In some situations, the contractor may have overlooked certain construction safety hazards and for these cases, the knowledge of the engineer with regard to the safety hazards and the exchange of this knowledge with the contractor will ensure that all safety hazards are taken into account.

The analysis of each case study resulted in different lessons that can be learned with regard to the safety of construction employees. These lessons confirmed that the construction site hazards mentioned in Chapter 3.3 are in fact legitimate. However, numerous other hazards were identified during the analysis of the eight case studies.

The following lessons were learned from the analysis of each of the eight primary case studies:

- The engineer should inform the contractor to keep the capabilities and limitations of employees in mind, such as the age and language of them.
- The engineer in collaboration with the contractor should ensure that all working - and storage areas are easily and safely accessible.
- When work needs to be performed at heights, the engineer can specify that non-fragile materials are used as work platforms.
- The engineer can monitor the contractor to ensure that all employees are assisted with fall protection equipment when work is performed at height.
- The engineer can also monitor the contractor so that all construction employees should undergo safety training related to hazards caused by work done at height, as stated in Clause 7.4 of the Construction Regulations.
- The engineer can require the use of fall arrest equipment by employees when work is done on building elements that are not permanently secured to the steel structure, by mentioning it in the health and safety specifications for the project.
- The design of a building should be reasonably practicable, i.e. to consider all relevant matters until a balance is achieved between constructability and the requirements of the

client. The balance should provide the highest level of protection against construction hazards that is both possible and reasonable in practice.

- The experience and knowledge of the engineer on construction methods should enable the engineer to adjust the design for the construction to be constructible and safe.
- The engineer and contractor should have regular meetings to discuss all possible construction hazards and undertake a descent quality control of the construction site.
- During construction site visits and meetings, the engineer should monitor that precast concrete erectors secure the precast slabs to the steel structure frame as soon as the slabs are placed into their final position.
- The engineer should analyse the drawings thoroughly and monitor that precast fabricators provide necessary supplemental supports where needed.
- It will be beneficial for the safety of employees if the engineer allows for the use of temporary works equipment and scaffolding, by monitoring that level surfaces and sufficient room are present around temporary works. Furthermore, that equipment is present for easy and safe access on the construction site.
- During regular site visits and meetings with the contractor, the engineer can require that a construction method statement be included in the health and safety plan. The latter should include the use of plant and equipment with adequate loading strength.
- In the construction method statement, the contractor should provide evidence that the construction terrain, weight and length of the steel beams are taken into account for transportation of the beams.
- As mentioned before, a contractor should ensure that all employees are informed, instructed and trained by a competent person regarding any hazard related to work procedures before any work commence (Department of Labour, 2003). Therefore, in the health and safety plan, the contractor can be required by the specifications of the engineer to include proof that all employees working on site received descent safety training. Therefore:
  - The engineer can enforce safety training programs with formal instructions that include lectures, discussions, interactive computer learning and written material.
  - The engineer can also enforce practical training that includes demonstrations performed by a safety trainer.
- When work needs to be performed in the proximity of electrical power lines, nonconductive materials and equipment can be specified in the design.

- Loading and unloading of construction equipment and materials should not take place beneath energized power lines.
- During the design phase, the engineer should be aware of the layout of the construction site, especially power lines.
- The engineer, in collaboration with the contractor, should undertake construction site surveys prior to the actual start of construction to identify potential hazards. According to the Construction Regulations, Clause 4.1(d), the engineer should take reasonable steps to ensure that the contractor's health and safety plan is implemented and maintained on site. These steps include periodic audits of the construction site by the engineer and mutually agreed upon with the contractor.
- As for the construction of buildings, demolition should be approached with a descent and safe design that identifies all possible hazards connected to demolition work.
- Prior to the actual demolition, the engineer in collaboration with the demolition contractor should engage in discussions and meetings to identify the hazards and methods to control it.
- The engineer should inform the contracting company to appoint an individual as a designated safety officer that would implement and develop a complete safety program.
- The engineer should provide information to the demolition contractors on load paths that include:
  - The critical loading conditions that may cause collapse.
  - Critical load-bearing elements that should not be removed without supporting arrangements (columns under supporting beams, floor beams, members providing lateral restraint to compression members).
  - Pre-stressed concrete elements which contain considerable tension.
- A thorough engineering survey should be done by the engineer and contractor before the demolition of any building or building elements.
- The engineering survey should include manners in which contractors and employees can communicate with emergency rescue providers if necessary.
- The contractor should always consult the engineer before modifying any construction methods specified on the engineered drawings.

### 4.13.2 Lessons learned from additional case studies

The following lessons were learned by investigating additional case studies as mentioned in Section 4.12:

- For both construction and demolition projects, the engineer, in collaboration with the contractor, should identify all building elements in order to develop a comprehensive plan to address construction site hazards.
- The engineer should communicate with the contractor and visit the construction site regularly to monitor that the contractor is forced to consult the engineer before construction or demolition, as mentioned in the Construction Regulations, Clause 4.1(d).
- It will be beneficial for the safety of the employees if the engineer requests the contractor to include a construction or demolition method statement into the mandatory health and safety plan to ensure that the contractor is aware of the possible hazards.
- The construction or demolition method statement should especially include the identification of employees that will perform work at height and that the contractor is aware that these employees should be equipped with fall protection equipment.
- The engineer should design electrical and mechanical equipment, which will be in need of maintenance in the future, to be located as close as possible to the ground level.
- The design should encompass adequate and safe access to maintenance areas.
- If it is impossible to design the location of equipment to be near ground level, permanent work platforms and walkways with guardrails should be designed to reach the equipment safely.
- Engineers should design embedded electrical lines deeper than the maximum depth of pipe hanger bolts.
- Engineers should clearly mark locations of electrical lines on contract drawings.
- The engineer should involve the contractor during the design phase in order to contribute towards a smooth transition from the design phase to construction with regard to safety of employees.
- The engineer can assist the contractor by monitoring that the choice of materials and finishes on-site are not hazardous.
- The engineer can also assist the contractor by monitoring that the construction methodologies are achievable in a safe manner.
- Regular meetings should be held with all project participants to discuss construction safety effectively.

- A safe design should be promoted by integrating construction safety and constructability.
- Safe design should also be promoted by planning and reviewing the design to learn from these processes.
- A site safety committee can be created as a vehicle for the discussion of safety concerns and to generate solutions to the concerns.
- Safe construction should be promoted by ensuring that the design is about quality and by appointing employees who can concentrate (through experience) on different design aspects.
- The design should specify that the best and most effective equipment are used to ensure quality and safety, although this equipment may cost more.
- During the review phase of the design, it should be passed onto the contractor for his review. If there is any safety concern, the contractor should raise it with the engineer to ensure that the safety issue is resolved by the two parties.

#### **4.13.3 Contents included in a health and safety plan**

As numerous of the lessons learned from the case studies include the provision of a health and safety plan by the contractor, it is important to be aware of the content of it as required by the Construction Regulations.

The lessons learned from the case studies also mention that, inter alia, a construction method statement, a demolition method statement, proof of safety training for employees, and the awareness that safe and adequate equipment are used should be included into the health and safety plan. However, international case studies were investigated. Therefore, it is important to investigate the Construction Regulations to determine whether the information mentioned above is actually required for a health and safety plan in South Africa.

According to definition a "health and safety plan" means a documented plan which addresses hazards identified and includes safe work procedures to mitigate, reduce or control the hazards identified (Department of National Treasury, 2012).

When referring to the development of the health and safety plan, the Construction Regulations, Clause 4.1(a) stipulate that it must be developed according to the health and safety specifications provided by the engineer, appointed as the client's agent. The plan must include the documented specification of all health and safety requirements relating to the associated works on a construction site, so as to ensure the health and safety of employees.

In practice, a health and safety plan could therefore be described as a documented summary of the legal requirements to be implemented on the construction site to ensure a safe and healthy work environment. It describes the potential hazards of the work site, along with all company policies, controls and work practices selected to minimize those hazards (Department of Labour, 2003).

The contractor is responsible for the development of the plan. The Construction Regulations, Clause 5.1 specify that the contractor must provide and demonstrate to the engineer a suitable and sufficiently documented health and safety plan, based on the engineer's documented health and safety specifications.

The contractor on the other hand will require a specific plan for the task at hand from the sub-contractors. The Construction Regulations, Clause 5.4 states that a sub-contractor shall provide and demonstrate to the contractor a suitable and sufficiently documented health and safety plan, based on the relevant sections of the contractor's health and safety specification. It is clear that these regulations require both contractors and sub-contractors to have a documented health and safety plan on site.

It is important to note that the content of the health and safety plan must be site specific in accordance to the health and safety specifications provided by the engineer. The following information is provided to show the content of a health and safety plan with regard to the objective of this research (Department of Labour, 2003) (Department of National Treasury, 2012):

**General content:**

- Notification of construction;
- Legal appointments to be made;
- Registers of training and induction courses;
- Assessment records;
- Personal protective equipment (PPE) and inspection records and registers;
- Plant and equipment used for construction registers;
- Records of inspections for plant and equipment;
- Registers and copies of audits conducted on site;
- Registers and copies of safety reports conducted on site;
- Registers and copies of risk assessments conducted on site;
- Registers and copies of incidents, first aid and reportable injuries on the site;
- Registers and copies of approved operators and their certificates of training;



**Method statements in terms of the following:**

- Construction work;
- Risk assessment;
- Fall protection plan;
- Excavations and backfilling;
- Pipe, duct or cabling;
- Testing of pressure pipelines;
- Electrical work;
- Structural concrete;
- Paving;
- Welfare;
- First aid;
- Form and support work;
- Demolitions;
- Scaffolding;

The health and safety plan must be kept on site at all times, from the date of commencement and for the duration of the construction work. This document should be consulted daily to ensure that the health and safety requirements are met and maintained on site (Department of National Treasury, 2012).

**4.13.4 Construction safety hazard prevention through design**

According to Markkanen, et al. (2010), the National Institute for Occupational Safety and Health established an initiative in 2007 called the Prevention through Design approach (PtD). The PtD approach focuses on designing out, or at least minimising, occupational hazards early in the design phases of a project to prevent injuries and illnesses. Construction Hazard Prevention through Design (CHPtD) is a procedure in which designers consider the safety of construction employees as they design a facility. For this research, the designer is referred to as the engineer (engineer employed by the client).

Although many articles on CHPtD have appeared in top construction journals, no technical principles have been addressed to help engineers improve CHPtD (Toole & Gambatese, 2008).

However, research done by Toole & Gambatese (2008) resulted in the following routes that can be followed to improve the manner in which engineers approach CHPtD:

- Engineers should design a building with the focus on using more prefabricated construction.
- The design should specify materials and construction systems that are the safest.
- The engineer should regularly apply considerations of the working environment to reduce employee hazards.

The above mentioned routes that can be followed will be addressed in Chapter 5 of this research where South African engineers will be consulted on this matter. Gambatese, et al. (2008) states the key component of the CHPtD process is the incorporation of site safety knowledge into design decisions. Therefore, an integrated approach between the engineer and contractor should be taken in order to ensure that construction methods and employee safety are considered from the beginning of the project.

Gambatese, et al. (2008) uses the process presented by Figure 18 to demonstrate CHPtD. It starts off by establishing design for safety expectations, including construction and operation viewpoints during design and identifying design for safety processes and tools. The process, importantly, identifies the involvement of the contractor early during the design phase of the project.

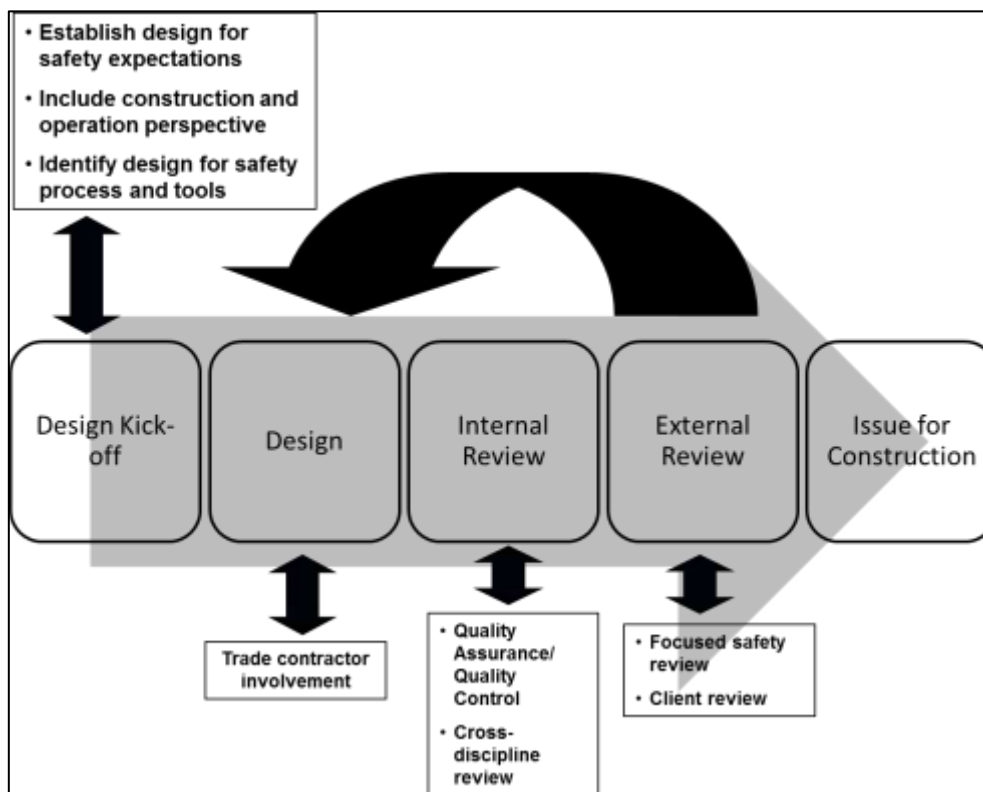


Figure 18: An illustration of the Construction Hazard Prevention through Design (CHPtD) process (Gambatese, et al., 2008)

As mentioned earlier, early contractor involvement will ensure an integrated approach from the start where construction methods, employee safety, and constructability are taken into account.

The work product of a CHPtD project does not differ from that of a standard project (Gambatese, et al., 2008). Therefore, the drawings and technical specifications will look the same as for a standard project; however, a CHPtD project will reflect an inherent safer construction process. Gambatese, et al. (2008) mentions that it is hoped that construction documents resulting from a CHPtD process will include safety enhancing details and notes that are not currently found on standard plans and specifications.

#### **4.13.5 Final thought**

The case studies that were analysed in Chapter 4 provided an overview of the hazardous construction industry and provided several lessons that can be learned from each. These lessons are focused on the role that the engineer should play throughout the life-cycle of a project with regard to health and safety.

One objective of the case studies was to identify whether the construction site hazards mentioned in Chapter 3 are legitimate. The answer is “yes”. The numerous case studies proved that working at heights or on roofs, demolition, plant and equipment, hazardous material, ergonomics, electrical works, etc. are construction processes that present safety hazards that engineers should take into account when designing a building. Amongst these hazards, several other construction site hazards were identified that can jeopardise the safety and health of employees. The more important lessons that were learned, that was present in almost every case study, were the fact that engineers should enforce the use of fall arrest systems when work needs to be performed on roofs or at heights. The engineer should monitor that the contractor have a formal safety training program in place and the engineer and contractor should have regular meetings to discuss possible site hazards.

The regular meetings will ensure the early involvement of the contractor during the design phase of the project as presented by the Construction Hazard Prevention through Design process in Figure 18. Early collaboration between the engineer and contractor, provided that their experience and knowledge on construction methods and safety are adequate, will result in a safe and constructible building site.

## CHAPTER 5: CONSTRUCTION SITE SAFETY - QUESTIONNAIRES

Inter alia, the literature study done in Chapter 3 investigated the definition of safety during design and identified the different health and safety hazards that a building construction site presents. Chapter 4 includes the investigation of case studies with the aim to identify whether construction site accidents do occur and certain lessons were learned from these case studies with regard to the responsibility of the engineer.

An electronic questionnaire was used as the third research instrument. Chapter 5 presents a discussion on the reasons for deciding on the use of a questionnaire, the objective, the technology used for designing and distributing it, and a discussion of each question. An example of the questionnaire; "Construction Site Safety through Design Questionnaire" can be found in Appendix C.

The results obtained from the completed questionnaires are also discussed in this chapter. Each question of the questionnaire is discussed individually and a spread sheet containing the results can be found in Appendix D. The graphs that present the results obtained from Parts 1 and 2 of the questionnaires are included in this chapter rather than in an appendix. The reason is that it provides a visual presentation of the scoring from the respondents. The graphs that represent the results of Parts 3 and 4 of the questionnaire are presented in Appendices E and F respectively.

### 5.1 Questionnaire Design

Questionnaires take many different forms and styles (Barnes, 2001). One option is face-to-face interviews where the researcher asks questions and is verbally answered by the respondent. Another option is an electronic or online questionnaire. In this case, a questionnaire, or a link to a questionnaire, is sent to respondents and the questionnaire is answered and submitted electronically.

Apart from the face-to-face interview and the electronic questionnaire, several other forms of questionnaires are possible. Amongst others, these include telephone interviews or postal questionnaires (Barnes, 2001). However, an electronic questionnaire was chosen as the third research instrument for this research.

#### 5.1.1 Reasons for deciding on electronic questionnaire

Barnes (2001) states that an electronic questionnaire is easier to respond to due to the respondent not necessarily being in direct contact with the researcher. However, not being in direct contact with the respondent makes it difficult to motivate people to respond and therefore, a 100% response rate is seldom achieved.

Among other reasons that will be discussed in this section, an electronic questionnaire was used for this research due to the respondents receiving all communications in writing. The latter includes the background and objectives of the research, the questionnaire itself, and the instructions for completing the questionnaire.

Other reasons for using an electronic questionnaire are the following:

- A questionnaire allows the researcher to obtain facts, attitudes and the opinion of individuals.
- The response to a questionnaire, especially in electronic format, is less time consuming than interviews. The electronic questionnaire is used and designed in a manner that the respondent spends little time answering it, because the electronic questionnaire allows the respondent to type short sentences or to choose the correct answer. Finally, the questionnaire is submitted on the internet and the use of scanners and e-mails are not necessary.
- The respondents stay anonymous as the information gathered from the responded questionnaires is treated in the strictest confidence and is used only for academic purposes. Therefore, individuals or companies are not identified in the published research results.
- An electronic questionnaire allows the researcher to obtain large amount of information from a large number of experienced individuals in a short period of time and in a relatively cost effective manner.
- The results obtained from the electronic questionnaires can easily be analysed by the researcher.
- The analysed results can be used to compare with other research results and may be used to measure change.

It is important for the questions to be understandable and it must be clear what the respondent is supposed to do. An electronic questionnaire allows the researcher to do this.

### **5.1.2 Technology used for electronic questionnaire design and distribution**

The technology that is used for the design of the questionnaire is important as the respondents should be able to access the software program and be able to work with it. Google Drive (available at <https://drive.google.com>) was used for the design of the electronic questionnaire for this research. In Google Drive, a form was created by making use of several types of questions, such as factual -, multiple choice -, ranking -, and attitude questions. Each question is discussed in Section 5.2.

Prior to the electronic questionnaires being sent to the respondents, an e-mail invitation was sent to numerous consulting engineers in South Africa. The invitation letter is presented in Appendix A. For those that responded positively to the invitation, the actual questionnaire was emailed. The cover letter for the questionnaire is presented in Appendix B.

## 5.2 Objectives of Questionnaire

The questions focused on the research described in Chapters 3 and 4. In Chapter 3 the aim was to identify the definition of safe design and the responsibilities of the engineer, with regard to construction employee safety.

Furthermore, Chapter 3 identified a proposed safe design approach from the results of previous research. However, the safe design approach in Chapter 3.2 only identifies the steps to result in safe construction activities with no actual focus on the duties of the designer. Therefore, different construction site hazards associated with building construction were identified in conjunction with possible duties of the engineer to minimise or eliminate the hazard.

The research in Chapter 4 investigated case studies where construction accidents had occurred. The latter resulted in lessons with regard to what the engineer can do to help prevent accidents occurring.

The main objective of the questionnaire is thus to use the research results obtained in Chapters 3 and 4 and to obtain the opinion of experienced consultant engineers on certain matters. The experience of the chosen respondents was not limited to a certain number of years. However, the results obtained from each respondent, together with the experience of each, will provide an understanding of the state of knowledge from engineers on construction site safety in South Africa.

The questionnaire consists of five parts (Refer to Appendix C) with each part consisting of various questions based on previous research results. The following paragraphs include the discussion of each question with focus being placed on the objective of each.

### 5.2.1 Part 1: Personal Information

The first part of the questionnaire requires the respondent to provide the number of years he or she has been working as a consultant engineer or as contractor. As mentioned in Chapter 1, Jerling (2009) makes the following statement concerning design knowledge of the engineer:

*“The designs provided by engineers are commonly seen as unsafe designs due to a lack of knowledge of construction processes and the risks associated with it.”*

A lack of construction processes may be due to the engineer stepping into a consultant engineering office after university with no, or little, experience working as a contractor. Associated with construction processes are construction risks. Therefore, a lack of knowledge of construction site risks may be due to a lack of knowledge of construction processes. The questionnaire aims to integrate the years of experience of each respondent with their opinion on construction site risks.

Part 1 of the questionnaire also requires the respondents to, with the help of an attitude question, provide their opinion on whether there is a lack of communication between employees and contractors. A lack of communication, inter alia, results in a lack of safety training of employees and a lack of hazard identification. This question is viewed as important due to a lack of safety training and hazard identification, according to Chapter 4, being common causes for construction site accidents. Furthermore, Part 1 of the questionnaire requires of the respondents to state whether they know how to improve the safety on construction sites. The latter does not only include identifying construction site hazards during the design phase, but being able to identify possible construction site hazards throughout the life-cycle of the project.

As presented by Table 1 in Chapter 3.1, the number of construction fatalities in South Africa increased from 2004 to 2008. The total number of injuries on construction sites also increased during this time period. Part 1 of the questionnaire asks respondents to state the number of the accidents that occurred on construction projects that their companies participated in during 2012/2013 and to briefly discuss one incident.

## **5.2.2 Part 2: Construction Employee Safety and Site Hazards**

The questions in part 2 of the questionnaire are based on the results obtained from Chapter 3.3, i.e. Construction Site Hazards for Buildings. However, prior to addressing the construction site hazards for buildings, respondents are required, by means of multiple choice questions, to state what the main reasons are for construction site accidents to occur in three scenarios.

The objective of the first scenario is to identify the main reason for construction site accidents to occur in general. According to Venter (2009), the reason for the increase in injuries on construction sites is not due to a lack of health and safety legislation in South Africa, but rather the enforcement of adequate health and safety systems within the construction industry. One of the multiple choice answers for this question is "Lack of legislation". Therefore, the opinion of South African engineers is important in this case as it will show whether South African engineers also believe that the increase in injuries on construction sites is due to causes other than health and safety legislation. A lack of construction knowledge from the engineer, a lack of safety knowledge from the engineer, a lack of

safety knowledge from the contractor, and careless employee attitudes are the other answers that can be chosen for this question.

The objectives of the other two scenarios are to identify the reasons for construction site accidents due to the shortcomings of the contractor or his or her employees.

An important question is asked in part 2, i.e. who is most responsible for construction site safety between the engineer and contractor. This question is compared with the results obtained from the question that asks the respondents to state the impact of a design engineer in ensuring the safety of construction employees for hazards associated with the following construction activities:

- Demolition;
- Electrical works;
- Ergonomics;
- Excavation;
- Hazardous substances;
- Maintenance;
- Manual handling;
- Plant and equipment;
- Refurbishment;
- Steelwork;
- Utilities;
- Work done on roofs.

The results obtained from these questions will be an indication of the attitude of some South African engineers towards construction site safety. It is also important to identify whether South African engineers are aware of the hazards associated with each construction activity and of the role the engineer can play to reduce or minimise the hazards.

### **5.2.3 Part 3: Lessons Learned from Case Studies**

The questions in part 3 are based on the lessons learned from investigating case studies. Primarily, the aim of the investigation of case studies is to identify the roles the engineer can play prior and during construction to prevent or minimise a construction site safety risk.

The respondents were asked to state whether they strongly agree, agree, disagree, or strongly disagree with the most common lessons that were learned from Chapter 4. It is important to note that these lessons do not represent what the engineer should do during the life-cycle of a building project; however, it is only guidelines for the engineer to prevent or minimise certain construction



risks. Therefore, a percentage of South African engineers were asked for their opinion on each lesson and to state whether they agree or not. The combination of the lessons learned from Chapter 4, and the opinion of South African engineers, will be a better indication of the importance of each lesson.

The final lesson that was learned from Chapter 4 was that engineers should design a building with the focus on using more prefabricated construction. Only positive opinion of South African engineers on this statement will result in a discussion on prefabricated construction and the advantages with regard to construction site safety.

#### **5.2.4 Part 4: Information Exchanged between Engineer and Contractor**

This section includes statements with information that the engineer should share with the contractor throughout the life-cycle of a project.

As mentioned in Chapter 3.4.4, integration between all project participants is necessary to improve the constructability of the project which in turn will lead to a safer working environment. The successful exchange of information between the engineer and the contractor is one way to ensure integration between them.

The Construction Regulations present the responsibilities of the client to ensure his or her compliance with the Occupational Health and Safety Act (1993). However, according to the Principle Building Agreement (2000), the engineer can be appointed as an agent for the client. Therefore, the responsibilities of the client in the Construction Regulations may also be applicable to the engineer. These responsibilities are seen as a general approach to what the engineer should do during a construction project and no specific details are provided.

The opinion of a percentage of South African engineers on the responsibilities of the engineer as stated in the Construction Regulations, is asked in Part 4. The answers obtained from the latter will be an indication of the knowledge of South African engineers of the Construction Regulations.

However, Part 4 also requires the respondents to briefly discuss the actual type of information that needs to be shared by the engineer with the contractor. This question is asked due to the problem that persists in the form of the uncertainty of the type of information that should be shared with the contractor by the engineer (Kuo, 2012).

#### **5.2.5 Part 5: Safe Design Process**

Various research results can be found that demonstrate safe design techniques, i.e. the steps that need to be taken prior to construction to ensure a safe and healthy construction site. Many of these

results identify the bigger picture of safe design, but few recognize the importance of the smaller, but still important, steps that should be taken in between the bigger steps.

In Chapter 3.2 a proposed safe design process is discussed; however, this process is a general approach towards designing for safety. The aim of the question in part 5 of the questionnaire is to obtain the opinion of a percentage of South African engineers, on the steps that need to be taken for a safe design process. This includes a safe design process with focus on all the steps that should be taken, including the smaller, but still important steps.

### **5.3 Questionnaire Results**

The invitation letter to the questionnaire (refer to Appendix A) was sent to 60 consulting engineers in South Africa. Twenty five (25) engineers responded positively to the invitation. Out of the 25 South African engineers, 23 engineers answered the questionnaire and this resulted in a 92% response rate.

This section includes the discussion and analysis of the responses to each question of the questionnaire. The answers to each question are presented in Appendix D by using the column numbers next to each question header as reference.

#### **5.3.1 Part 1 Results: Personal Information (Columns B – K)**

The results, comments, and recommendations to the questions for Part 1 of the questionnaire are presented in this section. Each question is numbered as shown in Appendix C and the numbers included in the sub-headers of this section should be used as reference to identify the corresponding results, comments and recommendations for each question.

##### **Questions 1 – 4: Results**

Part 1 of the questionnaire required from the respondents to state the number of years of experience they have as a consultant engineer or contractor. They were also required to state the number of years of experience they have in building design as a consultant engineer or any other occupation. Table 4 presents the results from the above mentioned questions.

As presented in Table 4, the average for the years of experience in building design and working as consultant engineers is 13 and 16 respectively.

The average of years of experience as a contractor is 1 and is much lower in comparison with the average of years working as engineers.

Table 4: Results from Part 1 of the questionnaire (Years of Experience)

Respondent #	Years' Experience			
	Building Design	Engineer	Contractor	Other Occupations
1	0	2.5	0	None
2	20	20	0	None
3	0	2	0	None
4	1	3	0	None
5	40	40	0	None
6	40	40	0	None
7	35	35	0	None
8	12	12	0	None
9	20	20	0	None
10	15	15	0	None
11	1	2.5	0	None
12	5	30	1	None
13	5	10	0	Architect
14	10	12	3	None
15	20	25	5	None
16	4	4	0	None
17	12	20	0	None
18	25	25	5	None
19	3	10	0	None
20	8	10	4	None
21	0	1	0.08	None
22	0	7	0	None
23	15	15	3	None
Average	13	16	1	

#### **Questions 1 – 4: Comments and Recommendations**

The average of the years of experience in comparison with the responses throughout the questionnaire would be a good indication of the construction safety knowledge and safety involvement of a percentage of South African engineers.

A percentage of South African engineers completed their studies and started working at a consultant engineering company with no real construction experience. The latter may be one reason why Jerling (2009) makes the following statement concerning design knowledge of the engineer:

*“The designs provided by engineers are commonly seen as unsafe designs due to a lack of knowledge of construction processes and the risks associated with it.”*

A lack of site experience may result in a lack of knowledge concerning construction processes and the safety hazards associated with each.

A recommendation to possibly solve the problem of inexperienced engineers, with regard to construction activities, is to ensure that engineers obtain a certain amount of years of site experience before being employed as a designer. Being aware of the possible safety hazards associated with construction processes would allow the engineer to design a building accordingly and avoid or minimise the risks associated with the hazards.

According to the Engineering Council of South Africa (ECSA) (2004) and as stated in Policy Statement R2/1A, the prescribed minimum practical training period, after obtaining a recognised qualification, is three years in order to register as a professional engineer. The practical training must include problem investigation, problem solution, and execution at increasing levels of responsibility (Engineering Council of South Africa (ECSA), 2004).

However, the question may be whether a minimum of three years of practical training is sufficient? Another question may be whether the requirements of ECSA are clear enough with regard to site experience? The latter means the actual time spent on a construction site where problem investigation, problem solution, and execution are observed in person.

### **Questions 5 and 6: Results**

Referring to Appendix D, the respondents were required to discuss the first thoughts that come to mind when they hear the word “safety” on a construction site (Column F). Furthermore, the respondents were required to state whether they have received any safety training as shown in Column G. A summary of the first thoughts that were most mentioned is:

- Ensuring safety near the proximity of equipment.
- Preventing construction accidents.
- Ensuring safe construction processes.
- Communication between project participants.
- Eliminating safety hazards as soon as possible.
- Planning ahead.
- Avoid time delays and additional costs.

Thirty nine percent (39%) of the respondents agree that construction hazards should be identified as soon as possible, i.e. during the concept design phase. The thoughts amongst only 13% of the respondents are that communication between project participants is essential in order to achieve a safe construction environment. Only 43% of the respondents received construction site safety training.

**Questions 5 and 6: Comments and Recommendations**

Knowledge on construction site safety will result, for example, in the engineer being aware of the necessary safety equipment that needs to be used by employees, or the procedures that need to be followed after an incident occurred. Therefore, it is essential for engineers to undergo descent construction safety training.

Communication and integration between the engineer and contractor is important and depending on the contract – and procurement strategy, the involvement of the contractor during the early design phases of a construction project will result in better communication, integration, and hazard identification. Therefore, safety and regular communication between project participants should go hand in hand. This will result in the early identification of all possible safety hazards and the design being done accordingly.

**Question 7: Results**

As shown in Appendix D, Columns H and I required respondents to state whether they strongly agree, agree, disagree, or strongly disagree with the following two statements:

1. In your experience, employees on construction sites have problems in communicating with their employers/supervisors.
2. You know how to improve the safety of construction sites.

Figure 19 presents a graph that shows the responses to the first statement and Figure 20 presents the responses to the second statement.

Communication between project participants was a common thought amongst a percentage of South African engineers when they hear the word “safety”. As shown in Figure 19, 61% of the respondents agreed, or strongly agreed, that employees on site have problems in communicating with their employers/supervisors.

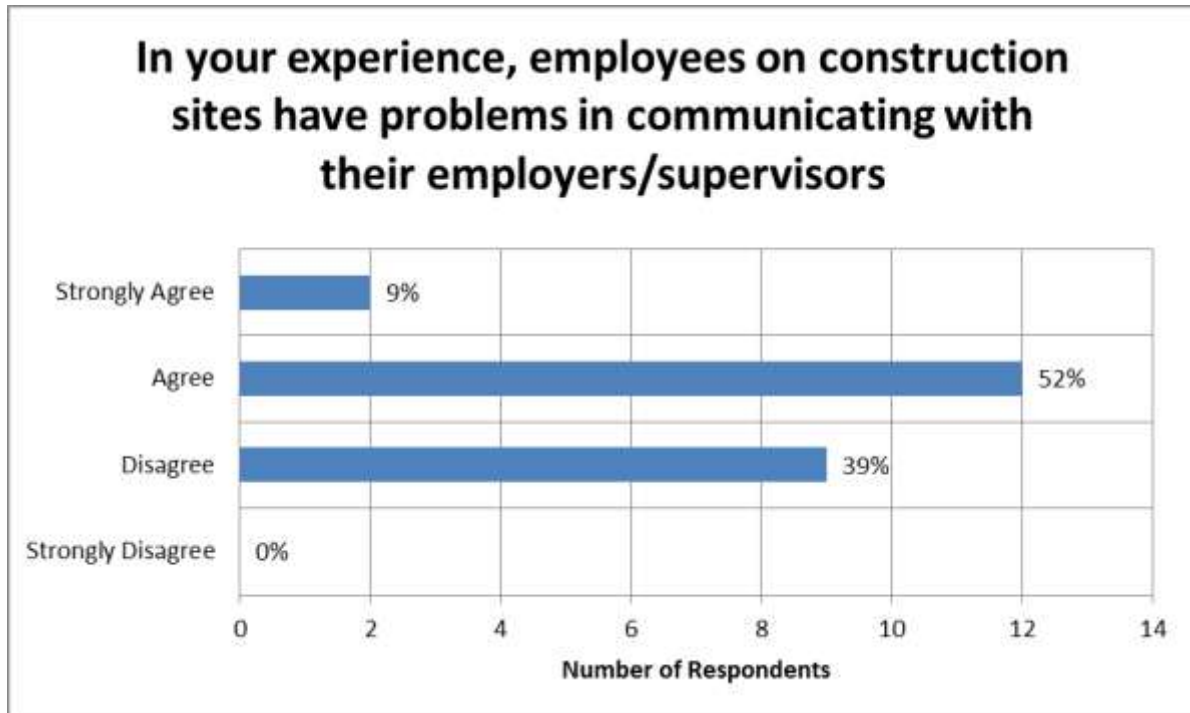


Figure 19: Response to statement: In your experience, employees on construction sites have problems in communicating with their employers/supervisors

Figure 20 presents an important part of the questionnaire. Forty three percent (43%) of the respondents mentioned that they do know how to improve the safety of construction sites and 57% stated that they do not know. Based on the average years of experience of respondents as engineers, 57% that do not know how to improve the safety is high.



Figure 20: Response to statement: You know how to improve the safety of construction sites.

**Question 7: Comments and Recommendations**

Regular and descent communication between project participants is essential for a project to be safe. For example, communication between the engineer and contractor is essential to identify and mitigate safety hazards and to ensure safe construction procedures. .

Despite that a small percentage of the respondents mentioned that communication between project participants is important when referring to construction site safety (13%), 61% mentioned communication between employees and their employers is currently a concern. Numerous factors may contribute to a lack of communication between project participants. Amongst others, these factors include language differences, lack of motivation, careless employee attitudes, and careless contractor attitudes.

Regular communication between the contractor/engineer and construction employees is important to inform the employees of construction safety hazards, safety and equipment, and procedures to avoid the safety hazards

As mentioned earlier, safety training for engineers is important. Descent safety training at the beginning of an engineer's career will ensure that he/she is aware of procedures to improve the safety on construction sites.

**5.3.2 Part 2 Results: Construction Employee Safety and Site Hazards (Columns L – AA)**

The questions in part 2 are based on the safety of construction employees and the possible hazards that are associated with various construction activities. Respondents were required to state the main reason for construction site accidents for three different scenarios. Furthermore, the respondents needed to state the effect that a design engineer has in ensuring the safety of construction employees.

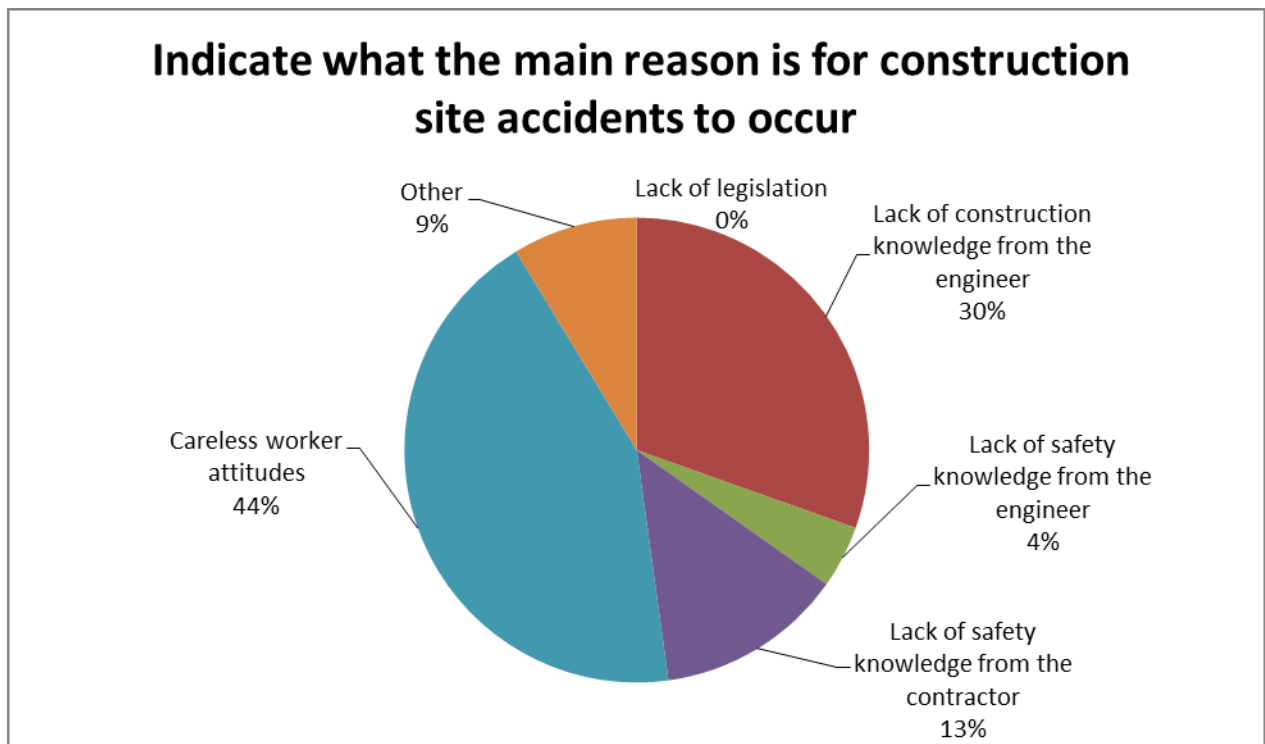
The results, comments, and recommendations to the questions for Part 2 of the questionnaire are presented in this section. Each question is numbered as shown in Appendix C and the numbers included in the sub-headers of this section should be used as reference to identify the corresponding results, comments and recommendations for each question.

**Question 10: Results**

Figure 21 presents a graph that includes the opinion of a percentage of South African engineers with regard to the main reason for construction accidents, i.e. the reason why construction sites are unsafe in general.

The results show that the majority of the respondents, 44%, feel that a careless employee attitude is the main reason for construction accidents to occur.

30% of the respondents feel that a lack of construction knowledge from the engineer is the reason for construction accidents to occur. Only 4% of the respondents feel that a lack of safety knowledge from the engineer is the main reason opposed to 13% that feels a lack of knowledge from the contractor is the cause for construction site accidents.



**Figure 21: A graph that presents the opinion of a percentage of South African engineers with regard to the main reason for construction site accidents in general**

### **Question 10: Comments and Recommendations**

It can be true that careless employee attitudes are causing construction site accidents since an uncaring behaviour from employees, with regard to safety, can result in a communication gap between the contractor and employees. A lack of communication would result in contractors or engineers not informing employees of construction safety hazards or it would cause a lack in safety training on site.

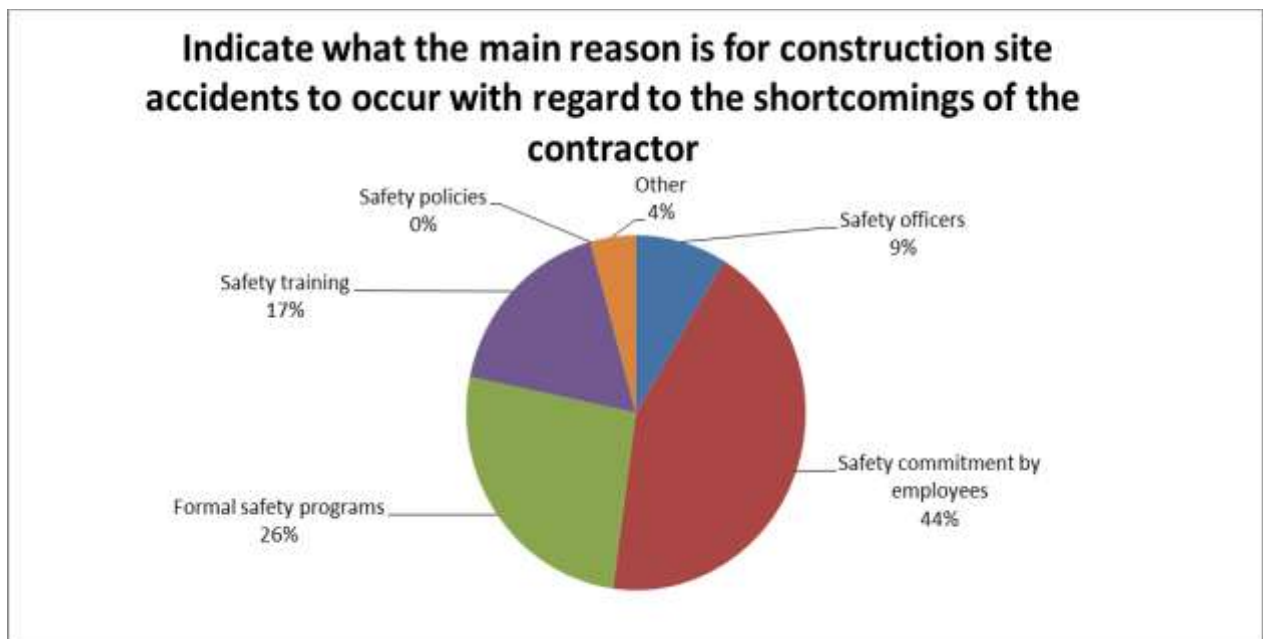
As mentioned in Section 5.2.1, only 43% of the respondents received construction safety training throughout their careers. The latter, in comparison with the results shown in Figure 21, is proof that the respondents feel that engineers are not responsible for construction safety.



As mentioned earlier, engineers should have adequate site experience before being employed by a consulting engineering company. This may help to ensure that the engineer is aware of construction processes and the safety hazards associated with each. Therefore, the engineer will be able to incorporate safety into the design. This will lead to more responsibility, with regard to safety, being placed on engineers and may contribute to a safer construction site.

### **Question 11: Results**

Figure 22 presents a graph that reflects the opinion of the respondents with regard to the cause for unsafe construction sites with regard to the shortcomings of the contractor.



**Figure 22: A graph that presents the opinion of a percentage of South African engineers with regard to the main reason for construction site accidents with regard to the shortcomings of contractors**

As presented by Figure 22, 44% of the respondents feel that contractors have a lack of safety commitment from their employees.

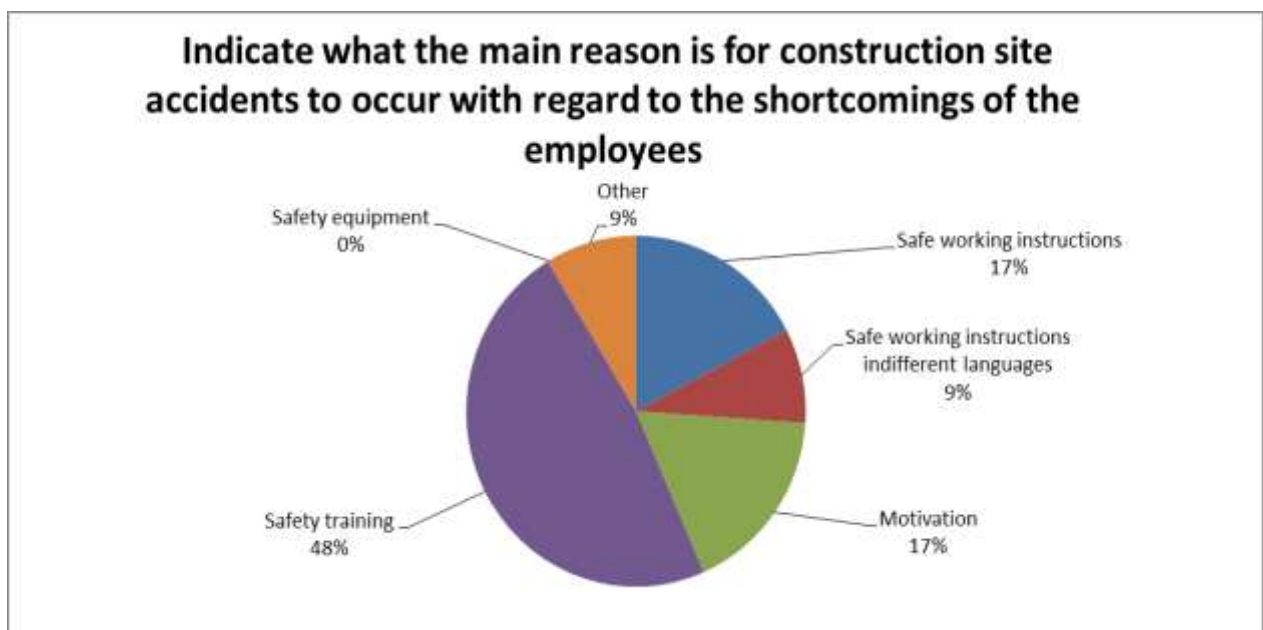
### **Question 11: Comments and Recommendations**

The results of Question 11 support the results shown in Figure 21. However, it is uncertain why employees have an uncaring commitment and attitude towards construction safety since construction employee safety is for their own benefit. Therefore, a better description may be that employees have a lack of safety knowledge, rather than having careless attitudes. This is an indication that safety training or safe working instructions is absent on construction sites.

Contractors should ensure that their employees undergo descent safety training. From the lessons learned in Chapter 4, the safety training should be presented in different languages and should inform the employees of the possible safety hazards and the manner in which safety equipment can be used to protect them from injuries.

### **Question 12: Results**

Figure 23 presents a graph that shows the opinion of the respondents with regard to the cause for unsafe construction sites based on shortcomings of the employees. As presented, the largest percentage of the respondents, 48%, feels that a lack of safety training for employees is the main cause for construction site accidents to occur.



**Figure 23: A graph that presents the opinion of a percentage of South African engineers with regard to the main reason for construction site accidents with regard to the shortcomings of employees**

### **Question 12: Comments and Recommendations**

Although descent safety training and safety programs are primarily the responsibility of the contractor, the engineer can play a role by enforcing the safety training to commence. The respondents were asked on this matter in Question 13. All the respondents feel that the contractor is mainly responsible for the safety of employees on construction sites (refer to Appendix D, Column O).

However, the engineer should monitor that the contractor provides formal safety programs to their employees. It can also be included as a cost item and in the health and safety specifications. The

safety programs should cover descent safety training that includes safe working instructions in different languages.

**Question 14:**

This section of Part 2 of the questionnaire required from the respondents to indicate the effect a design engineer has on construction safety for hazards associated with the construction activities mentioned in Chapter 3.3.

In Chapter 3.3 of this research, various safety hazards for employees working on a building site are associated with construction activities. The opinion of the respondents with regard to the effect of engineers on the hazards associated with the construction activities are represented on a scale from 0 to 5 (0 = no effect and 5 = largest effect) as shown by Figure 24 through to Figure 35. Please note that the percentage data labels for each graph present the percentage of respondents.

The results, comments, and recommendations for each construction activity are discussed below. The recommendations discussed in this section include the duties of the engineer to improve construction safety. These duties were derived from Chapter 3.3 and the lessons learned from the investigation of case studies in Chapter 4.

**Demolition - Results:**

Figure 24 presents a graph that shows the opinion of the respondents with regard to the effect of a design engineer on construction employee safety for the hazards associated with demolition.

As shown in Figure 24, 35% of the respondents feel that a design engineer has an effect of 3 on safety for hazards associated with demolition. In reference to the scale that was used, a magnitude of 3 is identified as moderate. Therefore, according to the respondents, engineers can play a moderate role in ensuring the safety of construction employees by incorporating safety awareness into the demolition design.

However, by adding the percentages of respondents that voted an effect of 3, 4, and 5, the majority of the respondents, 57%, feel that the engineer has a moderate to high effect on employee safety for demolition hazards.

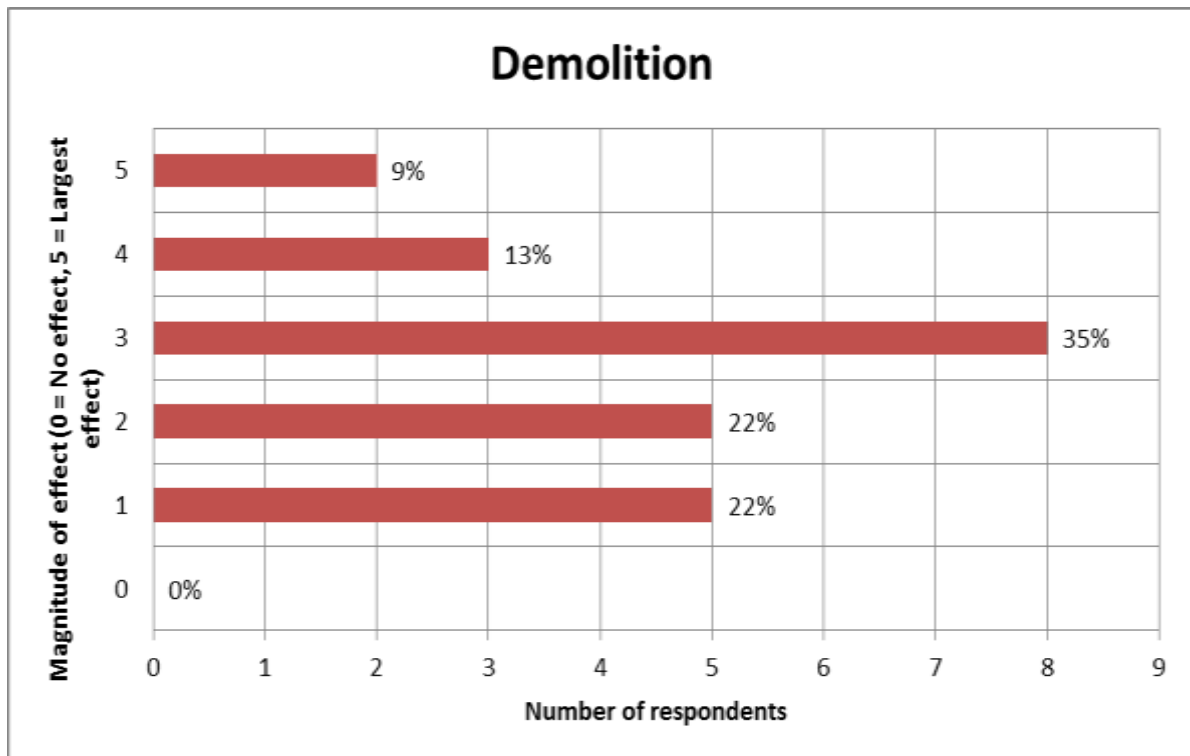


Figure 24: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with demolition

#### Demolition – Comments and Recommendations:

Since the respondents feel that the engineer has an effect on construction safety for demolition hazards, it is important to be aware of what exactly the role is that the engineer can play. Therefore, it is important to identify the duties of the engineer.

The following duties are recommended for the engineer (from Chapters 3 and 4):

- Engineers should monitor that employees working at heights are equipped with the necessary safety equipment by including it in the health and safety specifications of the project.
- Engineers should pass relevant information, such as surveys, historical drawings and service records, on to the demolition contractor.
- The engineer should supply information on load paths that include:
  - The critical loading conditions that may cause collapse.
  - Critical load-bearing elements that should not be removed without supporting arrangements (columns under supporting beams, floor beams, members providing lateral restraint to compression members).
  - Pre-stressed concrete elements which contain considerable tension.

- The engineer is responsible for identifying risks arising from temporary situations. These situations are for example the creation of retaining walls and excavations when basements and foundations are removed, or destabilising a structure when demolishing an adjoining structure.
- The engineer is responsible for identifying hazardous material that may be present during the demolition process or material that remains on the site.

### Electrical Works - Results:

Figure 25 presents a graph that shows the opinion of the respondents with regard to the effect of a design engineer on construction employee safety for the hazards associated with electrical works.

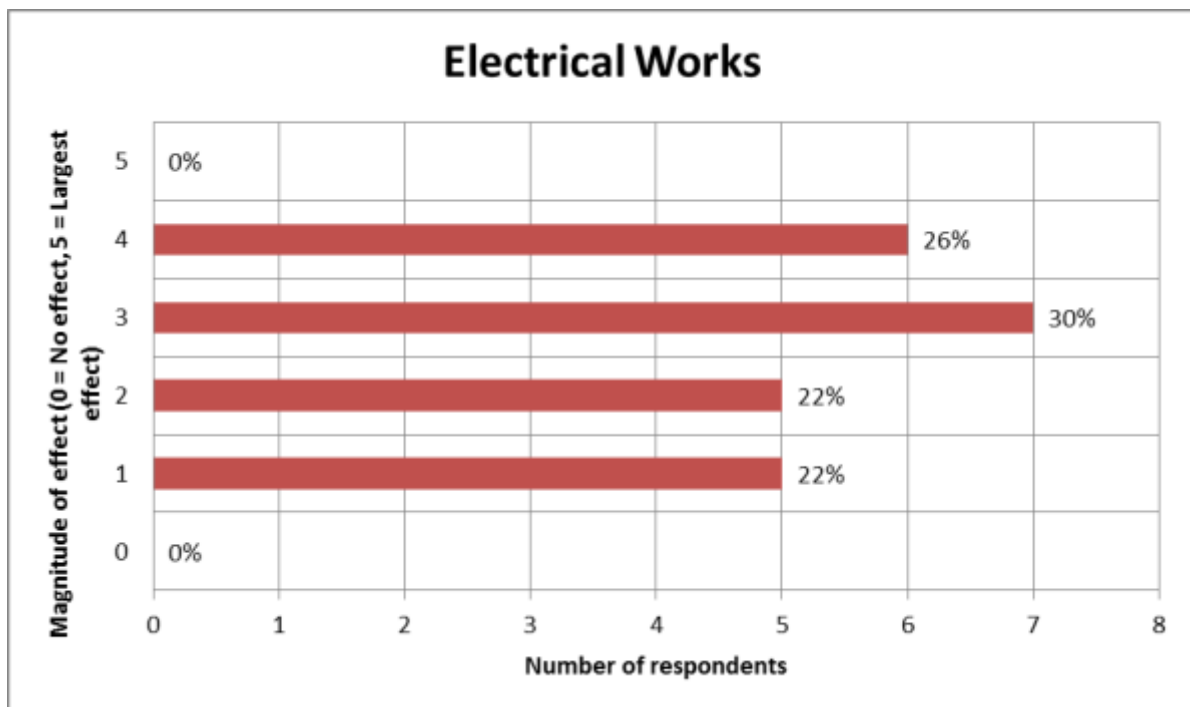


Figure 25: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with electrical works

As presented in Figure 25, 30% of the respondents voted an effect of 3 and 26% voted an effect of 4. By adding these percentages, the majority, 56%, of the respondents feel that a design engineer has a moderate to high effect on safety for hazards associated with electrical works. Therefore, the respondents agree that engineers do have a form of responsibility to ensure the safety of construction employees with regard to the design of electrical works.

**Electrical Works – Comments and Recommendations:**

The following duties are recommended for the engineer (from Chapters 3 and 4):

- The engineer should specify that overhead power lines be disconnected, re-routed, covered or be underground before construction can start.
- In situations where it is not possible to disconnect and re-route the power lines, the engineer should adjust the design to fit the layout of the power lines.
- The engineer should minimise the need for electricians to work in cramped or restricted work areas during construction or maintenance by, for example, ensuring adequate working space when the switchboard doors are opened and extra space for the manual handling of aids.
- Engineers should minimise the length of large cables by considering the location of the switch room. If possible, the engineer can advise the contractor that cables should always be laid “top down”, as gravity can assist in the laying of the cables, rather than moving them from the “bottom up”.
- The engineer should monitor that the contractor considers using mechanical cable pulling machinery, if possible, to avoid manual handling risks.

To summarise the engineer should be aware of the locations of underground electrical cables and overhead power lines. Furthermore, the engineer should incorporate these locations into the design to inform the contractor of possible electrical hazards. The design should also be a logical approach with regard to electrical works i.e. adequate space should be provided for the electrical sub-contractor to perform efficiently. The design should include that, if possible, mechanical machinery should be used for the placement of cables to minimise manual handling.

**Ergonomics - Results:**

Figure 26 presents a graph that shows the opinion of the respondents with regard to the effect of a design engineer on construction employee safety for the hazards associated with ergonomics.

As presented by Figure 26, 39% of the respondents feel that design engineers have a moderate effect on the safety of construction sites with regard to ergonomic hazards. 17% of the respondents voted an effect of 4. By adding these percentages, the majority of the respondents, 56%, feel that an engineer has a moderate to high effect on construction safety for hazards associated with ergonomics.

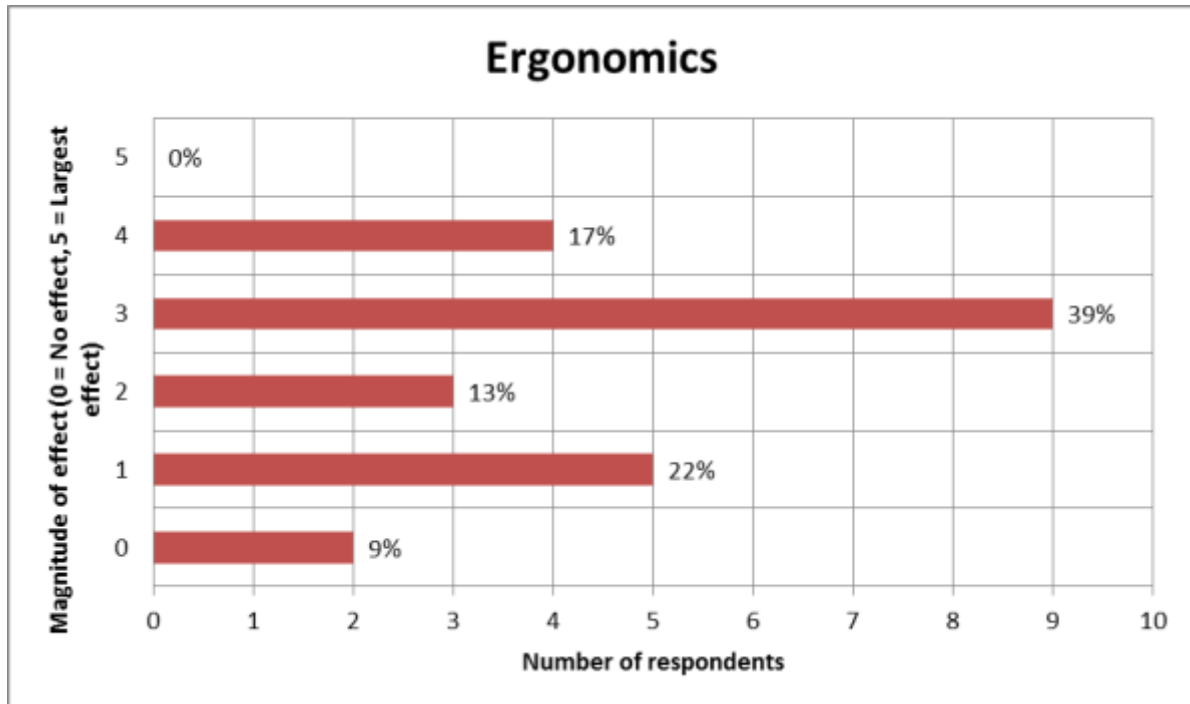


Figure 26: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with ergonomics

#### Ergonomics – Comments and Recommendations:

Ergonomics are generally defined as a discipline focused on making products and tasks comfortable for the user and the person performing the task. An example of an ergonomic consideration is for the engineer to avoid designing construction and maintenance activities that require work to be done in restricted areas or areas with difficult access. They should also aim to avoid designs that would require repetitive or prolonged movements to complete jobs.

The following duties are recommended for the engineer (from Chapters 3 and 4):

- The engineer should take the capabilities and limitations of the contractors and employees into account during the design phase.
- They should consider how the design and layout of the construction site will affect those working on site.

Ergonomic considerations during the design phase set the basis for other activities to be completed safely as it provides design factors that are intended to maximize productivity by minimizing employee fatigue and discomfort.

**Excavation - Results:**

Figure 27 presents a graph that shows the opinion of the respondents with regard to the effect of a design engineer on construction employee safety for the hazards associated with excavation.

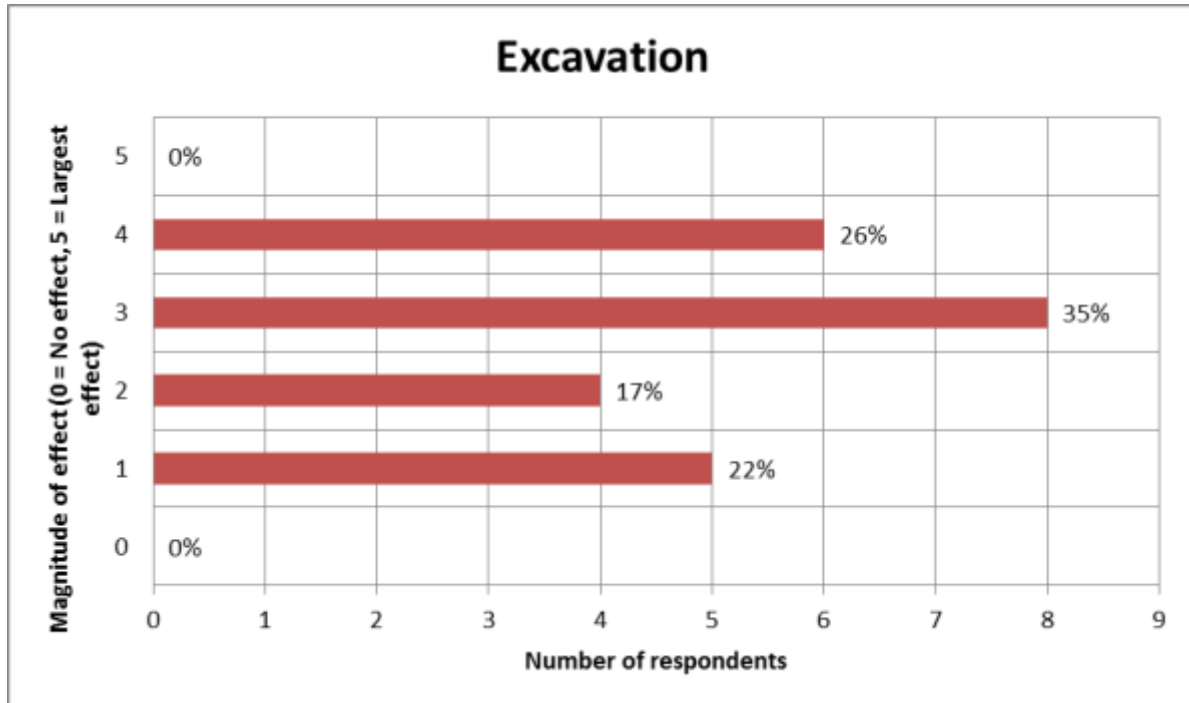


Figure 27: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with excavations

As presented by Figure 27, 35% of the respondents voted an effect of 3 and 26% of the respondents voted an effect of 4. Therefore, the majority of respondents feel that a design engineer has a moderate to high effect on the safety of employees with regard to the hazards associated with excavations.

**Excavation – Comments and Recommendations**

The aim for the engineer should be to design the excavation process in such a manner that it provides a safe working environment for the employees on site. The latter means that the engineer is responsible to identify those hazards associated with excavation and to inform the contractor of it.

The following duties are recommended for the engineer (from Chapters 3 and 4):

- The engineer should design alternative processes to avoid excavation in certain circumstances. For example, it may be possible to make use of piling in situations where the soil is poor, rather than digging down.



- The engineer should provide the exact locations of existing underground services that include electrical cables, gas pipes, and sewer - and water pipes.
- The engineer should adjust the position of the building or its temporary works to avoid contact with underground services.
- In scenarios where the position of the building or its temporary works cannot be adjusted, the engineer should indicate that the underground services are relocated. Therefore, the engineer should be aware of site conditions and construction processes that will enable him or her to adjust the design to fit the circumstances.
- The engineer should monitor that excavations are performed away from static loads (such as buildings, wall, and immobile plant) or dynamic loads (such as traffic and excavation equipment).

The engineer plays a part during excavation to prevent collapse of the excavation or objects and employees falling into it. The same as for a number of other construction site hazards, the responsibility of the engineer is not to avoid risks during the actual excavation process, rather during the design process. For the actual excavation process, the contractor is responsible to ensure the safety of the excavated and surrounding area.

#### **Hazardous Substances - Results:**

Figure 28 presents a graph showing the opinion of the respondents with regard to the effect of a design engineer on construction employee safety for the hazards associated with hazardous substances. The results indicate that the respondents feel that engineers have a moderate to large effect.

By referring to Figure 28, 4% of the respondents indicated an effect of 5, 43% indicated an effect of 4, and 13% indicated an effect of 3. By adding these three percentages together, the majority of the respondents, 60%, indicated that the engineer has a moderate to high effect on construction safety for hazards associated with hazardous substances.

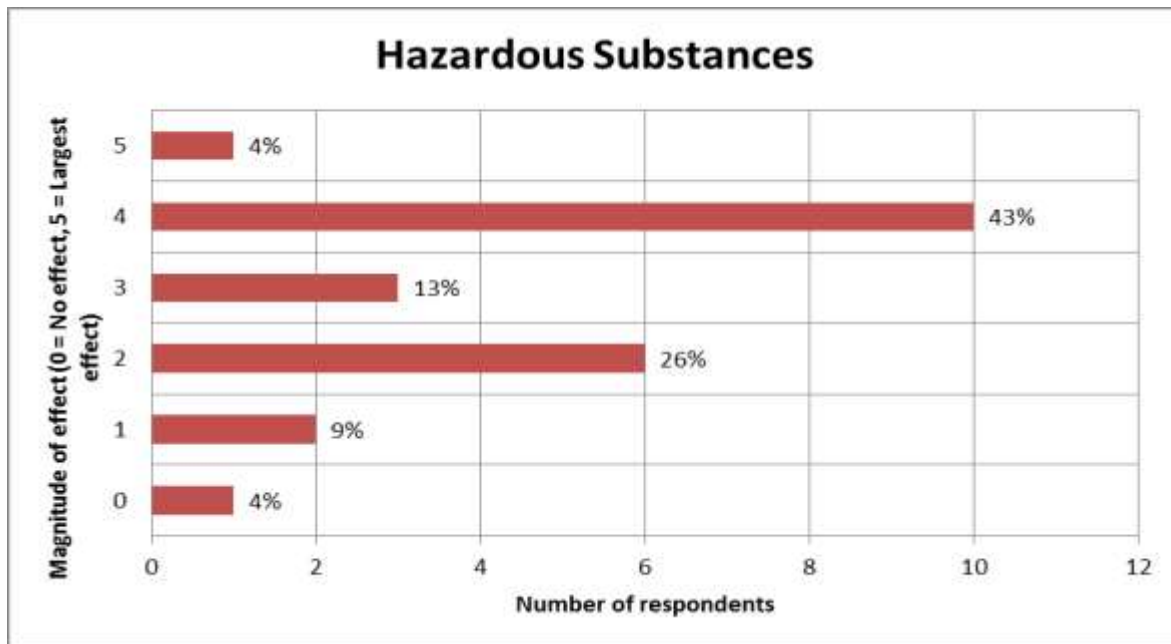


Figure 28: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with hazardous substances

#### **Hazardous Substances – Comments and Recommendations:**

The engineer can play a large role by incorporating the prevention of hazardous substance on construction sites in the design. Throughout the construction process, employees are exposed to hazardous substances that are the result of a certain construction activity. During demolition and refurbishment, the removal of asbestos may be required. The materials that asbestos consist of presents major health risks to those employees working on site.

The following duties are recommended for the engineer (from Chapters 3 and 4):

- The engineer should have sufficient knowledge on different construction activities and processes to design a healthy and safe working environment.
- The engineer should monitor that employees are equipped with the necessary safety equipment when work is performed in the proximity of hazardous substances.
- The engineer should recommend alternative construction methods, if possible, to manage the amount of hazardous substances.
- The engineer should monitor that only licensed asbestos removal contractors carry out the removal of asbestos.

**Maintenance - Results:**

Figure 29 presents a graph that shows the opinion of the respondents with regard to the effect of a design engineer on construction employee safety for the hazards associated with maintenance.

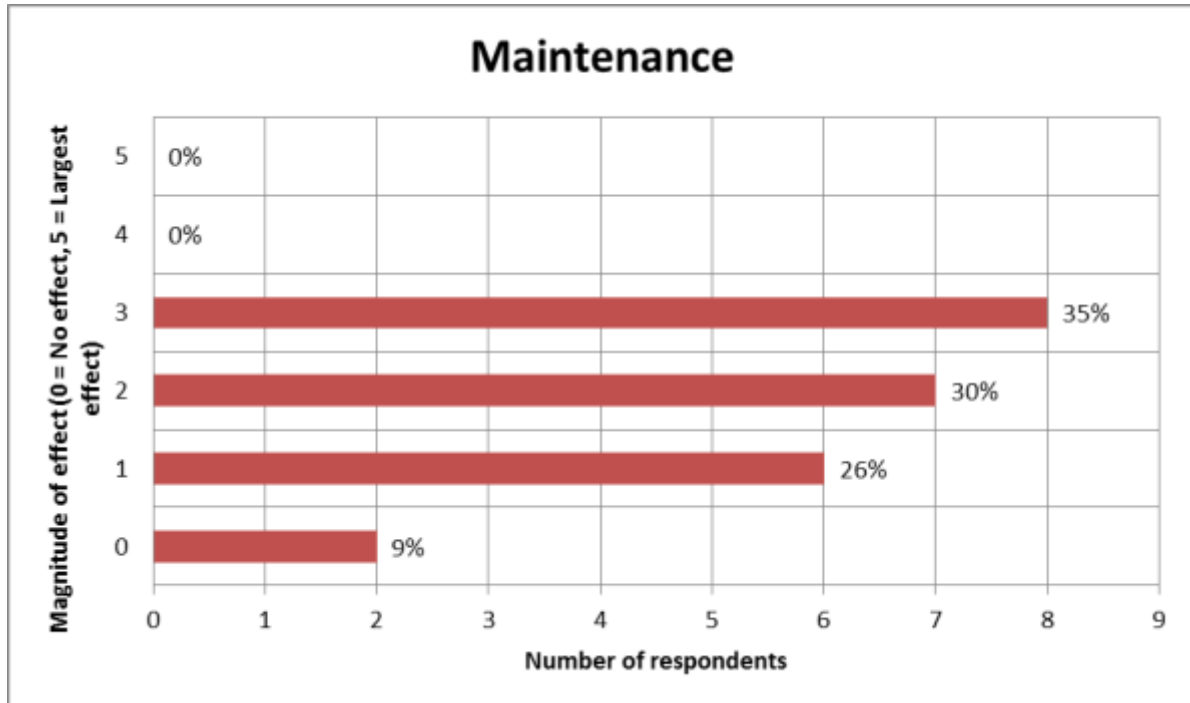


Figure 29: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with maintenance

The feeling amongst all the respondents is that the engineer has a moderate to small effect on construction safety for maintenance hazards. By referring to Figure 29, 35% of the respondents indicated an effect of 3, 30% indicated an effect of 2, 26% indicated an effect of 1, and 9% indicated an effect of 0.

**Maintenance – Comments and Recommendations:**

It is understandable why the respondents feel that a design engineer has little effect on the safety of construction employees for maintenance activities. The respondents may feel that safety hazards associated with maintenance is out of the control of the design engineer. The latter is true. However, this research addresses hazards associated with maintenance by referring to the ergonomic issues associated with it.

The following duties are recommended for the engineer (from Chapters 3 and 4):

- The engineer should incorporate safe access to roofs, plant rooms, and windows in the design.

- The engineer should avoid unsafe access by locating plant rooms reasonably and sensibly. For example, serviceable plant and pipe-work should be located at ground level, rather than roofs or other heights.
- The engineer should ensure that permanent safe access is provided as part of the building. This includes designing stairs or walkways with guardrails, externally by providing a building maintenance unit or other access system for window cleaning, or internally by providing balconies or suitable reversible windows.
- If possible, the engineer should specify materials with high durability and low maintenance requirements in the design of the building.

**Manual Handling - Results:**

Figure 30 presents a graph showing the opinion of the respondents with regard to the effect of a design engineer on construction employee safety for the hazards associated with manual handling.

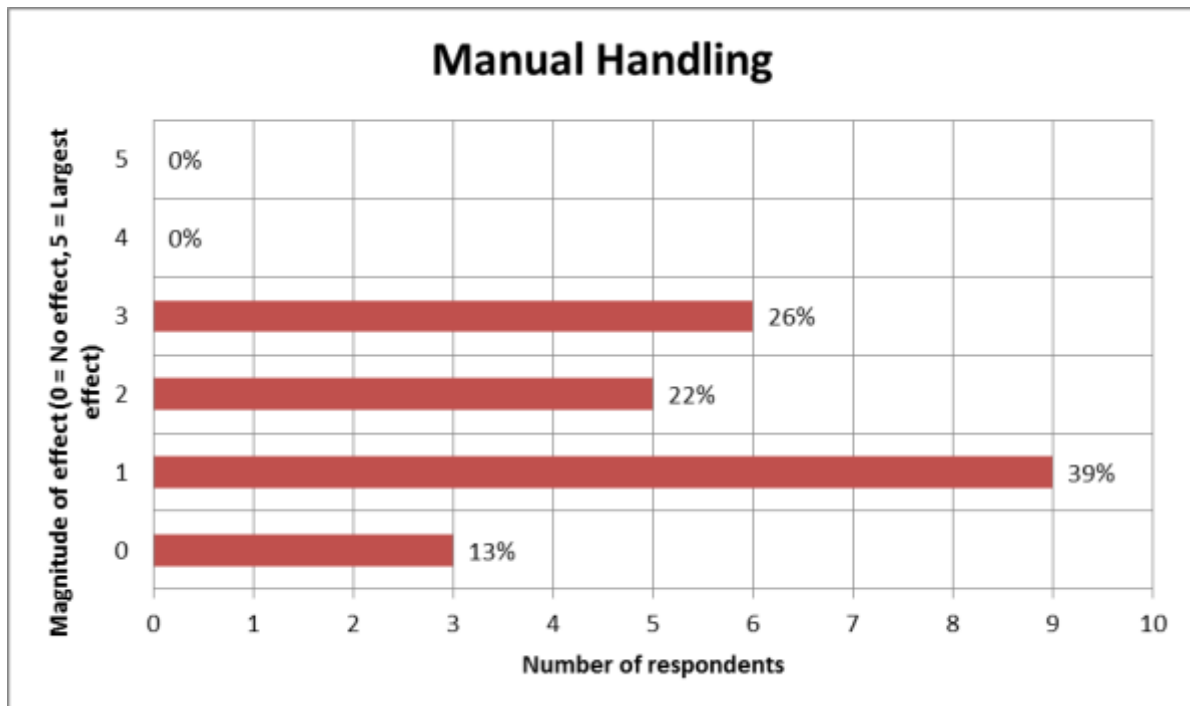


Figure 30: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with manual handling

The respondents indicated that the engineer has a moderate to small effect. By referring to Figure 30 and by adding the percentages together that indicated an effect of 3, 2, 1, and 0 respectively, all the respondents indicated that the engineer has no control over construction safety for manual handling hazards.

**Manual Handling – Comments and Recommendations:**

Building materials that may be manually handled by employees include concrete blocks, cladding, and temporary structures, such as scaffolding. These materials are often specified by the engineer during the design phase and may have a serious impact on the safety of employees moving and installing them.

The following duties are recommended for the engineer (from Chapters 3 and 4):

- The engineer should eliminate the need for manual handling of heavy components by specifying lighter products that meet the design criteria.
- The engineer should monitor that the delivery point for materials is at a convenient location to shorten manual hauls. However, large pre-fabricated building components should be lifted by a crane to prevent ergonomic issues.

Similar to maintenance, the engineer has no responsibility with regard to the actual manual handling processes, i.e. the engineer is not always present on the construction site to monitor that employees do not carry heavy materials or equipment by hand. Nevertheless, the engineer has a responsibility with regard to the ergonomic issues associated with manual handling.

**Plant and Equipment - Results:**

Figure 31 presents a graph that shows the opinion of the respondents with regard to the effect of a design engineer on construction employee safety for the hazards associated with plant and equipment.

As presented by Figure 31, the respondents had mixed opinions with regard to the effect of the engineer on safety for hazards associated with plant and equipment. 43% (calculated by adding 13% and 30%) of the respondents feel that engineers have a moderate or slightly higher than moderate effect on construction safety. 57% (calculated by adding 35% and 22%) indicated that they have less than moderate effect.

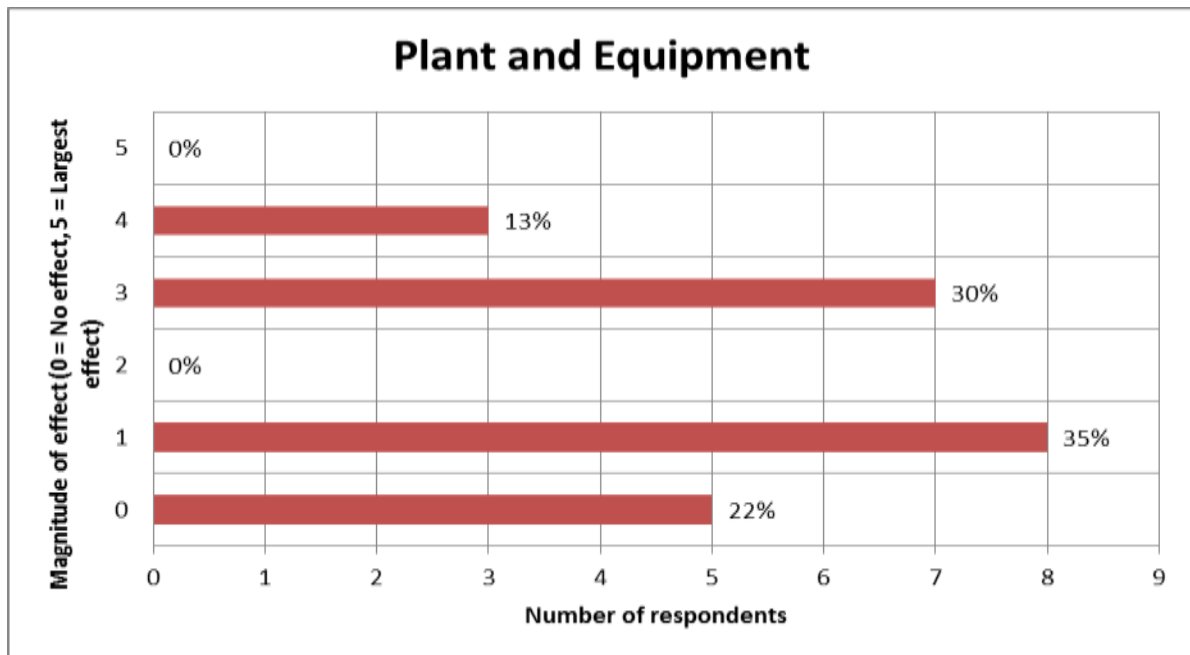


Figure 31: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with plant and equipment

#### **Plant and Equipment – Comments and Recommendations:**

With regard to construction safety that is affected by plant and equipment, the contractor is mainly responsible party. However, the engineer should still play a part during the design phase as it may result in the safety of the construction site to increase.

The following duties are recommended for the engineer (from Chapters 3 and 4):

- Safety hazards associated with plant and equipment that the engineer should monitor and share with the contractor include the following:
  - The contractor should ensure level surfaces and sufficient room around temporary work and equipment for easy and safe access on the construction site.
  - The contractor is responsible to ensure sufficient room and good foundations for the movement of cranes. Good foundations mean to avoid poor or uneven ground.
- The engineer should specify that the contractor includes proof in the health and safety plan that he or she is aware of the hazards associated with plant and equipment and that all machinery are reliable.

#### **Refurbishment - Results:**

Figure 32 presents a graph that shows the opinion of the respondents with regard to the effect of a design engineer on construction employee safety for the hazards associated with refurbishment.

The majority of the respondents feel that engineers have a moderate to small effect. As shown in Figure 32, 35% of the respondents indicated an effect of 3, 26% of the respondents indicated an effect of 2, and 35% of the respondents indicated an effect of 1. Therefore, by adding these three percentages together, 96% of the respondents feel that the engineer has a moderate to small effect on construction safety for hazards associated with refurbishment.

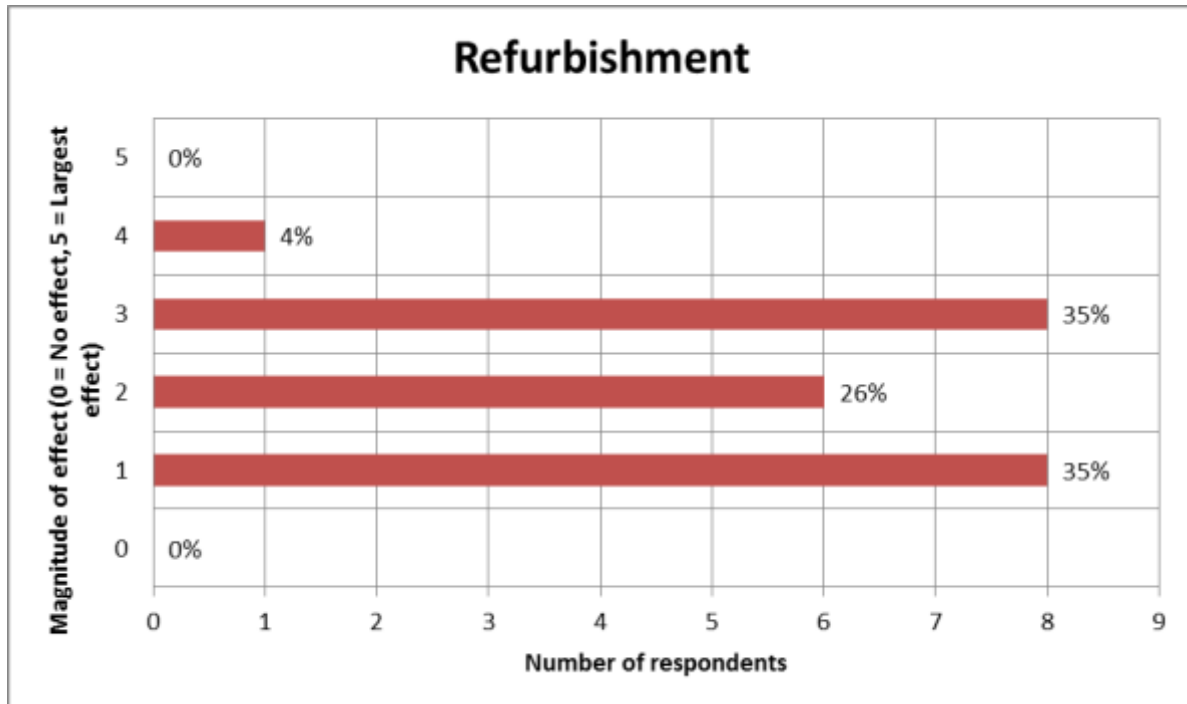


Figure 32: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with refurbishment

#### **Refurbishment – Comments and Recommendations:**

The safety hazards caused by refurbishment include:

- Structural collapse.
- Exposure to hazardous substances.
- Falls from heights.
- Working in confined spaces.

Once the construction of the building has been completed, hazards may be more difficult to control where the premises remain occupied by the public during refurbishment. Therefore, the engineer who is employed for the design of refurbishment should detail the works to minimise the risk of public access to areas where work is to be carried out.

The design engineer has no effect on the safety of employees with regard to refurbishment hazards. However, the engineer that is appointed to design the renovation processes has a large effect and should be aware of the following structural information (from Chapters 3 and 4):

- The age of the building that will provide information on the building and design techniques employed during its construction.
- The strength of the building which will identify how structural additions should be supported by the additional structure.
- The actual condition of the building which will identify possible weaknesses of the structure.
- The materials used will also provide information on the strength and condition of the building.

### **Steelwork - Results:**

Figure 33 presents a graph shows the opinion of the respondents with regard to the effect of a design engineer on construction employee safety for the hazards associated with steelwork.

The respondents feel that engineers play a moderate role with regard to employee safety associated with steelwork hazards as 26% indicated a magnitude of 4, 26% indicated a magnitude of 3, and 26% indicated a magnitude of 2.

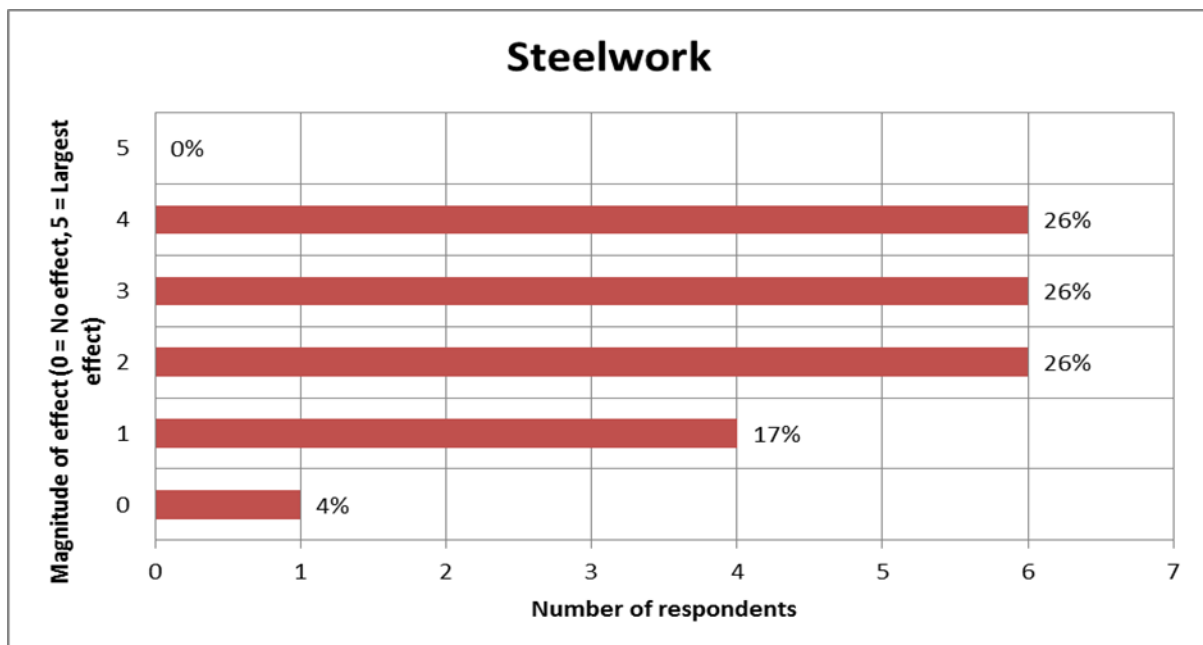


Figure 33: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with steelwork



**Steelwork – Comments and Recommendations:**

The information to improve safety associated with steelwork hazards should be shared with the contractor and the steel fabricators.

The provisions for steelwork are generally the responsibility of the steel fabricator. However, the engineer is able to improve the safety of steelwork erection by monitoring and specifying that the provisions are met and that the design allow for and enable it.

The following duties are recommended for the engineer (from Chapters 3 and 4):

- The engineer should monitor that the patterns of bolt holes are as uniform as possible throughout the frame for easy insertion of bolts.
- The engineer should monitor that pre-attached seating cleats on columns at joints with beams are provided. This will ensure that the ends of the beams are stationary while bolts are inserted.
- The engineer should ensure that safe access stairs form part of the original structure to avoid the use of loose ladders and beams.
- The engineer should specify that holes are drilled into columns during fabrication. This will allow steel erectors to use the columns as anchors for fall-arrest systems.
- The engineer should monitor that temporary bracing is used for vulnerable steel members

**Utilities - Results:**

Figure 34 presents a graph that shows the opinion of the respondents with regard to the effect of a design engineer on construction employee safety for the hazards associated with utilities.

Mixed opinions from the respondents are presented in Figure 34. The majority of the respondents, 56% (calculated by adding 26% and 30%), feel that engineers have a moderate to slightly higher than moderate effect on safety for hazards associated with utilities. Forty three percent (43%) (calculated by adding 17%, 22%, and 4%) of the respondents feel that engineers have a less than moderate effect.

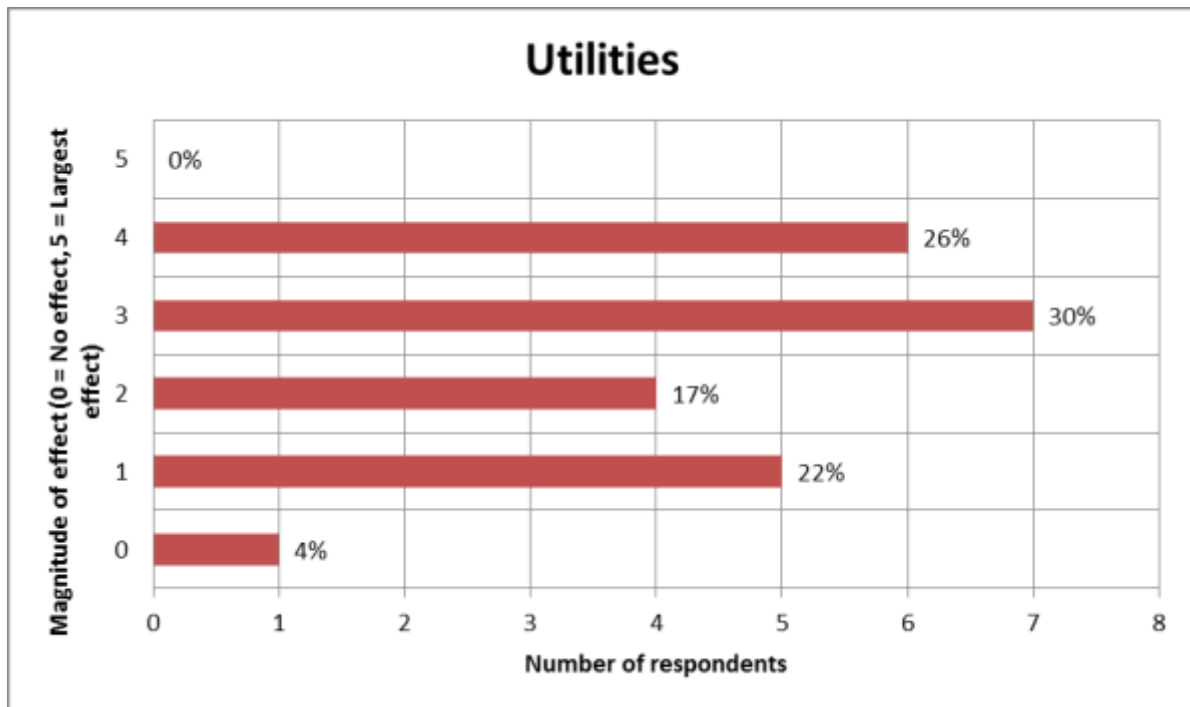


Figure 34: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with utilities

#### Utilities – Comments and Recommendations:

The design of utilities, such as electricity, gas, water and telecommunications, is usually carried out by specialist subcontractors or their appointed engineers. Similar to the case study investigated in Chapter 4.11 and the design responsibilities for refurbishment as discussed earlier in this section, the design engineer has little effect on the safety for employees with regard to utilities.

It is important to distinguish between the types of engineers that are responsible for the design each of construction activity. In this case, the design of utilities is the responsibility of the employed subcontractor or his or her engineer. However, the responsibilities of the engineer designing the utilities are irrelevant for the objectives of this research.

The design engineer is still responsible to design provisions in the building for utilities to be installed.

The following duty is recommended for the design engineer (from Chapters 3 and 4):

- The engineer should design adequate space for channels and equipment for subcontractors to work from safe positions.

If this specific question was reflected towards the effect the engineer, designing the utilities, have on employee safety; the respondents would have most likely indicated a larger effect.

**Work Performed on Roofs - Results:**

Figure 35 presents a graph that shows the opinion of the respondents with regard to the effect of a design engineer on construction employee safety for the hazards associated with work performed on roofs.

By referring to the results shown in Figure 35, 17% of the respondents indicated an effect of 3, 17% indicated an effect of 2, 17% indicated an effect of 1 and 9% indicated an effect of 0. Therefore, the majority of the respondents feel that an engineer has a moderate to small effect. The single highest percentage of respondents, 39%, feel that the engineer has a higher than moderate effect.

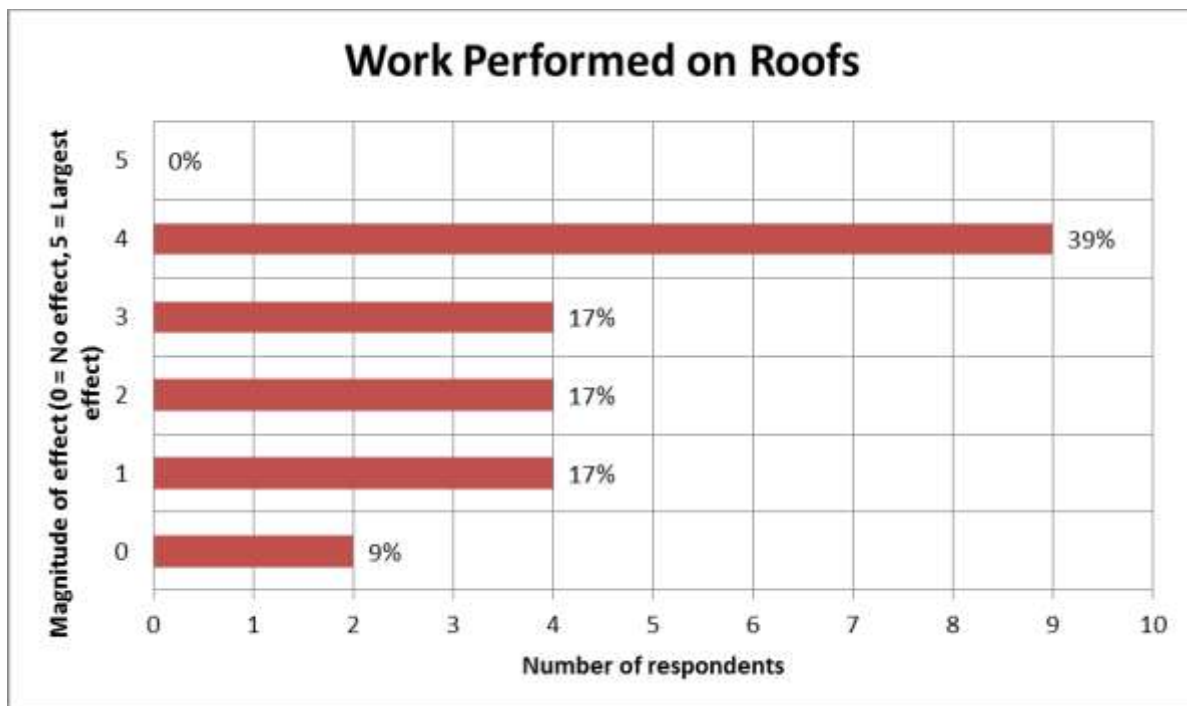


Figure 35: A graph that presents the opinion of a percentage of South African engineers with regard to the effect design engineers have on safety hazards associated with work performed on roofs

**Work Performed on Roofs – Comments and Recommendations:**

Work done on roofs is seen as hazardous to employees due to severe heights. Also, fragile materials are often involved. The risk of falling from edges or through fragile or incomplete roofing surfaces is a possibility.

The following duties are recommended for the engineer (from Chapters 3 and 4):

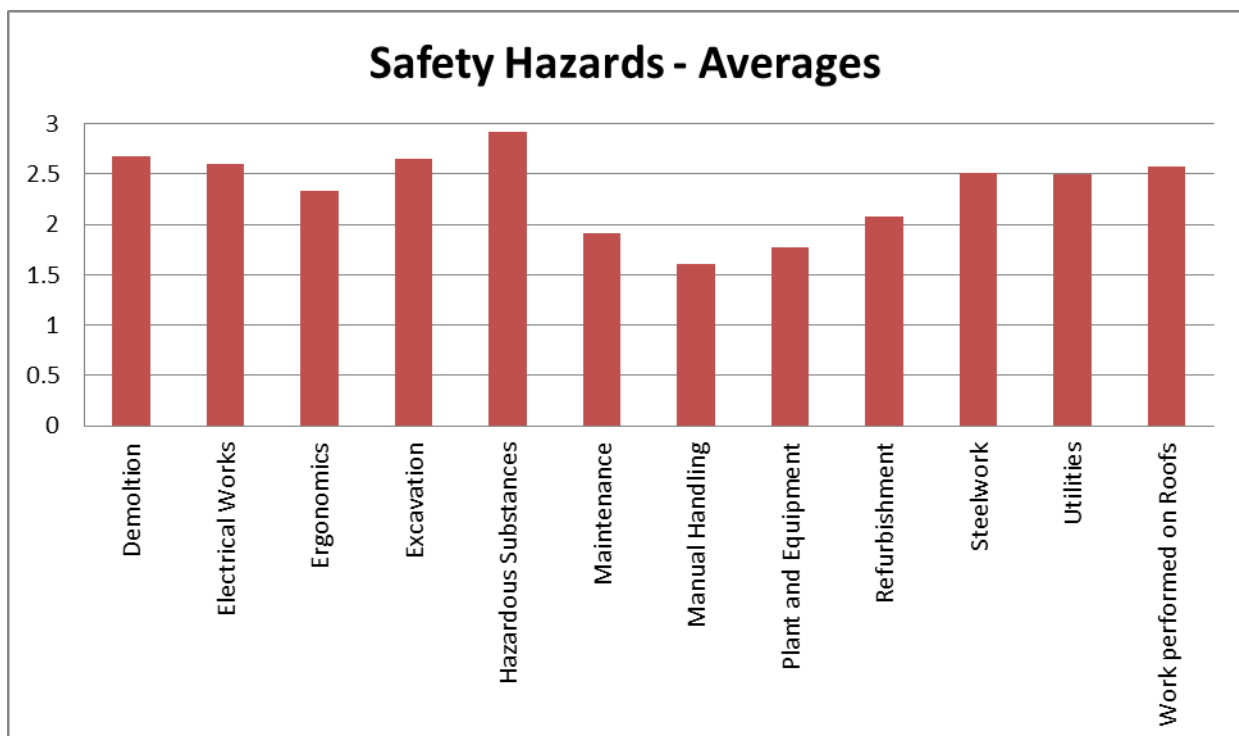
- The engineer should monitor the use of fall prevention equipment (guardrails and guardrail attachments at the perimeter).

- The engineer should monitor measures to prevent falls through the roof, such as roof member spacing and safety nets. This matter is primarily the responsibility of the contractor. However, the engineer can assist the contractor by bringing this matter to the attention of him or her.
- The engineer should monitor that anchorage points are provided for a fall arrest system (refer to steelwork).
- The engineer should design and monitor safe access to or through the roof space.
- The engineer should only specify non-fragile materials to be used on roofs.

Therefore, the engineer has a moderate to high effect on the safety of employees in the sense that the engineer should be an assistant to the contractor. The engineer should be aware of the matters mentioned above and share it with the contractor and specify it to him or her.

#### **Question 14 – Averages:**

Figure 36 presents a graph that shows the average results from the questionnaire of the effect an engineer has on safety for each construction activity in Question 14.



**Figure 36: The average of the effect an engineer has on safety for each construction activity**

As presented by Figure 36, the respondents feel that an engineer has the largest effect on safety for hazards associated with hazardous substances. The average for hazardous substances is a magnitude of 2.9 and this is seen as moderate. However, the variation of the results is small; indicating that the

respondents feel that an engineer has a moderate effect on safety for hazards associated with all of the construction activities.

As mentioned, the respondents feel that the contractor is responsible to create a safe construction site. This is an indication why the respondents feel that an engineer only has a moderate effect on safety.

Based on the comments and recommendations that were made throughout this section, the engineer should contribute more towards a safer and healthier construction site. It will be beneficial for the health and safety of construction employees if the engineer is also aware of the possible safety hazards and as a team, the engineer and contractor can identify the hazards and mitigate them before any accidents occur. Also, the Construction Regulations states the engineer should share **any** information with the contractor that might affect the health and safety of employees. However, it seems South African engineers are not fully aware of the requirements of the Construction Regulations.

The effect of an engineer on safety should be higher than what is shown in Figure 36. Engineers should focus on designing for safety and increase the effect they have on construction health and safety.

### **5.3.3 Part 3 Results: Lessons Learned from Case Studies (Columns AB – AY)**

Question 15 in Part 3 of the questionnaire is based on the lessons that were learned by investigating the case studies in Chapter 4. It is important to note that these lessons do not state what the engineer is obliged to do. They are assumptions that were made from the case studies that were investigated and based on the opinion obtained from the respondents, will contribute to the production of a safe design process that are discussed in Chapter 6. Therefore, the question required the opinion of the respondents with regard to each lesson. They needed to state whether they strongly agree, agree, disagree, or strongly disagree with each lesson.

This section includes a discussion of the responses, focusing on the opinion of the majority of the respondents. Therefore, the results from Chapter 4 and the opinion of the respondents are taken into consideration to result in procedures engineers should follow to improve construction employee safety. Visual presentations of the responses to the questions can be found in Appendix E in the form of Bar-graphs. In this section, the responses are divided into eleven groups with the header of each group being the graphs that are referred to in Appendix E.

In some cases, the percentage of the respondents that indicated that they strongly agree or agree with a lesson was added together to result in one percentage. The same was done for those that

indicated that they disagree or strongly disagree. Therefore, a single percentage is used to indicate whether the respondents agree or disagree with the lessons that were learned in this research. After the single percentages that were calculated, the two percentages that were added together are shown in brackets.

#### **Figure E1:**

When referring to the results presented in Appendix E and starting with Figure E1, 78% (52% and 26%) of the respondents stated that the responsibility for construction safety is not only confined to construction work on site. Therefore, other parties (excluding the contractor) do play a role with regard to construction employee safety. The Construction Regulations acknowledge the fact that most safety hazards are the responsibility of the contractors; however, in Clause 4.1(b) of the Construction Regulations it is stipulated that the engineer should share any information with the contractor that might affect the health and safety of the employees. Therefore, as stated in the Construction Regulations and mentioned by the respondents, engineers do play a role to improve construction employee safety.

#### **Figures E2 and E4:**

As presented by Figure E2, 65% (17% and 48%) of the respondents agree that a lack of communication between the engineer and the contractor is a cause for designs being unsafe. Regular and descent communication between project participants is essential for a project to be safe. For example, communication between the engineer and contractor is essential to identify and mitigate safety hazards and to ensure safe construction procedures. 70% (22% and 48%) of the respondents also feel that safety and constructability of a building should be addressed during the design phase (refer to Figure E4). This indicates the importance of the contractor being involved early during the design stage. However, based on the procurement strategy for each project, the contractor is not always present during the design stage. Thus, the engineer should have an adequate knowledge with regard to safe construction processes.

#### **Figures E3 and E5:**

When referring to Figure E3, 61% (48% and 13%) of the respondents feel that construction site safety is not included in the design of a building due to a lack of involvement in safety by the engineer. Furthermore, 74% (70% and 4%) of the respondents agree with Jerling (2009), i.e. engineers have a lack of construction and constructability knowledge (refer to Figure E5). A lack of involvement in safety by engineers may be an indication that more risk should be placed on them in

South Africa to enforce the involvement in construction site safety. It will be beneficial for the safety of employees if engineers have experience working as contractors prior to being appointed as an engineer. The latter may result in the engineer being aware of safe construction processes and that these processes can be included early during the design phase.

#### **Figures E6, E7, and E8:**

The questions that resulted in the responses presented by Figures E6, E7, and E8 were based on the knowledge of the respondents with regard to what the Construction Regulations stipulates about the involvement of health and safety during the early design stages.

66% (9% and 57%) of the respondents stated they have an adequate knowledge with regard to the responsibilities of the engineer for construction safety as stated in the Construction Regulations (refer to Figure E6). With average years of experience of 16 as engineers, more of the respondents should be aware of what the Construction Regulations entail. 100% (57% and 43%) of the respondents agree that the Construction Regulations include all project participants in the construction process (refer to Figure E7). However, when referring to Figure E8, 87% (48% and 39%) of the respondents are aware that the Construction Regulations convince project participants that health and safety management should be included during the planning and design stages of any construction project. Despite the fact that only 66% of the respondents are aware of what the Construction Regulations entail, 13% (9% and 4%) of the respondents are unaware that the Construction Regulations, Clause 6.7, stipulates the importance of health and safety management during the early stages of a project (refer to Figure E8).

#### **Figures E9, E10, and E11:**

With reference to the limitations and capabilities of employees, 61% (4% and 57%) of the respondents feel that the engineer should consider it during the design phase (refer to Figure E9). However, the limitations and capabilities of the employees are primarily the responsibility of the contractor (Department of Labour, 2003). The engineer can still play a part by monitoring that the contractor takes this ergonomic issue into account during construction. Therefore, the engineer can include it into the safety specifications of the project and monitor it during regular site meetings (Department of Labour, 2003).

When referring to Figure E10, 78% (35% and 43%) of the respondents state engineers can specify non-fragile materials to be used when work is to be performed at heights. 87% (48% and 39%) of the respondents feel that the engineer can monitor that the contractor provides all employees with the necessary fall protection equipment.

**Figure E12:**

One hundred percent (100%) (39% and 61%) of the respondents feel that the experience and knowledge of the engineer on construction methods should be adequate in order for him or her to adjust the design in a constructible and safe manner whenever modification to the design is needed (refer to Figure E12). Therefore, the latter indicates the importance of an engineer to have experience as a contractor. The question, however, is how much experience?

**Figures E13, E14, E15, and E23:**

An important lesson that was learned is the requirement of the contractor to provide a construction method statement included in the mandatory health and safety plan. It includes the use of plant and equipment that provides adequate loading strength. When referring to Figure E13, 91% (13% and 78%) of the respondents agree with the lesson learned on the construction method statement. The contractor should include records of inspections for plant and equipment (Department of Labour, 2003). 74% (13% and 61%) of the respondents also agree that the engineer should specify the best and most effective equipment to ensure quality and safety, even if this equipment will cost more (refer to Figure E23).

The contractor should also include registers and copies of approved employees and their certificates of training (Department of Labour, 2003). Therefore, the contractor needs to provide proof that all employees did undergo safety training. When referring to Figures E14 and E15 respectively, 79% (22% and 57%) and 78% (17% and 61%) of the respondents agree that the engineer can enforce formal safety training programs and safety training demonstrations to be held by the contractor by specifying it in the health and safety specifications.

**Figures E16 and E17:**

As presented by Figure E16, 70% (61% and 9%) of the respondents disagree that when work needs to be performed in the proximity of electrical power lines, it is solely the responsibility of the contractor to specify that non-conductive materials and equipment are used. Furthermore, Figure E17 shows that 92% (35% and 57%) of the respondents feel that the engineer should be aware of the layout of the construction site, including the locations of power lines.

In the safety specifications of the project, the engineer should provide the contractor with any information that might affect the health and safety of the construction employees (Department of Labour, 2003). Therefore, identifying and specifying the use of non-conductive materials and equipment in the proximity of electrical power lines is also a responsibility of the engineer. However,



the engineer should be aware of the positions of power lines and indicate it on the design drawings, before specifying the materials and equipment.

**Figures E18, E19, and E20:**

According to the Construction Regulations, Clauses 7.1 and 4.1(d), the engineer and contractor should undertake periodic audits of the construction site prior to the actual construction or demolition. These audits should include the identification of possible safety hazards. As presented by Figures E18 and E19 respectively, 100% (17% and 83%) and 91% (30% and 61%) of the respondents agree that a descent site survey should commence prior to construction or demolition processes to identify possible hazards and minimise or eliminate them.

Furthermore, 79% (9% and 70%) of the respondents feel that the survey should include manners in which construction site employers and employees can communicate with emergency rescue providers if necessary (refer to Figure E20). As discussed in Chapter 4.13.3, the contractor should provide method statements for various activities that include first aid (Department of Labour, 2003). Therefore, the actual hazard identification survey might not include methods to communicate with emergency rescue providers; however, the safety specifications provided by the engineer can require the contractor to include it in the health and safety plan of the project.

**Figures E21 and E22:**

As presented by Figure E21, 100% (65% and 35%) of the respondents agree that the contractor should always consult the engineer before modifying any construction methods specified on the engineered drawings. The latter is rather a responsibility for the contractor than a responsibility for the engineer. However, the engineer can monitor that the contractor consults him or her by means of regular site visits or periodic audits.

The consultation of the engineers for modifications will most likely be unnecessary if the contractor is involved during the design stage. As mentioned before, early contract involvement may result in a smooth transition from the design phase to construction with regard to safety of employees. An early involvement of the contractor will also ensure that the design is based on construction processes that are both safe and constructible. 70% (9% and 61%) of the respondents agree with the latter (refer to Figure E22).

**Figure E24:**

One of the lessons that was learned in Chapter 4, i.e. engineers should design a building with the focus on using more prefabricated construction, was derived from manners to improve the approach taken by engineers for Construction Hazard Prevention through Design (CHPtD). A positive opinion of the respondents on this statement will result in a discussion on prefabricated construction and the advantages it brings forth with regard to construction site safety. However, as presented by Figure E24, 57% (48% and 9%) of the respondents disagreed. Therefore, the discussion and advantages of using pre-fabricated construction elements for buildings will not be investigated in this research.

**5.3.4 Part 4: Information Exchanged between Engineer and Contractor (Columns AZ – BE)**

This section includes the discussion of the opinion of the respondents to statements that are based on information that the engineer should share with the contractor throughout the life-cycle of a project. These statements were produced by investigating case studies (refer to Chapter 4) and the content of the Construction Regulations.

Firstly, the Construction Regulations, Clause 4.5, stipulate that the client may appoint an agent to act on his behalf and in these cases; the responsibilities of the client become the responsibilities of the agent (Department of Labour, 2003). It is important to note that the appointed agent may also be the project manager or the architect. However, for this research, the assumption was made that the appointed agent is the engineer.

Clause 4.1 of the Construction Regulations mentions the responsibilities of the engineer with regard to the type of information he or she needs to share with the contractor. This section includes the opinion of the respondents with regard to these responsibilities as stated in the Construction Regulations.

Furthermore, this section includes the opinion of the respondents with regard to the additional information that needs to be shared with the contractor by the engineer.

**Question 16 – Discussion and Analysis**

The visual presentations of the responses are presented in Appendix F. This section includes a discussion and analysis of the opinion of the respondents with regard to the graphs shown in Appendix F.

As presented by Figure F1, 83% (61% and 22%) of the respondents feel that the engineer should share the health and safety specifications for the construction work with the contractor. Therefore, 17% of the respondents are unaware that in Clause 4.1(a) of the Construction Regulations, it states the engineer should prepare the health and safety specifications for the construction work and provide it to the contractor. Therefore, from the results in Figure F1, it is clear that a percentage of South African engineers are unaware of the responsibilities of the engineer as stated in the Construction Regulations.

Similar to the results presented by Figure F1, the results shown in Figure F2 reveals that 91% (52% and 39%) of the respondents are aware of the fact that the engineer should share any information that might affect the health and safety of the project with the contractor. 9% of the respondents are unaware that the engineer should share this information. Although 9% is small, it is still necessary for all of South Africa's engineers to be aware of what the Construction Regulations entail, especially with regard to the responsibilities of the engineer.

When referring to Figures F3 and F4, it is still clear that a percentage of the respondents are unaware of the contents of the Construction Regulations. With reference to periodic audits (refer to Figure F3), 74% (48% and 26%) of the respondents agree that the engineer should undertake periodic audits and share the results of the audits with the contractor. In Figure F4, 96% (70% and 26%) of the respondents agree that the engineer should stop the contractor from executing any construction work which is not in accordance to the health and safety plan. All the respondents agree that the engineer should share sufficient health and safety information with the contractor for situations where modifications to the project should be made (refer to Figure F5).

#### **Question 17 – Results and Comments:**

It is uncertain what type of information, as stated in Clause 4.1(b) of the Construction Regulations, should be shared between the engineer and contractor. As mentioned before, this research aims to identify the information, in specific detail, that should be shared with the contractor by the engineer that will contribute towards a safe and constructible working environment. Therefore, the respondents were asked to briefly discuss and provide their own opinion on what type of information needs to be shared with the contractor (refer to Column BE in Appendix D).

Below is a summary that includes the thoughts that were most common between the respondents. The summary of the results, as obtained from Column BE (refer to Appendix C), is:

- Safe construction methods.
- Any non-typical construction methods that may be required.

- Construction safety hazards that had been identified.
- Design loads.
- Stripping times for various construction elements.
- Mitigation techniques for hazard prevention.

Another thought amongst the respondents were:

*“All necessary information that will make a construction site safer should be shared with the contractor.”*

The latter is also stipulated in Clause 4.1(b) of the Construction Regulations. However, it is unclear from the above results what the necessary information is that the engineer should share with the contractor to ensure safety for the employees. No specific detail is provided by the respondents.

Therefore, in Chapter 6, a recommended safe design process is presented. It will discuss the detailed information that should be shared with the contractor by the engineer and should be helpful, as a guide, to a percentage of South African engineers.

### **5.3.5 Part 5: Safe Design process (Column BF)**

The respondents were required to state the steps, in their own opinion, which are included in a safe design process. The integration of the responses to this question, the proposed safe design process discussed in Chapter 3.4, and the lessons learned throughout Chapters 4 and 5 will result in the recommended safe design process that is discussed in Chapter 6.

When referring to the results in Column BF in Appendix D, the respondents had similar opinions with regard to the steps that need to be taken for a safe design process.

The first step should be to appoint the design team to identify the possible safety hazards during the conceptual design phase of the project. The contractor should be included during the early design stages of the project for an integrated approach towards safety hazard identification. As mentioned in Chapter 1.2.1, a Design-and-Construct procurement strategy and a Management procurement strategy includes the contractor in the design phase of a building. Therefore, for these procurement strategies, both parties will identify the possible safety hazards and a smooth transition from design to construction will commence. In cases where the engineer does not possess adequate construction knowledge, the contractor can act as an assistant to monitor that safe construction methods are incorporated into the design.

The second step is to identify the safety hazards and the mitigation techniques to prevent them by making use of a risk register. The risk register will allow the engineer to adequately identify the health and safety specifications of the project that are provided to the contractor. From the latter,

the contractor will be able to develop his or her health and safety plan accordingly. Therefore, this step will result in all necessary information, which might affect the health and safety of construction employees, being shared with the contractor.

The actual design of the building should be done and reviewed in collaboration with the identified safety hazards and constructability principles. Therefore, apart from designing with safety hazards in mind, a safe design process should also involve designing the building with the incorporation of the following (refer to Chapter 3.5.2):

- Simplicity - The engineer as designer should attempt to produce details at the most simplistic level that fits the requirements of the building.
- Level of tolerance – The engineer should recognise that different materials and components that are used on site have different composition.
- Proper scheduling – The engineer should also aim to produce proper construction scheduling during the design phase in order to contribute towards smooth construction progress.
- No damage to finished elements – The building and construction processes should be designed in a manner where damage to finished elements of the building is avoided.
- Accessibility - The design should promote easy access to construction materials and equipment for construction employees.
- Standardization – Engineers should design building to be constructed by using standardized construction elements and components.

If the design needs modification, the engineer and contractor should discuss the modifications and ensure that safe procedures are followed. If any alternative construction methods should be used, the contractor should inform the engineer about it and it should be incorporated in the design.

Prior to the construction of any part of the building, the engineer and contractor should undertake audits with regard to the health and safety of the employees. The latter will ensure that construction is taking place according to the health and safety plan set out by the contractor.

Similar to the discussion of a proposed safe design process in Chapter 3.4, this section includes a general approach towards safe design. The problem is still to identify the specific information that the engineer should share with the contractor. Chapter 6 provides a recommended safe design process that includes all the necessary steps that should be taken and detailed information that needs to be shared.

## 5.4 Results from Questionnaires on Construction Site Safety - Conclusion

A response rate of 92% was achieved as 23 of the 25 South African engineers that received the questionnaire responded. Since 23 engineers is small in comparison with all the engineers in South Africa, the responses resulted in conclusions that can be made with regard to the knowledge of a **percentage** of South African engineers on construction site safety and construction methods. The opinion of the respondents was also valuable with reference to the lessons that were learned in Chapter 4 and their degree of credibility.

The average years of experience of the respondents that had been working as consultant engineers (16 years) and participated in building design (13 years) is adequate to define the results obtained from the questionnaire as credible and trustworthy. However, the responses to the questionnaire resulted in the opinion that prior to being appointed by a consulting engineering company, engineers should have adequate experience on construction sites to be aware of construction methods and the hazards associated with them.

Although the Construction Regulations state that the safety hazards associated with most construction activities are the responsibility of the contractor, it will be beneficial for the safety of the employees if the engineer informs the contractor on the hazards identified by him or her during the early design stages. However, more adequate safety hazard identification and hazard mitigation will commence if the contractor is included during the early design stages.

Thirty four percent (34%) of the respondents have a lack of knowledge with regard to the contents of the Construction Regulations. The Construction Regulations includes, inter alia, the responsibilities of the engineer for a construction project and it is therefore important for engineers to be aware of the contents of the Construction Regulations.

However, it is important to note that 83% of the respondents feel that the engineer should share the health and safety specifications for the construction work with the contractor. Ninety one percent (91%) of the respondents are aware of the fact that the engineer should share any information that might affect the health and safety of the project with the contractor. Therefore, despite the low percentage (66%) of respondents that is aware of the contents of the Construction Regulations, the respondents acknowledge that engineers should also be aware of construction safety hazards.

Therefore, the respondents feel that engineers can be part in improving the safety of construction sites. The role they can play is based on the information that the engineer should share with the contractor prior and during construction. This information includes the identification of employee safety hazards associated with various construction activities and informing the contractor on

methods to prevent accidents. Engineers should also monitor that contractors have formal safety programs that include descent safety training.

The next chapter presents a recommended safe design process. This process is derived from the results of this research and includes the necessary steps that are recommended to an engineer to contribute towards a safer construction site.

## CHAPTER 6: RECOMMENDED SAFE DESIGN PROCESS

Chapter 6 presents recommendations in the form of a recommended safe design process that includes the detailed steps to be taken and information that needs to be shared by the engineer.

### 6.1 Introduction

It is important to note that the recommended safe design process is formulated from considering the results of this research and is only relevant for building projects that consist of the following scenarios:

- The form of contract being used for the building project is the Principal Building Agreement of the JBCC Series 2000.
- The type of procurement strategy is either the Design-Construct-, or Design-Manage strategy (which allows sufficient collaboration between the engineer and contractor).
- The consulting engineer is appointed as the design engineer and the person that provides the contractor with the health and safety specifications of the project.
- Only the following construction activities are considered in these recommendations:
  - Demolition;
  - Electrical works;
  - Ergonomics;
  - Excavation;
  - Hazardous substances;
  - Maintenance;
  - Manual handling;
  - Plant and equipment;
  - Refurbishment;
  - Steelwork;
  - Utilities;
  - Work done on roofs.

The recommended safe design process only considers the steps to ensure or improve the safety of employees working on a building construction site.

### 6.2 Detailed Steps

This section presents 6 steps that should be taken by the engineer in order to contribute towards a safer construction site. The information provided in each step is a combination of the results



obtained throughout this research, i.e. the results and lessons from the literature study, the investigation of case studies, and the questionnaire.

### 6.2.1 Step 1: Conceptual design and hazard identification

The client appoints the consulting engineer to act on his or her behalf and he/she communicates the requirements of the building with the engineer. The engineer creates a risk register that is used to identify the probability of the hazards and risks to occur and their impact on the project cost and schedule.

The following health and safety hazards and risks are associated with the construction processes for buildings:

- **Demolition:**
  - Employees can fall from high locations.
  - During demolition, the building or building elements can collapse and fall onto employees.
  - Employees can be exposed to hazardous substances.
- **Electrical works:**
  - Cranes, mobile plant, scaffolding, and other tall non-conductive equipment can come in contact with overhead power lines or underground electrical cables.
  - Electricians work in cramped or restricted work areas.
  - Employees can get injured due to manual handling of large cables.
- **Ergonomics:**
  - Employees can be unable to perform efficiently due to discomfort or fatigue.
- **Excavations:**
  - The excavation can collapse.
  - Objects, equipment or employees can fall into an excavation.
  - Employees can be exposed to hazardous substances during the excavation process.
- **Hazardous substances:**
  - Employees can be exposed to substances that harm their health or safety, i.e. flammable materials or emissions of toxic fumes.
  - A lack of ventilation in cramped or enclosed areas is a possibility.

- **Maintenance:**
  - Unsafe access to areas where maintenance activities will occur.
- **Manual handling:**
  - Employees can get injured due to the manual handling of heavy and large building materials or components and long manual hauls.
- **Plant and equipment:**
  - Surfaces are not level.
  - Insufficient room around temporary work and equipment for easy and safe access.
  - Plant and equipment do not provide the adequate loading strength.
- **Refurbishment:**
  - Structural collapse.
  - Employees can be exposed to hazardous substances.
  - Employees can fall from heights.
  - Work can be performed in confined spaces.
- **Steelwork:**
  - Steel beams can be unsecured when work needs to be performed on them.
  - Employees can fall from high working areas.
  - Access to areas where work needs to be performed on steel elements can be unsafe, i.e. ladders or beams are being used for access.
  - Temporary bracing may be needed.
- **Utilities:**
  - Inadequate space for channels and equipment for subcontractors to install utilities and work from safe and comfort positions.
- **Work done on roofs:**
  - Employees can fall from roof edges or work platforms made out of fragile materials.
  - Employees can fall through fragile or incomplete roofing surfaces.
  - Objects can fall from heights causing damage to underlying building elements or employees.

### **6.2.2 Step 2: Provide a first report to the client**

If the procurement strategy enables and allows it, the principal contractor should be appointed at this stage. The engineer and contractor undergo an integrated approach towards identifying more

health and safety hazards and safe construction methods to mitigate the hazards. In collaboration, the engineer and contractor produce an initial report and provide it to the client

The initial report includes the following information:

- A record of the identified construction site hazards and risks.
- An assessment of these hazards and risks for the client to understand their relative importance and to prioritise control measures.
- How these hazards and risks can occur.
- An explanation of design measures that address the hazards and risks.

### 6.2.3 Step 3: Incorporate constructability principles into the design

On the basis of the identified hazards, risks, and safe construction processes, the engineer designs the actual building. To ensure constructability, it is recommended that the engineer considers the following constructability principles for the design:

- **Simplicity:**
  - The engineer attempts to produce details at the most simplistic level that fits the requirements of the building.
- **Level of tolerance:**
  - The engineer recognises that different materials and components that are used on site have different composition.
- **Proper scheduling:**
  - The engineer aims to produce proper construction scheduling during the design phase in order to contribute towards smooth construction progress.
- **No damage to finished elements:**
  - The building and construction processes are designed in a manner where damage to finished elements of the building is avoided.
- **Standardization:**
  - The engineer designs the building to be constructed by using standardized construction elements and components.
- **Integrated approach between participants:**
  - The contractor is allowed to provide input during the design of the building.

#### 6.2.4 Step 4: Incorporate safety into the design

With regard to the identified construction processes, it is recommended that the engineer incorporates the following safety considerations into the design:

- **Demolition:**
  - The engineer passes relevant information, such as surveys, historical drawings and service records on to the demolition contractor.
  - The engineer supplies information on load paths that include:
    - The critical loading conditions that may cause collapse.
    - Critical load-bearing elements that should not be removed without supporting arrangements (columns under supporting beams, floor beams, members providing lateral restraint to compression members).
    - Pre-stressed concrete elements which contain considerable tension.
  - The engineer indicates the critical sequences that need to be followed during demolition.
  - Alongside structural instability, any pre-tensioned or post-tensioned components of the building should also be indicated by the engineer.
- **Electrical works:**
  - The engineer should indicate (if possible) that overhead power lines be disconnected, re-routed, covered or be underground before construction can start.
  - However, in situations where it is not possible to disconnect and re-route the power lines, the engineer adjusts the design to fit the layout of the power lines.
  - The engineer ensures adequate working space for electrical installations by considering the location of, access to, egress from, and space where electrical work needs to be performed.
  - Access roads, material dumping sites and unloading are located away from overhead power lines.
- **Ergonomics:**
  - Design areas for construction and maintenance activities to be spacious, comfort and have safe access.

- **Excavation:**
  - The engineer indicates the exact locations of existing underground services that include electrical cables, gas pipes, and sewer - and water pipes.
  - The engineer adjusts the position of the building or its temporary works (if possible) to avoid contact with underground services.
  - The design should ensure excavations to be performed away from static loads (such as buildings, wall, and immobile plant) or dynamic loads (such as traffic and excavation equipment).
  - In scenarios where the position of the building or its temporary works cannot be adjusted, the engineer indicates that the underground services are relocated.
- **Hazardous substances:**
  - The engineer designs for sufficient ventilation in confined spaces.
- **Maintenance:**
  - The engineer designs safe access to roofs, plant rooms and windows.
  - The design indicates that plant rooms are reasonably and sensibly located. For example, serviceable plant and pipe-work should be located at ground level, rather than on roofs or other heights.
  - The engineer designs stairs or walkways with guardrails, externally by providing a building maintenance unit or other access system for window cleaning, or internally by providing balconies or suitable reversible windows.
  - The engineer includes materials with high durability and low maintenance requirements in the design of the building.
- **Manual handling:**
  - The engineer designs by specifying the use of lighter products that meet the design criteria.
  - The location of the delivery point for materials should be designed and indicated at a convenient location to shorten manual hauls.
- **Plant and equipment:**
  - The engineer has no control over plant and equipment during the actual design.

- **Refurbishment:**
  - The engineer has no control over refurbishment during the actual design. The engineer responsible for the design of refurbishment has control over it. Recommendations for the refurbishment engineer with regard to safe design are provided in Section 6.3.5.
- **Steelwork:**
  - The engineer should monitor that following provisions are done :
    - Patterns of bolt holes are as uniform as possible throughout the frame for easy insertion of bolts.
    - Pre-attached seating cleats on columns at joints with beams are provided. This will ensure that the ends of the beams are stationary while bolts are inserted.
    - Safe access stairs forms part of the original structure to avoid the use of loose ladders and beams for access.
    - Holes are drilled into columns during fabrication. This will allow steel erectors to use the columns as anchors for fall-arrest systems.
- **Utilities:**
  - The engineer designs adequate space for channels and equipment for subcontractors to work from safe positions.
- **Work done on roofs:**
  - The engineer does not specify fragile materials to be used on roofs.
  - The design provides anchorage points for a fall arrest system (refer to steelwork).
  - The design indicates adequate strength of the roof members to which guardrails are attached or which act as an anchorage point for a fall arrest system.
  - The design provides safe access to or through the roof space.

### **6.2.5 Step 5: Provide the contractor with the health and safety specifications of the building project**

(Please note that the headings in this step are the same as for Step 4. However, the content under each heading is different since Step 5 discusses the information that should be included in the health and safety specifications, while Step 4 discussed the safety considerations that should be incorporated into the design.)

On the basis of the information provided in the initial report, the client may agree on modifications to be made to the design. Therefore, the engineer and contractor review the design and incorporate the modifications with health and safety in mind.

The engineer provides the necessary information, in the form of the health and safety specifications, which the contractor should be aware of to ensure a healthy and safe working environment. The engineer monitors that the contractor ensures that all employees under his or her control are informed, instructed and trained by a competent person regarding any hazard related to work procedures before any work commence. Therefore the contractor can be required by the specifications of the engineer to include proof that all employees working on site received descent safety training. Therefore:

- The engineer can enforce safety training programs with formal instructions that include lectures, discussions, interactive computer learning and written material.
- The engineer can also enforce practical training that includes demonstrations performed by a safety trainer.

With regard to the identified construction processes, it is recommended that the engineer includes the following considerations in the health and safety specifications:

- **Demolition:**
  - The requirement for the contractor to proof that employees working at heights are equipped with the necessary safety equipment.
  - Employees are equipped with safety equipment that is necessary when working with, or in the proximity of hazardous material or substances.
- **Electrical works:**
  - Non-conductive equipment is used near electrical power lines or cables.
  - Loading and unloading of construction equipment and materials should not take place beneath energized power lines.
  - Advise the contractor that cables should always be laid “top down”, as gravity can assist in the laying of the cables, rather than moving them from the “bottom up”.
  - The engineer specifies that the contractor should consider using mechanical cable pulling machinery, if possible, to avoid manual handling risks.

- **Ergonomics:**
  - Take the capabilities and limitations of employees into account, including the age and language of them.
- **Excavation:**
  - Specify that the contractor should be aware of underground services that include electrical cables, gas pipes, and sewer - and water pipes.
  - Awareness of sufficient space for the sloping and benching of excavations. Excavations to be performed away from static loads (such as buildings, wall, and immobile plant) or dynamic loads (such as traffic and excavation equipment).
  - Specifying that employees should be equipped with the necessary safety equipment, for example, hardhats and fall arrest systems.
  - Specifying that the employees are equipped with the necessary safety equipment for exposure to hazardous substances during the excavation process.
- **Hazardous substances:**
  - Specifying that the contractor should be aware of the hazardous material or substances that will be used on site, or are released during construction activities.
  - Specifying that employees need to be equipped with the necessary safety equipment.
  - Use alternative construction methods, if possible, to reduce the amount of hazardous substances.
  - Specify that proof is required from the contractor that he or she is licensed to work with hazardous material. For example, only licensed asbestos removal contractors should be used for the removal of asbestos.
- **Maintenance:**
  - Specifying that materials with high durability and low maintenance requirements are used for construction. This will increase the periods between maintenance activities and decrease the probability of maintenance hazards occurring.
- **Manual handling:**
  - Lighter products and material that meet the design criteria should be used.



- Contractor should be aware of the location of the delivery point for materials. It should be specified at a convenient location to shorten manual hauls.
- The contractor should prevent manual handling of large building components as these components should be lifted by a crane to reduce ergonomic issues.
- **Plant and equipment:**
  - The contractor should ensure that level surfaces and sufficient room around temporary work and equipment for easy and safe access are present on the construction site.
  - The contractor is also responsible to ensure sufficient room and good foundations for the movement of cranes. Good foundations mean to avoid poor or uneven ground.
  - The contractor should be able to provide records of inspections for plant and equipment.
  - Specification that the contractor should provide proof that he or she is aware of the hazards associated with plant and equipment and that all machinery are reliable with regard to construction safety and loading strength.
  - The engineer requires a construction method statement from the contractor that includes the use of plant and equipment that provide adequate loading strength.
- **Refurbishment (with reference to the engineer designing for refurbishment):**

The engineer responsible for the design of the renovation process should share the following information with the contractor or employees performing the renovation activities:

- The age of the building that will provide information on the building and design techniques employed during its construction.
- The strength of the building which will identify how structural additions should be supported by the additional structure.
- The actual condition of the building which will identify possible weaknesses of the structure.
- The materials used will also provide information on the strength and condition of the building.

- Renovation employees working at heights should be equipped with fall arrest systems.
- Employees can be exposed to hazardous substances or falling building components caused by structural collapse. Therefore, employees should be equipped with the necessary safety equipment.
- **Steelwork:**
  - Employees working at heights should be equipped with fall arrest systems.
  - The contractor should be aware that temporary bracing is needed for vulnerable steel members.
- **Utilities:**
  - The contractor should provide health and safety specifications to his or her sub-contractors responsible for the utilities.
- **Work done on roofs:**
  - Specifying non-fragile materials to be used on roofs.
  - The use of fall prevention equipment (guardrails and guardrail attachments at the perimeter).
  - Measures to prevent falls through the roof, such as roof member spacing and safety nets. This matter is primarily the responsibility of the contractor. However, the engineer assists the contractor by bringing this matter to the attention of him or her.
  - Provide anchorage points for a fall arrest system (refer to steelwork).
  - The strength of the roof members to which guardrails are attached or which act as an anchorage point for a fall arrest system.
  - Provisions for safe access to or through the roof space.
  - All construction employees should undergo safety training related to hazards caused by work done at height.

Based on the information included in the health and safety specifications, the contractor creates and provides the engineer with his or her health and safety plan. The engineer takes reasonable steps to ensure that the contractor's health and safety plan is implemented and maintained on site. These steps include periodic audits of the construction site by the engineer and mutually agreed upon with the contractor.

### **6.2.6 Step 6: Provide final report to client**

A final report should be provided to the client by the joint project team that includes the engineer and contractor. The final report includes the following:

- A record of the identified construction site hazards and risks.
- An assessment of these hazards and risks for the client to understand their relative importance and to prioritise control measures.
- How these hazards and risks can occur.
- An explanation of design measures that address the hazards and risks.
- Information included in the health and safety specifications to improve health and safety on site.
- The health and safety plan provided by the contractor.

## CHAPTER 7: FINAL CONCLUSIONS

In this chapter, a summary of the key results and findings from the literature study, the case studies, and the questionnaires are presented. The summarised conclusions arising from the complete discussions in Chapters 3, 4 and 5 are provided briefly in this chapter. Primarily, this chapter presents the general conclusion of the identified construction site safety problem.

### 7.1 Summary of Key Results and Findings

This research aimed to achieve the following objectives:

- a. To understand the role of the engineer with regard to the safety of employees on construction sites of buildings.
- b. To identify the safety hazards associated with the construction activities that are performed for the construction of a building.
- c. To identify the role of the engineer with regard to construction site safety, and to investigate the opinion of South African engineers with regard to the role of the engineer.
- d. To identify the effect of engineers on the safety of employees with regard to the safety hazards associated with the construction processes that are used during the construction of a building.
- e. To identify whether safety training takes place on construction sites.

Furthermore, this research tested the following two hypotheses:

Hypothesis 1: South African engineers have a lack of experience in the processes that are used during the construction phase of a project.

Hypothesis 2: Engineers can play a role in improving the safety of construction employees on building sites, i.e. construction site safety is not solely the responsibility of the contractor.

#### 7.1.1 Designing for safety - literature study

The literature study explored existing and related research on designing for safety with focus on the responsibilities of the engineer, as designer, throughout the life-cycle of the building project. The responsibility of designing is the responsibility of the engineer if the procurement strategy is the Conventional strategy, Design-and-Construct strategy or the Design-and-Manage strategy. The engineer may also be appointed as the designer if the choice of contracting strategy is the Principal Building Agreement of the JBCC Series 2000.

The total of construction accidents in South Africa, whether it is fatal, non-fatal or non-casualty, increased for the period from 2004 to 2008. The reason for the increase is not due to a lack of health

and safety legislation in South Africa, but rather to the enforcement of adequate health and safety systems within the construction industry. Inter alia, an adequate health and safety system includes a safe design process. A safe design process is the integration of hazard identification and risk assessment methods early in the design process to eliminate or minimise the risks of injury throughout the life of the product being designed.

Depending on the hazard, the engineer plays either a direct or indirect role in contributing towards a safe working environment. For some of the hazards, the responsibility of the engineer is limited to only identifying the hazard and pointing it out to the contractor or sub-contractor. Therefore, for some hazards the engineer acts as an assistant to the responsible party. However, for most hazards, the engineer can contribute towards a safe construction site by taking the hazards into consideration during the actual design. An engineer will also benefit from site experience as this will improve his knowledge of construction processes and it can then be incorporated into the design.

Since the engineer is responsible to identify and point out the various construction site hazards to the contractor, the two parties should be in close collaboration. This will ensure that the possible hazards and the best possible manner in which hazards can be mitigated are identified. A close collaboration can be achieved by the effective transfer of knowledge between the engineer and the contractor. Effective construction knowledge transfer between the engineer and contractor ensures the constructability of the building to increase. Alongside the identification of construction site hazards, a safe design approach will also be achieved if the engineer considers constructability principles.

The literature study also identifies primary and secondary legislation in South Africa that has an impact on construction health and safety. The primary legislation is identified to be the Occupational Health and Safety Act No.85 of 1993, and the Occupational Injuries and Disease Act No.130 of 1993. One of the regulations that are distributed under the Occupational Safety and Health Act is the Construction Regulations that were promulgated in July 2003.

The Construction Regulations can be seen as a document that defines the legal duties for the safe operation of South African construction sites. The legal duties are specifically placed on clients, designers and contractors and assist these parties in their approach to health and safety.

### **7.1.2 Case studies on construction site safety**

The case studies that were analysed in Chapter 4 provided an overview of the hazardous construction industry and provided several lessons that can be learned from each. These lessons are focused on the role that the engineer should play throughout the life-cycle of a project with regard to health and safety.

One objective of the case studies was to identify whether the construction site hazards mentioned in Chapter 3 are legitimate. The answer is “yes”. The numerous case studies proved that working at heights or on roofs, demolition, plant and equipment, hazardous material, ergonomics, electrical works, etc. are construction processes that present safety hazards that engineers should take into account when designing a building. Amongst these hazards, several other construction site hazards were identified that can jeopardise the safety and health of employees.

Important lessons that were learned from almost every case study, were that engineers should monitor the use of fall arrest systems when work needs to be performed on roofs or at heights, the engineer should enforce the contractor to have a formal safety training program in place, and the engineer and contractor should have regular meetings to discuss possible site hazards.

The regular meetings will ensure the early involvement of the contractor during the design phase of the project. Early collaboration between the engineer and contractor, provided that their experience and knowledge on construction methods and safety are adequate, will result in a safe and constructible building site.

### **7.1.3 Questionnaires on construction site safety**

The average years of experience of the respondents as contractors are low (1 year). This may be an indication that the respondents have a lack of site experience and therefore, a lack of knowledge with regard to construction processes. The responses to the questionnaire resulted in the opinion that prior to being appointed by a consulting engineering company, engineers should obtain site experience to be aware of construction methods and the hazards associated with each.

According to the Engineering Council of South Africa (ECSA) (2004) and as stated in Policy Statement R2/1A, the prescribed minimum practical training period in order to register as a professional engineer, after obtaining a recognised qualification, is three years. The practical training must include problem investigation, problem solution, and execution at increasing levels of responsibility (Engineering Council of South Africa (ECSA), 2004).

As mentioned in Chapter 5.3.1, the question may be whether a minimum of three years of practical training is sufficient? Another question may be whether the requirements of ECSA are clear enough with regard to site experience?

Although the Construction Regulations state that safety hazards associated with most construction activities are the responsibility of the contractor, it will be beneficial for the safety of the employees if the engineer also informs the contractor on the hazards identified by him or her during the early design stages. However, more adequate safety hazard identification and hazard mitigation will

commence if the contractor is included during the early design stages. Therefore, making use of the Design-Construct -, or Design-Manage procurement strategies should be promoted in South Africa.

Thirty four percent (34%) of the respondents have a lack of knowledge with regard the Construction Regulations. The Construction Regulations include the responsibilities of the engineer for a construction project and it is therefore essential for engineers to be aware of the information in the Construction Regulations.

However, it is important to note that 83% of the respondents feel that the engineer should share the health and safety specifications for the construction work with the contractor. Ninety one percent (91%) of the respondents are aware of the fact that the engineer should share any information that might affect the health and safety of the project with the contractor. Therefore, despite the low percentage (66%) of respondents that is aware of the contents of the Construction Regulations, the respondents acknowledge that engineers should also be aware of construction safety hazards.

Therefore, the respondents feel that engineers can play a role in improving the safety of construction sites. The role they can play is based on the information that the engineer should share with the contractor prior and during construction. This information includes the identification of employee safety hazards associated with various construction activities and consulting the contractor on methods to prevent them.

Forty eight percent (48%) of the respondents believe that a lack of safety training for employees is the main cause for construction site accidents to occur. This resulted in the conclusions that more contractors in South Africa should have formal safety programs that include descent safety training and the training programs should be monitored by the engineer.

## **7.2 General Conclusions**

The results and findings obtained from the research methodologies used, i.e. literature study, investigation of case studies, and questionnaires allowed the objectives of this research to be achieved.

This section includes the general conclusions arising from this research. It is important to note that the detailed reasoning that led to these points is not included in this section; these are only the final conclusive remarks.

It was established that:

- The engineer is responsible for the design of a building if the procurement strategy is the Conventional -, Design-Construct -, or Design-Manage strategy.

- The engineer can be appointed as the Principal Agent, as stated in the Principal Building Agreement, and has full authority and obligation to act in terms of the agreement.
- The engineer can be appointed to act on behalf of the client as stipulated in the Construction Regulations.
- A building design should be reasonable practicable and therefore, the engineer should consider the likelihood of risks occurring and their degree of harm during the early design stages.
- The engineer should have adequate knowledge with regard to construction processes to ensure a safe and constructible design.
- With regard to improving the safety of construction employees, the engineer plays a direct or indirect role, depending on the construction process and the hazards associated with each.
  - Direct role meaning the engineer considers the hazards during the design stage and avoids the risks associated with the hazards by designing accordingly.
  - Indirect role meaning the engineer assists the contractor in safety hazard prevention by identifying hazards and sharing his or her knowledge with the contractor.
- To comply with the responsibilities of the engineer as stated in the Construction Regulations, the engineer should share any information that might affect the health and safety with contractor.
- The information, mentioned above, is shared by the engineer by indicating safety hazards on the actual drawings, including it in the health and safety specifications of each project, or by communicating it with the contractor during regular meetings.
- Although the Construction Regulations state that the safety hazards associated with most construction processes are the responsibility of the contractor, it will be beneficial for the safety of the employees if the engineer also informs the contractor on the hazards identified by him or her during the early design stages.
- The Design-Construct - or Design-Manage procurement strategies include the contractor during the design stages of the project.
- Early collaboration between the engineer and contractor is beneficial for the safety of construction employees as an integrated approach will be taken towards safety hazard identification and mitigation.
- The respondents to the questionnaire indicated that they have a small number of average years of experience as contractors (1 year) and this is an indication that a percentage of South African engineers have a lack of construction site experience.



- Thirty four percent (34%) of the respondents have a lack of knowledge with regard to the content of the Construction Regulations. This is an indication that a percentage of South African engineers are unaware that the contents include the safety responsibilities of the engineer for a construction project.
- Engineers can play a role in improving the safety of construction sites. The role they can play is based on the information that the engineer should share with the contractor prior and during construction. This information includes the identification of employee safety hazards associated with various construction activities and consulting the contractor on methods to prevent them.
- A lack of safety training for employees is the main cause for construction site accidents. Therefore, contractors should have formal safety programs that include descent safety training in different languages and the safety programs should be monitored by the engineer.
- Although descent safety training and safety programs are primarily the responsibility of the contractor, the engineer can also play a role by enforcing the implementation of safety training, i.e. Specifying that proof of safety training programs are provided to the engineer and included in the health and safety plan of the contractor.

Therefore, the two hypotheses for this research are true.

Hypothesis 1: South African engineers have a lack of experience in the processes that are used during the construction phase of a project:

True, based on the results obtained from the questionnaire. The respondents indicated that they have little experience as contractors (1 year). Seventy four percent (74%) of the respondents agree with Jerling (2009), i.e. engineers have a lack of construction and constructability knowledge (refer to Figure E5). However, it was established that engineers can play a role in improving the health and safety of construction sites by being aware of the safety hazards associated with construction processes and designing accordingly. However, only 43% of the respondents agreed that they know how to improve the safety of a construction sites. Therefore, only 43% of the respondents are capable of incorporating safety into the design. Adequate construction knowledge will allow the engineer to incorporate safety measures into the design as he or she will be aware of the safety hazards associated with each construction process.

Figure 36 in Chapter 5.3.2 indicates that the respondents feel that an engineer has a moderate effect on safety for hazards associated with all of the construction activities. Therefore, all the respondents are unaware of the impact they can have on safety. They are unaware that for each construction

process, they are in a position to either incorporate safety directly into the design or identifying safety hazards and mentioning them in the health and safety specifications. Although it was established that a percentage of South African engineers have a lack of experience in the processes that are used during construction, it was also established that a percentage of South African engineers are unaware of the role and responsibilities of the engineer in order to improve construction site safety.

Hypothesis 2: Engineers can play a role in improving the safety of construction employees on building sites, i.e. construction site safety is not solely the responsibility of the contractor:

True. The engineer plays a role in improving the safety of employees on construction sites as he or she is obliged, according to the Construction Regulations, to share any information that might affect the health and safety of the employees with the contractor. Therefore, having adequate knowledge of construction processes allows the engineer to be aware of all possible safety hazards. This will result in the correct information to be shared with the contractor and to be incorporated into the early design phases of the project. The result will be a healthy and safe working environment.

Although employee safety and knowledge of safety hazards on construction sites are primarily the responsibility of the contractor, the engineer should also participate by identifying safety hazards and informing the contractor of it; hence the term *consulting engineer*.

### 7.3 Future Research

Future research should investigate the health and safety considerations associated with more civil engineering disciplines, i.e. transport, geotechnical, coastal, water resources, etc. With regard to structures, it should aim to identify more construction activities associated with buildings and the health and safety hazards associated with each. Future research can also include the use of other contracting strategies and investigate design responsibilities as stated in each. Other contracting strategies include the General Conditions of Contract (GCC), the International Federation of Consulting Engineers (FIDIC), and the New Engineering Contract (NEC).

Since it was established throughout the research that a percentage of South African engineers have a lack of knowledge with regard to construction processes, future research should investigate ways to provide engineers with this knowledge, other than working as contractors.

As it was not established in this research, future research should investigate whether a minimum of three years of practical training to register as professional engineer, as required by ECSA, is adequate. It should also investigate the acceptable number of years of experience an engineer should have in order to be able to design safe and healthy.

Future research can also investigate whether safety training and safety awareness education should take place at an undergraduate level.

## REFERENCES

- Aspirata, 2009. *Aspirata Health Safety and Laboratory Services*. [Online] Available at: <http://www.aspirata.co.za/Industries/Construction.aspx> [Accessed 20 February 2013].
- Barnes, S., 2001. *Contract Research Online Survey*, Bristol: Institute for Learning and Research Technology.
- Behm, M., 2006. *An Analysis of COstruction Accidents from a Design Perspective*, Greenville, North Carolina: CPWR (Center to protect Worker's Rights).
- Brown, K., Ryan, R. & Charles, M., 2007. *Guide to best practice for safer construction: Case Studies*, Brisbane: Icon.net Pty Ltd.
- Caple, D. C., 2010. *Safety in Design - How do you do it?*, Melbourne: David Caple & Associates .
- Cascade Corporation, 2009. *Technical Bulletin: Fork Modification and Inspection*, Kempton Park, Johannesburg: Cascade.
- Cheng, M., 2009. *Research on the Knowledge Transfer in Construction Projects*, Shanghai, P.R. China: School of Management, Shanghai University.
- CIDB, 2010. *Executing a construction project*, s.l.: The Construction Industry Development Board.
- Construction Industry Development Board (CIDB), 2005. *Choosing an appropriate form of contract for engineering and construction works*, Pretoria: CIDB.
- Davis, P., 2008. *Building Procurement Methods*, Melbourne: Curtin University of Technology.
- Department of Labour, 2003. *Construction Regulations*, s.l.: Department of Labour, Occupational Health and Safety Act, 1993.
- Department of National Treasury, 2012. *Occupational health and safety specification for construction works contracts*, South Africa: s.n.
- El Hourani, E. M., 2008. *Factors that Hamper the Implementation of Constructability in the Gaza Strip* , s.l.: Islamic University of Gaza.
- Emmitt, S., Sander, D. & Chridtoffersen, A. K., 2005. *Implementing value through lean design managment*, Denmark: Department of Civil Engineering, Technical University of Denmark.
- Engineering Council of South Africa (ECSA), 2004. *Acceptable Engineering Work for Candidate Engineers for Registration as Professional Engineers*, Johannesburg: ECSA.

Engineering Council of South Africa (ECSA), 2012. *The role, Responsibilities and Conduct of persons registered with ECSA appointed for small building works*, Johannesburg, South Africa: ECSA.

Enslin, N., 2011. *Safe Build*. [Online] Available at: <http://forum.safebuild.co.za/showthread.php?555-Construction-accidents-%91halved-in-five-years%92>

[Accessed 20 February 2013].

Gambatese, J. A., 2000. *Safety Constructability: Designer Involvement in Construction Site Safety*, Orlando, Florida, United States: ASCE (American Society of Civil Engineers).

Gambatese, J., Toole, M. & Giles, B., 2008. *The future of design for construction safety*. Rosemont, Alliance.

Gilbertson, A. & Arup, O., 2007. *Construction work sector guidance for designers*, London: CIRIA (Construction industry research and information association).

Griffith, A. & Sidwell, A. C., 1997. Development of constructability concepts, principles and practices. *Engineering, Construction and Architectural Management*, 4(4), pp. 295-310.

Hide, S. et al., 2003. *Causal Factors in Construction Accidents*, Leicestershire: Crown.

Higgins, D. N., 2004. *National Institute for Occupational Safety and Health*. [Online] Available at: <http://www.cdc.gov/niosh/face/In-house/full200406.html> [Accessed 21 May 2013].

Higgins, D. N., 2004. *National Institute for Occupational Safety and Health: Fatality assessment and control evaluation report*. [Online] Available at: <http://www.cdc.gov/niosh/face/In-house/full200406.html> [Accessed 4 June 2013].

Jergeas, G. & Van der Put, J., 2001. Benefits of Constructability on Construction Projects. *Journal of Construction Engineering and Management*, 127(4), pp. 281-290.

Jerling, W., 2009. *Construction risks generated by employers from the perspective of SA contractors*, University of Bath: Department of Architecture and Civil Engineering.

Joint Building Contracts Committee Inc, 2000. *Principal Buidling Agreement*. 5th ed. s.l.:JBCC.

Jones, C., 2009. *Controlling Construction Site Hazards*, New South Wales: Chris Jones Risk Management Pty Limited.

Kogi, K. & Serbitzer, J., 1992. *Safety and Health in Construction*, Geneva, Switzerland: International labour office Geneva.

Krishnamurthy, N., 2007. *Forensic Engineering in Structural Design and COnstruction*, Bangalore, India: Structural Engineers World Congress 2007.

Kuo, V., 2012. *The role of knowledge management in improving constructability*, Stellenbosch, Cape Town: SUNScholar Research Repository, University of Stellenbosch.

Markkanen, P., Kriebel, D., Tickner, J. & Jacobs, M., 2010. *Injuries are not accidents: Construction will be safe when it's designed to be safe*, Massachusetts: University of Massachusetts Lowell.

Massachusetts State Fatality Assessment and Control Evaluation, 2006. *National Institute for Occupational Safety and Health*. [Online] Available at: <http://www.cdc.gov/niosh/face/stateface/ma/04ma038.html> [Accessed 22 June 2013].

Mroszczyk, J., 2005. *Designing for Construction Safety*, Massachusetts: Northeast Consulting Engineers.

National Institute for Occupational Safety and Health, 2012. *Centers for Disease Control and Prevention*. [Online] Available at: <http://www.cdc.gov/niosh/face/inhouse.html> [Accessed 07 August 2013].

Nebraska State Fatality Assessment and Control Evaluation Department, 2005. *National Institute for Occupational Safety and Health: Fatality assessment and control evaluation*. [Online] Available at: <http://www.cdc.gov/niosh/face/stateface/ne/05ne012.html> [Accessed 12 June 2013].

New York State Department of Health, 2009. *National Institute for Occupational Safety and Health: Fatality assessment and control evaluation report*. [Online] Available at: <http://www.cdc.gov/niosh/face/stateface/ny/07NY015.html> [Accessed 10 June 2013].

Ratay, R. T., 2010. *Forensic Structural Engineering Handbook*. 2nd ed. s.l.: McGraw-Hill Professional, Access Engineering.

Safe Work Australia, 2011. *Interpretive guideline—Model work Health and Safety act - The meaning of reasonable practicable*, s.l.: s.n.

Sedgley, M., 2007. *Effective Learning Service: Introduction to research and research methods*, Bradford, West Yorkshire, England: University of Bradford, School of Management.

Singh, H., 2009. *Construction Contracts: An Overview*, s.l.: s.n.

Smallwood, J., Haupt, T. & Shakantu, W., 2009. *Construction Health & Safety in South Africa*, s.l.: The Construction Industry Development Board.

Sullivan, C. C., 2007. *Integrated BIM and design review for safer, better buildings*, s.l.: McGraw-Hill Construction.

Tien, E. T. K., 2011. *Construction Safety: Accident Case Studies & Enforcement Analysis*, s.l.: Ministry of Manpower.

- Toole, T. M. & Gambatese, J., 2008. *The trajectories of prevention through design in construction*, Lewisburg: Civil & Environmental Engineering, Bucknell University.
- Venter, I., 2009. *Engineering News*. [Online] Available at: <http://www.engineeringnews.co.za/article/sa-construction-industrys-health-and-safety-statistics-in-need-of-revamp-cidb-2009-06-11> [Accessed 20 February 2013].
- Wilkinson, D. & Birmingham, P., 2003. *Using Research Instruments: A guide for researchers*, London: RoutledgeFalmer.
- Work Safe Compensation Board of British Columbia, 2010. *Incident Investigation Report: Construction employee struck by falling wall formwork*, Vancouver, British Columbia: WorkSafeBC.
- Work Safe Compensation Board of British Columbia, 2010. *WorkSafeBC*. [Online] Available at: <http://www2.worksafebc.com/Topics/AccidentInvestigations/IR-Construction.asp> [Accessed 07 August 2013].
- WorkCover NSW, 2009. *Safe Design of Buildings and Structures*, s.l.: New South Wales Government.
- WorkSafe Compensation Board of British Columbia, 2007. *Incident Investigation Report: Worker falls through insulation to concrete floor*, British Columbia: WorkSafeBC Investigations Division.
- WSH Council, 2009. *Guidelines on design for safety in buildings and structures*, s.l.: s.n.
- Yates, J. K. & Lockley, E. E., 2002. Documenting and Analyzing Construction Failures. *Journal of Construction Engineering and Management*, 128(1), pp. 8-17.
- Zou, P. X., Zang, G. & Wang, J.-Y., 2007. Understanding the key risks in construction projects in China. *International Journal of Project Management*, 25(6), pp. 601-614.

## **APPENDIX A: INVITATION LETTER FOR QUESTIONNAIRE**



***Dear Sir/Madam***

We are busy with a research project at Stellenbosch University under the Chair for Construction Engineering and Management to investigate the role of structural designers in site safety.

We plan to send out a questionnaire to obtain input from practitioners and are keen to involve you in the survey. The survey should take about 10 minutes to complete and will be sent out early next week (19 August).

If you are willing to participate, please advise by a return e-mail to the above address.

Your participation will be most appreciated.

Kind regards

***Bernard Vermeulen***

***Masters student in Construction Engineering and Management***

***Department of Civil Engineering Stellenbosch Engineering Faculty***

## **APPENDIX B: COVER LETTER FOR QUESTIONNAIRE**

***Dear (name and surname)***

I am currently undertaking a Master's degree at Stellenbosch University under the Chair for Construction Engineering and Management. In fulfilment of this qualification, I am required to do research on a topic and produce a thesis.

The topic I have chosen is "Analysing construction employee safety of building projects as function of design engineer responsibilities"

I would be grateful if you or another appropriate person in your company could complete the electronic questionnaire found below and submit it at the end. The questionnaire was created using Google Drive and therefore, an internet connection is required. The questionnaire consists of 5 parts and will take no more than 10 minutes. All the information will be treated in strictest confidence and will be used for academic purposes only. Individuals and, or companies will not be identified in the research results.

Please click on the following URL to open the questionnaire. At the end, please remember to click submit.

<https://docs.google.com/forms/d/1zqXTDSHYLuQ8G1On1VZlle7JN5h1Y7Nx4qnleNvk7P8/viewform>

I sincerely thank you for your participation.

Yours Faithfully

***Bernard Vermeulen***

***Masters student in Construction Engineering and Management***

***Department of Civil Engineering Stellenbosch Engineering Faculty***

## APPENDIX C: QUESTIONNAIRE

## Construction Site Safety through Design Questionnaire

The aim of the research is identify the possible hazards that exist, for employee health and safety, during the construction phase of buildings and how the engineer can play a role in eliminating these hazards prior and during construction. Furthermore, the research aims to produce a safe design process that clearly states the correct steps that should be taken in order to provide a safe working environment. It is important to note that throughout the questionnaire, the engineer is referred to as the party responsible for the design.

The research techniques used are a literature study and the investigation of international case studies where accidents occurred on building construction sites. Finally, an electronic questionnaire is prepared with the aim to investigate the opinions of South African engineers on construction site safety with regard to design.

\* Required

1. **1. Personal Information \***

Please state the number of years' experience you have in building design:

---

2. \*

Please state the number of years' experience you have been working as a consultant engineer:

---

3. \*

Please state the number of years' experience you have been working as a contractor:

---

4. \*

Please specify any other occupation you practiced that entailed the design or construction of buildings:

---

5. \*

When you hear the word "safety" on the job, what are the first thoughts that come to your mind?

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APPENDIX C: QUESTIONNAIRE

6. \*  
Did you ever attend any construction safety courses? If yes, please state where did you receive the training

.....  
 .....  
 .....  
 .....

7. \*  
Please indicate whether you Strongly Agree, Agree, Disagree or Strongly Disagree with the statements below:

*Mark only one oval per row.*

	Strongly Agree	Agree	Disagree	Strongly Disagree
In your experience, employees on construction sites have problems in communicating with employers/supervisors	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
You know how to improve the safety of construction sites	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

8. \*  
Approximately, how many accidents occurred on construction sites that your company participated in during 2012/2013?

.....

9. Briefly explain a construction site accident that you experienced in the past. Indicate whether it was fatal or non-fatal:

.....  
 .....  
 .....  
 .....

### Construction Employee Safety and Site Hazards

The following questions is based on the safety of construction employees and the possible hazards that are associated with various construction activities.

APPENDIX C: QUESTIONNAIRE

10. For the following questions, if you choose the answer "other", please specify \*

Please indicate what the main reason is for construction site accidents to occur;

Mark only one oval.

- Lack of legislation
- Lack of construction knowledge from the engineer
- Lack of safety knowledge from the engineer
- Lack of safety knowledge from the contractor
- Careless worker attitudes
- Other: .....

11. \*

The main reason for construction site accidents is that the contractor is short of:

Mark only one oval.

- Safety officers
- Safety commitment by employees
- Formal safety programs
- Safety training
- Safety policies
- Other: .....

12. \*

The main reason for construction site accidents is that employees are short of:

Mark only one oval.

- Safety equipment
- Safety training
- Safe working instructions
- Safe working instructions in different languages
- Motivation
- Other: .....

13. \*

In your opinion, which party is the most responsible for the safety of employees on construction sites?

Mark only one oval.

- Engineer
- Contractor

APPENDIX C: QUESTIONNAIRE

14. \*

Please indicate the magnitude of effect a design engineer has in ensuring the safety of construction employees for hazards associated with the following: (0 = No effect, 5 = Largest effect)

Mark only one oval per row.

	0	1	2	3	4	5
Demolition	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Electrical Works	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ergonomics (making tasks comfortable for the person performing the task)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Excavation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hazardous substances	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Maintenance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Manual handling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Plant and equipment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Refurbishment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Steelwork	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Utilities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Work performed on roofs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

### Lessons Learned from Case Studies

This section entails 24 lessons that were learned by investigating numerous case studies. Your opinion on each statement is asked.

15. \*

Please indicate whether you Strongly Agree, Agree, Disagree or Strongly Disagree with the statements below. There is no correct answer, the best answers are those that honestly reflect your opinion:

Mark only one oval per row.

	Strongly Agree	Agree	Disagree	Strongly Disagree
Responsibility for construction safety is only confined to construction work on site.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There is a lack of communication between engineers and contractors that lead to designs being unsafe.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Construction site safety is generally not included in the design due to a lack of involvement in safety by the engineer.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



APPENDIX C: QUESTIONNAIRE

Safety constructability is a process in which construction site safety is addressed during the design phase.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A lack of involvement in safety by the engineer can be attributed to a lack of construction and constructability knowledge by the engineer.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Your knowledge is adequate with regard to the responsibilities of the engineer for construction safety as stated in the Construction Regulations.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The Construction Regulations include all participants in the construction process from the employer through to the final end-user.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The Construction Regulations convince project participants that health and safety management is a requirement that needs to be included into the planning and design of all construction projects.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
During the design phase, the engineer should keep the capabilities and limitations of employees in mind, such as the age and language of employees.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
When work needs to be performed at heights, the engineer can specify that non-fragile materials are used as work platforms.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The engineer can enforce the contractor that all employees are assisted with fall protection equipment when work is performed at height.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The experience and knowledge of the engineer on construction methods should be adequate in order for the engineer to adjust the design in a constructible and safe manner whenever modification to the design is needed.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The engineer should obtain a construction method statement from the contractor that includes the use of plant and equipment that provide adequate loading strength.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

## APPENDIX C: QUESTIONNAIRE

The engineer can enforce safety training programs with formal instructions that include lectures, discussions, interactive computer learning and written material.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The engineer can also enforce practical training that includes demonstrations performed by a safety trainer.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
When work needs to be performed in the proximity of electrical power lines, it is solely the responsibility of the contractor to specify that non-conductive materials and equipment are used.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
During the design phase, the engineer should be aware of the layout of the construction site, including locations of plant, equipment and power lines.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The engineer, in collaboration with the contractor, should undertake construction site surveys prior to the actual start of construction to identify potential hazards.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A thorough engineering survey should be done by the engineer and contractor before the construction or demolition of any building or building elements.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The engineering survey should include manners in which construction site employers and employees can communicate with emergency rescue providers if necessary.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The contractor should always consult the engineer before modifying any construction methods specified on the engineered drawings.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The engineer should involve the contractor during the design stage to ensure a smooth transition from the design phase to construction with regard to safety of employees.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The designer should specify that the best and most effective equipment are used to ensure quality and safety, even if this equipment will cost more.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

APPENDIX C: QUESTIONNAIRE

For a safer construction process, engineers should design a building with the focus on using more prefabricated construction.

### Information Exchanged

This section encompasses statements that are based on information that the engineer should share with the contractor throughout the life-cycle of a project. Please provide your opinion on each statement and provide information that the engineer should share with regard to safety, according to your experience.

**16. 3. Information exchanged between engineer and contractor: \***

Please indicate whether you Strongly Agree, Agree, Disagree or Strongly Disagree with the statements below. There is no correct answer; the best answers are those that honestly reflect your opinion:

*Mark only one oval per row.*

	Strongly Agree	Agree	Disagree	Strongly Disagree
The engineer should share the health and safety specifications for the construction work with the contractor.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The engineer should share information which might affect the health and safety of any employee carrying out construction work.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The engineer should also undertake periodic audits and share the results of the audits.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The engineer should stop the contractor from executing any construction work which is not in accordance to the health and safety plan of the contractor.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sufficient health and safety information needs to be shared with the contractor to ensure that the work is executed safely where changes are brought about.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17. Briefly discuss, in your opinion, what type of information, with regard to safety, needs to be shared with the contractor by the engineer. (This question is not compulsory)

.....

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.....

## Safe Design Process

Various research results can be found that is based on safe design techniques, i.e. the steps that need to be taken prior to construction. Many of these results identify the bigger picture of safe design as few recognizes the importance of the smaller, but still important, steps that should be taken in between the bigger steps.

### 18. 4. Safe design process \*

According to your experience, briefly state all steps taken to ensure a safe design process prior to the actual construction. (For example: Discuss the project, identify the design team, prepare a risk identification register, etc.)

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## **APPENDIX D: QUESTIONNAIRE RESULTS SPREADSHEET**

Please note:

- Pages 170, 171, and 172 presents the answers for Column A to Column N.
- Pages 173, 174, and 175 presents the answers for Column O to Column AG.
- Pages 176, 177, and 178 presents the answers for Column AH to Column AV.
- Pages 179, 180, and 182 presents the answers for Column AW to Column BF.

[A] Timestamp	[B]1. Personal Information (Years' experience in building design)	[C] Years' experience as engineer	[D] Years' experience as contractor	[E] Please specify any other occupation you practiced that entailed the design or construction of buildings	[F] When you hear the word "safety" on the job, what are the first thoughts that come to your mind?	[G] Did you ever attend any construction safety courses? If yes, please state where did you receive the training	[H] [In your experience, employees on construction sites have problems in communicating with employers or supervisors]	[I] [You know how to improve the safety of construction sites]	[J] Approximately, how many accidents occurred on construction sites that your company participated in during 2012/2013?	[K] Briefly explain a construction site accident that you experienced in the past. Indicate whether it was fatal or non-fatal:	[L] Please indicate what the main reason is for construction site accidents to occur:	[M] The main reason for construction site accidents is that the contractor is short of:	[N] The main reason for construction site accidents is that employees are short of:
8/19/2013 1:31:44	0	2.5	0	none	Proper measures, clothing and control to do a job with out any accident	-	Agree	Disagree	none I can recall		Careless worker attitudes	Safety commitment by employees	Motivation
8/19/2013 11:07:12	20	20	0	0	ensure nobody gets hurt during construction	Some in-house training induction when visiting construction site	Agree	Agree	none	n/a	careless contractor attitudes	Safety officers	not properly supervised
8/19/2013 12:51:37	0	2	0	None	OHS PPE Organized and orchestrated activities Planning	Road works signage (South African Roads Federation)	Disagree	Disagree	1	Non-fatal A flaglady was hit by a slow moving vehicle at a road closure on a roads rehabilitation project.	Lack of safety knowledge from the contractor	Safety commitment by employees	Safety training
8/19/2013 13:31:13	1	3	0	none	Precautions taken by means of measures to avoid any injury or death	no, only site safety induction	Disagree	Disagree	roughly 2	By stepping on scaffolding "catwalk" floors in a "basement" excavation that was not poperly fixed and barricaded. the person fell down from the platform into the excavation. the accident was non-fatal and the person landed on his feet, and only suffered some cuts on his hand.	Careless worker attitudes	Safety commitment by employees	Safe working instructions in different languages
8/19/2013 13:57:10	40	40	0	N/A	Safe working practices	Yes, in-house.	Disagree	Agree	None	1990 - Explosion in storage tank under construction during internal painting operation - 1 fatality	Careless worker attitudes	Safety training	Safety training
8/19/2013 14:15:32	40	40	0	0	THE PUBLIC	NO	Disagree	Disagree	0		Lack of safety knowledge from the contractor	Safety commitment by employees	Safety training
8/19/2013 17:04:43	35	35	none	none	- somebody falling off scaffolding - something falling on a worker	no	Disagree	Agree	probably 5	I do not recall detail	lack of safety discipline on sites	zero-tolerance w.r.t. sub-contractors	Motivation
8/20/2013 8:22:16	12	12	0	n/a	In order that no injuries happen on site	No	Agree	Disagree	0		Careless worker attitudes	Safety commitment by employees	Safety training
8/26/2013 15:35:09	20 plus	20 plus	0	0	overkill	no	Disagree	Disagree	1	leg broken non fatal	Careless worker attitudes	Safety commitment by employees	commitment
8/26/2013 8:12:11	15	15	0	0	protection	yes, in Europe for site inductions	Disagree	Disagree	-	na	Careless worker attitudes	Safety commitment by employees	Motivation
8/26/2013 8:19:50	1	2.5	0	-	Safety on site around equipment and physical conditions	No	Disagree	Disagree	0	Non-fatal, Equipment falling down from scaffolding	Careless worker attitudes	Safety commitment by employees	Motivation
8/26/2013 10:15:09	5	30	1	nil	Think ahead	No	Disagree	Agree	Don't know	Fatal accident due to electrification from overhead line	Careless worker attitudes	Safety training	Safety training
8/27/2013 14:05:22	5	10	0	None	Preventing injuries or accidents	No	Agree	Disagree	2	Worker fell through roof opening. Non-Fatal	Lack of safety knowledge from the engineer	Formal safety programs	Safety training

[A] Timestamp	[B]1. Personal Information (Years' experience in building design)	[C] Years' experience as engineer	[D] Years' experience as contractor	[E] Please specify any other occupation you practiced that entailed the design or construction of buildings	[F] When you hear the word "safety" on the job, what are the first thoughts that come to your mind?	[G] Did you ever attend any construction safety courses? If yes, please state where did you receive the training	[H] [In your experience, employees on construction sites have problems in communicating with employers or supervisors]	[I] [You know how to improve the safety of construction sites]	[J] Approximately, how many accidents occurred on construction sites that your company participated in during 2012/2013?	[K] Briefly explain a construction site accident that you experienced in the past. Indicate whether it was fatal or non-fatal:	[L] Please indicate what the main reason is for construction site accidents to occur:	[M] The main reason for construction site accidents is that the contractor is short of:	[N] The main reason for construction site accidents is that employees are short of:
8/29/2013 14:16:01	10	12	3	None	Delays in time Preventing injuries Training	Yes, some in-house training	Agree	Agree	0	Non-fatal. Two construction workers fell into a trench on site	Lack of safety knowledge from the contractor	Safety commitment by employees	Safety training
8/30/2013 9:27:15	20	25	5	Architect	Preventing injuries Plan ahead Communication between construction employers and employees	Yes. Private in-house training and on certain sites	Agree	Agree	3	All non-fatal. Inhaling hazardous gasses, allergic reactions to certain substances. A concrete beam fell onto the leg of a construction worker	Lack of construction knowledge from the engineer	Formal safety programs	Safe working instructions
8/30/2013 12:34:34	4	4	0	None	Minimizing construction hazards	None	Agree	Disagree	2		Lack of construction knowledge from the engineer	Safety training	Safety training
8/31/2013 9:48:58	12	20	0	None	Design safe Planning Risks	Yes.	Agree	Agree	Don't know		Lack of construction knowledge from the engineer	Formal safety programs	Safe working instructions
8/31/2013 10:50:53	25+	25+	5	None	Reduce accidents Avoid time delays, avoid additional costs	Yes. On-site training	Agree	Agree	0	Electrical contractor was electrocuted. Non-fatal	Lack of construction knowledge from the engineer	Formal safety programs	Safe working instructions in different languages
8/31/2013 11:21:22	3	10	0	nil	Design and complete project with no accidents	yes. In-house induction training on construction sites	Strongly Agree	Disagree	2	No Comment	Lack of construction knowledge from the engineer	Formal safety programs	Safety training
8/31/2013 14:40:07	8	10	4	None	Safe construction processes Preventing accidents through design	Yes. As a contractor on- site training	Strongly Agree	Disagree	0		Lack of construction knowledge from the engineer	Formal safety programs	Safe working instructions

[A] Timestamp	[B]1. Personal Information (Years' experience in building design)	[C] Years' experience as engineer	[D] Years' experience as contractor	[E] Please specify any other occupation you practiced that entailed the design or construction of buildings	[F] When you hear the word "safety" on the job, what are the first thoughts that come to your mind?	[G] Did you ever attend any construction safety courses? If yes, please state where did you receive the training	[H] [In your experience, employees on construction sites have problems in communicating with employers or supervisors]	[I] [You know how to improve the safety of construction sites]	[J] Approximately, how many accidents occurred on construction sites that your company participated in during 2012/2013?	[K] Briefly explain a construction site accident that you experienced in the past. Indicate whether it was fatal or non-fatal:	[L] Please indicate what the main reason is for construction site accidents to occur:	[M] The main reason for construction site accidents is that the contractor is short of:	[N] The main reason for construction site accidents is that employees are short of:
9/1/2013 12:11:15	0	1	4 weeks	None	It is unnecessary and nobody bother to follow the rules.	No	Agree	Agree	5	Flagman hit by a car-Non-fatal but can be fatal Bitumen splashed in a labour's eye.	Careless worker attitudes	Safety officers	Safe working instructions
9/2/2013 8:14:52	0	7	0	None	Prevent injuries to workers. Communication between project manager and workers. Supervision by safety officers.	No	Agree	Disagree	0	N/A	Lack of construction knowledge from the engineer	Safety training	Safety training
9/3/2013 10:25:40	15	15	3	None	Integration between employers and employees to discuss all safety hazards. Eliminating safety hazards as soon as possible.	Yes. On-site induction training	Agree	Agree	About 3	Three workers suffered ear damage. Protective equipment was not used. Non-Fatal	Careless worker attitudes	Safety commitment by employees	Safety training



[O] In your opinion, which party is the most responsible for the safety of employees on construction sites?	[P] Please indicate the magnitude of effect a design engineer has in ensuring the safety of construction employees for hazards associated with the following: (0 = No effect, 5 = Largest effect) [Demolition]	[Q] [Electrical Works]	[R] [Ergonomics (making tasks comfortable for the person performing the task)]	[S] [Excavation]	[T] [Hazardous substances]	[U] [Maintenance]	[V] [Manual handling]	[W] [Plant and equipment]	[X] [Refurbishment]	[Y] [Steelwork]	[Z] [Utilities]	[AA] [Work performed on roofs]	[AB] [Responsibility for construction safety is only confined to construction work on site.]	[AC] [There is a lack of communication between engineers and contractors that lead to designs being unsafe.]	[AD] [Construction site safety is generally not included in the design due to a lack of involvement in safety by the engineer.]	[AE] [Safety constructability is a process in which construction site safety is addressed during the design phase.]	[AF] [A lack of involvement in safety by the engineer can be attributed to a lack of construction and constructability knowledge by the engineer.]	[AG] [Your knowledge is adequate with regard to the responsibilities of the engineer for construction safety as stated in the Construction Regulations.]
Contractor	4	4	1	4	4	3	3	1	3	3	4	4	Disagree	Disagree	Agree	Agree	Agree	Disagree
Contractor	3	3	1	3	2	0	0	0	1	2	2	1	Disagree	Strongly Agree	Strongly Agree	Strongly Disagree	Disagree	Strongly Disagree
Contractor	1	1	2	1	2	1	1	0	1	1	1	2	Strongly Disagree	Disagree	Strongly Disagree	Agree	Strongly Agree	Disagree
Contractor	1	4	3	1	2	2	2	0	1	1	3	2	Agree	Agree	Agree	Agree	Disagree	Agree
Contractor	2	2	2	3	3	2	2	1	2	2	2	2	Disagree	Strongly Disagree	Disagree	Strongly Disagree	Strongly Disagree	Strongly Agree
Contractor	5	2	2	1	1	1	1	1	1	2	1	1	Strongly Agree	Strongly Agree	Strongly Agree	Agree	Agree	Disagree
Contractor	1	2	0	1	3	0	0	0	1	0	0	0	Agree	Disagree	Strongly Disagree	Strongly Disagree	Strongly Disagree	Agree
Contractor	3	4	4	2	2	3	3	1	2	2	1	1	Disagree	Agree	Disagree	Agree	Agree	Disagree
Contractor	3	3	3	3	3	3	3	3	3	3	3	3	Disagree	Disagree	Disagree	Disagree	Disagree	Agree
Contractor	1	1	1	1	2	1	1	1	1	1	1	1	Agree	Disagree	Disagree	Disagree	Disagree	Agree
Contractor	5	2	1	4	5	1	1	3	1	3	3	4	Disagree	Disagree	Agree	Disagree	Agree	Agree
Contractor	2	1	1	2	1	2	1	1	2	2	2	2	Disagree	Disagree	Disagree	Disagree	Agree	Agree
Contractor	1	1	0	2	2	1	1	1	2	2	2	3	Agree	Agree	Agree	Strongly Agree	Agree	Agree

[O] In your opinion, which party is the most responsible for the safety of employees on construction sites?	[P] Please indicate the magnitude of effect a design engineer has in ensuring the safety of construction employees for hazards associated with the following: (0 = No effect, 5 = Largest effect) [Demolition]	[Q] [Electrical Works]	[R] [Ergonomics (making tasks comfortable for the person performing the task)]	[S] [Excavation]	[T] [Hazardous substances]	[U] [Maintenance]	[V] [Manual handling]	[W] [Plant and equipment]	[X] [Refurbishment]	[Y] [Steelwork]	[Z] [Utilities]	[AA] [Work performed on roofs]	[AB] [Responsibility for construction safety is only confined to construction work on site.]	[AC] [There is a lack of communication between engineers and contractors that lead to designs being unsafe.]	[AD] [Construction site safety is generally not included in the design due to a lack of involvement in safety by the engineer.]	[AE] [Safety constructability is a process in which construction site safety is addressed during the design phase.]	[AF] [A lack of involvement in safety by the engineer can be attributed to a lack of construction and constructability knowledge by the engineer.]	[AG] [Your knowledge is adequate with regard to the responsibilities of the engineer for construction safety as stated in the Construction Regulations.]
Contractor	2	3	3	4	4	2	0	1	2	3	4	4	Disagree	Agree	Agree	Strongly Agree	Agree	Agree
Contractor	3	3	3	3	4	3	2	3	3	4	4	4	Disagree	Agree	Agree	Strongly Agree	Agree	Agree
Contractor	2	3	3	3	4	3	2	3	3	4	3	4	Disagree	Agree	Agree	Agree	Agree	Disagree
Contractor	4	4	3	4	4	2	2	3	3	3	4	4	Strongly Disagree	Agree	Strongly Agree	Strongly Agree	Agree	Strongly Agree
Contractor	3	3	3	3	4	3	3	4	2	3	3	3	Strongly Disagree	Agree	Agree	Agree	Agree	Agree
Contractor	2	2	3	4	4	2	1	3	3	4	3	4	Strongly Disagree	Agree	Agree	Agree	Agree	Agree
Contractor	3	4	4	3	4	2	3	3	4	4	4	4	Strongly Disagree	Strongly Agree	Agree	Agree	Agree	Agree

[O] In your opinion, which party is the most responsible for the safety of employees on construction sites?	[P] Please indicate the magnitude of effect a design engineer has in ensuring the safety of construction employees for hazards associated with the following: (0 = No effect, 5 = Largest effect) [Demolition]	[Q] [Electrical Works]	[R] [Ergonomics (making tasks comfortable for the person performing the task)]	[S] [Excavation]	[T] [Hazardous substances]	[U] [Maintenance]	[V] [Manual handling]	[W] [Plant and equipment]	[X] [Refurbishment]	[Y] [Steelwork]	[Z] [Utilities]	[AA] [Work performed on roofs]	[AB] [Responsibility for construction safety is only confined to construction work on site.]	[AC] [There is a lack of communication between engineers and contractors that lead to designs being unsafe.]	[AD] [Construction site safety is generally not included in the design due to a lack of involvement in safety by the engineer.]	[AE] [Safety constructability is a process in which construction site safety is addressed during the design phase.]	[AF] [A lack of involvement in safety by the engineer can be attributed to a lack of construction and constructability knowledge by the engineer.]	[AG] [Your knowledge is adequate with regard to the responsibilities of the engineer for construction safety as stated in the Construction Regulations.]
Contractor	3	1	4	2	0	1	1	0	1	1	1	0	Disagree	Agree	Disagree	Agree	Agree	Disagree
Contractor	3	3	3	3	4	3	3	4	3	4	3	3	Strongly Disagree	Agree	Disagree	Agree	Agree	Disagree
Contractor	4	4	4	4	4	3	1	4	3	4	4	4	Disagree	Strongly Agree	Agree	Strongly Agree	Agree	Agree

[AH] [The Construction Regulations include all participants in the construction process from the employer through to the final end-user.]	[AI] [The Construction Regulations convince project participants that health and safety management is a requirement that needs to be included into the planning and design of all construction projects.]	[AJ] [During the design phase, the engineer should keep the capabilities and limitations of employees in mind, such as the age and language of employees.]	[AK] [When work needs to be performed at heights, the engineer can specify that non-fragile materials are used as work platforms.]	[AL] [The engineer can enforce the contractor that all employees are assisted with fall protection equipment when work is performed at height.]	[AM] [The experience and knowledge of the engineer on construction methods should be adequate in order for the engineer to adjust the design in a constructible and safe manner whenever modification to the design is needed.]	[AN] [The engineer should obtain a construction method statement from the contractor that includes the use of plant and equipment that provide adequate loading strength.]	[AO] [The engineer can enforce safety training programs with formal instructions that include lectures, discussions, interactive computer learning and written material.]	[AP] [The engineer can also enforce practical training that includes demonstrations performed by a safety trainer.]	[AQ] [When work needs to be performed in the proximity of electrical power lines, it is solely the responsibility of the contractor to specify that non-conductive materials and equipment are used.]	[AR] [During the design phase, the engineer should be aware of the layout of the construction site, including locations of plant, equipment and power lines.]	[AS] [The engineer, in collaboration with the contractor, should undertake construction site surveys prior to the actual start of construction to identify potential hazards.]	[AT] [A thorough engineering survey should be done by the engineer and contractor before the construction or demolition of any building or building elements.]	[AU] [The engineering survey should include manners in which construction site employees and employees can communicate with emergency rescue providers if necessary.]	[AV] [The contractor should always consult the engineer before modifying any construction methods specified on the engineered drawings.]
Strongly Agree	Agree	Agree	Agree	Agree	Strongly Agree	Strongly Agree	Agree	Agree	Disagree	Agree	Agree	Agree	Agree	Strongly Agree
Agree	Strongly Disagree	Agree	Agree	Disagree	Agree	Agree	Disagree	Disagree	Agree	Agree	Agree	Agree	Agree	Strongly Agree
Agree	Agree	Strongly Disagree	Strongly Agree	Strongly Agree	Strongly Agree	Disagree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Agree	Strongly Agree	Strongly Agree	Strongly Agree
Agree	Agree	Disagree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Strongly Agree
Strongly Agree	Strongly Agree	Agree	Strongly Agree	Strongly Agree	Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Disagree	Agree	Agree	Strongly Agree	Strongly Agree	Strongly Agree
Strongly Agree	Strongly Agree	Strongly Disagree	Strongly Disagree	Strongly Agree	Strongly Agree	Agree	Agree	Agree	Strongly Agree	Strongly Agree	Agree	Strongly Agree	Agree	Strongly Agree
Agree	Disagree	Strongly Disagree	Strongly Disagree	Strongly Disagree	Strongly Agree	Strongly Disagree	Strongly Disagree	Strongly Disagree	Agree	Agree	Agree	Strongly Agree	Strongly Disagree	Strongly Agree
Strongly Agree	Strongly Agree	Agree	Disagree	Strongly Agree	Agree	Agree	Disagree	Disagree	Disagree	Agree	Agree	Disagree	Disagree	Strongly Agree
Agree	Agree	Disagree	Disagree	Disagree	Agree	Agree	Disagree	Disagree	Disagree	Disagree	Agree	Agree	Agree	Agree
Agree	Agree	Disagree	Disagree	Agree	Agree	Agree	Disagree	Disagree	Disagree	Agree	Agree	Agree	Agree	Agree
Strongly Agree	Agree	Strongly Agree	Strongly Agree	Strongly Agree	Agree	Agree	Agree	Agree	Strongly Agree	Strongly Agree	Agree	Strongly Agree	Agree	Agree
Agree	Disagree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Disagree	Agree	Agree	Disagree	Agree	Strongly Agree
Strongly Agree	Strongly Agree	Disagree	Agree	Agree	Agree	Agree	Agree	Agree	Agree	Disagree	Strongly Agree	Agree	Disagree	Agree

[AH] [The Construction Regulations include all participants in the construction process from the employer through to the final end-user.]	[AI] [The Construction Regulations convince project participants that health and safety management is a requirement that needs to be included into the planning and design of all construction projects.]	[AJ] [During the design phase, the engineer should keep the capabilities and limitations of employees in mind, such as the age and language of employees.]	[AK] [When work needs to be performed at heights, the engineer can specify that non-fragile materials are used as work platforms.]	[AL] [The engineer can enforce the contractor that all employees are assisted with fall protection equipment when work is performed at height.]	[AM] [The experience and knowledge of the engineer on construction methods should be adequate in order for the engineer to adjust the design in a constructible and safe manner whenever modification to the design is needed.]	[AN] [The engineer should obtain a construction method statement from the contractor that includes the use of plant and equipment that provide adequate loading strength.]	[AO] [The engineer can enforce safety training programs with formal instructions that include lectures, discussions, interactive computer learning and written material.]	[AP] [The engineer can also enforce practical training that includes demonstrations performed by a safety trainer.]	[AQ] [When work needs to be performed in the proximity of electrical power lines, it is solely the responsibility of the contractor to specify that non-conductive materials and equipment are used.]	[AR] [During the design phase, the engineer should be aware of the layout of the construction site, including locations of plant, equipment and power lines.]	[AS] [The engineer, in collaboration with the contractor, should undertake construction site surveys prior to the actual start of construction to identify potential hazards.]	[AT] [A thorough engineering survey should be done by the engineer and contractor before the construction or demolition of any building or building elements.]	[AU] [The engineering survey should include manners in which construction site employers and employees can communicate with emergency rescue providers if necessary.]	[AV] [The contractor should always consult the engineer before modifying any construction methods specified on the engineered drawings.]
Strongly Agree	Strongly Agree	Agree	Strongly Agree	Strongly Agree	Agree	Agree	Agree	Agree	Disagree	Agree	Strongly Agree	Strongly Agree	Agree	Agree
Strongly Agree	Agree	Disagree	Agree	Agree	Agree	Agree	Agree	Agree	Disagree	Strongly Agree	Agree	Agree	Disagree	Strongly Agree
Agree	Agree	Agree	Agree	Strongly Agree	Strongly Agree	Agree	Agree	Agree	Disagree	Strongly Agree	Agree	Agree	Agree	Agree
Strongly Agree	Strongly Agree	Disagree	Strongly Agree	Strongly Agree	Strongly Agree	Agree	Agree	Agree	Disagree	Strongly Agree	Agree	Agree	Disagree	Agree
Strongly Agree	Strongly Agree	Agree	Strongly Agree	Strongly Agree	Agree	Strongly Agree	Strongly Agree	Strongly Agree	Disagree	Strongly Agree	Strongly Agree	Strongly Agree	Agree	Agree
Strongly Agree	Strongly Agree	Agree	Strongly Agree	Agree	Agree	Agree	Agree	Agree	Disagree	Agree	Agree	Agree	Agree	Strongly Agree
Strongly Agree	Strongly Agree	Agree	Agree	Agree	Strongly Agree	Agree	Agree	Agree	Strongly Disagree	Agree	Agree	Agree	Agree	Strongly Agree

[AH] [The Construction Regulations include all participants in the construction process from the employer through to the final end-user.]	[AI] [The Construction Regulations convince project participants that health and safety management is a requirement that needs to be included into the planning and design of all construction projects.]	[AJ] [During the design phase, the engineer should keep the capabilities and limitations of employees in mind, such as the age and language of employees.]	[AK] [When work needs to be performed at heights, the engineer can specify that non-fragile materials are used as work platforms.]	[AL] [The engineer can enforce the contractor that all employees are assisted with fall protection equipment when work is performed at height.]	[AM] [The experience and knowledge of the engineer on construction methods should be adequate in order for the engineer to adjust the design in a constructible and safe manner whenever modification to the design is needed.]	[AN] [The engineer should obtain a construction method statement from the contractor that includes the use of plant and equipment that provide adequate loading strength.]	[AO] [The engineer can enforce safety training programs with formal instructions that include lectures, discussions, interactive computer learning and written material.]	[AP] [The engineer can also enforce practical training that includes demonstrations performed by a safety trainer.]	[AQ] [When work needs to be performed in the proximity of electrical power lines, it is solely the responsibility of the contractor to specify that non-conductive materials and equipment are used.]	[AR] [During the design phase, the engineer should be aware of the layout of the construction site, including locations of plant, equipment and power lines.]	[AS] [The engineer, in collaboration with the contractor, should undertake construction site surveys prior to the actual start of construction to identify potential hazards.]	[AT] [A thorough engineering survey should be done by the engineer and contractor before the construction or demolition of any building or building elements.]	[AU] [The engineering survey should include manners in which construction site employers and employees can communicate with emergency rescue providers if necessary.]	[AV] [The contractor should always consult the engineer before modifying any construction methods specified on the engineered drawings.]
Agree	Agree	Agree	Agree	Strongly Agree	Strongly Agree	Agree	Strongly Agree	Agree	Disagree	Agree	Strongly Agree	Agree	Agree	Strongly Agree
Agree	Strongly Agree	Agree	Strongly Agree	Strongly Agree	Agree	Agree	Agree	Agree	Disagree	Agree	Agree	Agree	Agree	Strongly Agree
Strongly Agree	Strongly Agree	Agree	Agree	Agree	Strongly Agree	Agree	Strongly Agree	Strongly Agree	Disagree	Strongly Agree	Agree	Agree	Agree	Strongly Agree

[AW] [The engineer should involve the contractor during the design stage to ensure a smooth transition from the design phase to construction with regard to safety of employees.]	[AX] [The designer should specify that the best and most effective equipment are used to ensure quality and safety, even if this equipment will cost more.]	[AY] [For a safer construction process, engineers should design a building with the focus on using more prefabricated construction.]	[AZ] Information exchanged between engineer and contractor: [The engineer should share the health and safety specifications for the construction work with the contractor.]	[BA] [The engineer should share information which might affect the health and safety of any employee carrying out construction work.]	[BB] [The engineer should also undertake periodic audits and share the results of the audits.]	[BC] [The engineer should stop the contractor from executing any construction work which is not in accordance to the health and safety plan of the contractor.]	[BD] [Sufficient health and safety information needs to be shared with the contractor to ensure that the work is executed safely where changes are brought about.]	[BE] Briefly discuss, in your opinion, what type of information, with regard to safety, needs to be shared with the contractor by the engineer	[BF] 4. Safe design process
Agree	Agree	Disagree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree		N/C
Disagree	Disagree	Disagree	Disagree	Disagree	Disagree	Strongly Agree	Agree	Much of the problem lies in the fact that the design is completed before the contractor is appointed and there is thus no continuity of people and relationships.	Very little direct attention to safe design takes place, it is only considered in constructability from the design engineer side, and clients are usually not concerned with these aspects its the contractor's problem.
Agree	Strongly Agree	Strongly Disagree	Disagree	Disagree	Strongly Agree	Strongly Agree	Agree	The OHS and other applicable safety manuals.	Include safety procedures and clauses in the project documentation. Enforce penalties if unsafe practises are performed by the contractor.
Disagree	Disagree	Disagree	Strongly Agree	Strongly Agree	Agree	Strongly Agree	Agree		Identify possible safety issues. design in order to prevent these issues if the issues are not preventable, specify methods or specifications to be used by the contractor to ensure safety and effectiveness.
Strongly Agree	Strongly Agree	Disagree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Any non-typical construction methodologies that may be required.	Early identification of any non-standard construction techniques, sequencing, etc that may be necessary. "Brain-storming" to evaluate possible alternatives. Design reviews to include constructability/buildability evaluations.
Agree	Agree	Agree	Agree	Agree	Disagree	Strongly Agree	Strongly Agree		DISCUSS THE PROJECT FULLY WITH THE DESIGN TEAM AT DESIGN STAGE, AND WITH THE CONTRACTOR PRIOR TO COMMENCING ON SITE
Strongly Disagree	Strongly Disagree	Strongly Disagree	Disagree	Agree	Strongly Disagree	Strongly Disagree	Agree	design loads backpropping requirements special construction sequences required stripping times for various elements	all information to be shared to be annotated on drawings. discuss around a table w.r.t. complex construction sequences
Disagree	Strongly Agree	Disagree	Agree	Agree	Disagree	Agree	Agree	The Health and safety consultant should ensure that all necessary information is shared with the contractor.	xyz
Agree	Agree	Disagree	Agree	Agree	Disagree	Agree	Agree		safety consultant should do this
Disagree	Disagree	Disagree	Disagree	Agree	Disagree	Agree	Agree		0
Disagree	Disagree	Disagree	Strongly Agree	Agree	Agree	Strongly Agree	Strongly Agree	Known hazards on site and how to handle them	Possible hazards need to be identified. Design safety standards need to be followed.
Disagree	Disagree	Disagree	Strongly Agree	Strongly Agree	Agree	Agree	Agree		Constant awareness
Agree	Agree	Agree	Strongly Agree	Strongly Agree	Strongly Agree	Agree	Strongly Agree	Safety hazards Safe construction methods Alternative construction methods	Concept design Detailed engineering Identify hazards Procurement

[AW] [The engineer should involve the contractor during the design stage to ensure a smooth transition from the design phase to construction with regard to safety of employees.]	[AX] [The designer should specify that the best and most effective equipment are used to ensure quality and safety, even if this equipment will cost more.]	[AY] [For a safer construction process, engineers should design a building with the focus on using more prefabricated construction.]	[AZ] Information exchanged between engineer and contractor: [The engineer should share the health and safety specifications for the construction work with the contractor.]	[BA] [The engineer should share information which might affect the health and safety of any employee carrying out construction work.]	[BB] [The engineer should also undertake periodic audits and share the results of the audits.]	[BC] [The engineer should stop the contractor from executing any construction work which is not in accordance to the health and safety plan of the contractor.]	[BD] [Sufficient health and safety information needs to be shared with the contractor to ensure that the work is executed safely where changes are brought about.]	[BE] Briefly discuss, in your opinion, what type of information, with regard to safety, needs to be shared with the contractor by the engineer	[BF] 4. Safe design process
Agree	Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Safety risks Safe and efficient construction methods	Concept design Identify project team Identify design hazards Revisit concept design Eliminate hazards Detailed design
Agree	Agree	Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Safety risks Safe design specifications Adequate and safe design drawings Mitigation techniques	Discuss the project Identify design team and contractor Integration between contractor and engineer Identify possible hazards Design safe and constructible Review design Start construction
Strongly Agree	Agree	Strongly Agree	Agree	Agree	Strongly Agree	Agree	Strongly Agree	Advice on safe construction processes	Identify the need for the project Appoint designers and engineers Discuss possible hazards in a risk register Appoint contractor Communicate risks and construction processes with contractor Review design
Agree	Agree	Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Depends on procurement procedure Contractor is not always part of the design phase All safety hazards that were identified during the design phase	Concept Appoint engineer Hazard identification Report on hazards Design Review design Communicate safe design with contractors Request safe construction method statement from contractors Start construction
Agree	Agree	Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Information regarding possible hazards and processes to prevent them	Engineer and contractor identifying hazards Design according to safety standards Communicate hazards with all employees Mitigate hazards and redesign Review new design
Agree	Agree	Agree	Strongly Agree	Strongly Agree	Agree	Strongly Agree	Strongly Agree	Safety hazards Ways to minimize and eliminate hazards	Don't know
Agree	Agree	Disagree	Agree	Agree	Strongly Agree	Strongly Agree	Agree	All information that will make the project safer. Possible hazards, Advice on safe construction methods, Mitigation techniques for hazards	Identify hazards early in the design stage Share hazards with contractor and sub-contractors Adjust design after hazard identification



[AW] [The engineer should involve the contractor during the design stage to ensure a smooth transition from the design phase to construction with regard to safety of employees.]	[AX] [The designer should specify that the best and most effective equipment are used to ensure quality and safety, even if this equipment will cost more.]	[AY] [For a safer construction process, engineers should design a building with the focus on using more prefabricated construction.]	[AZ] Information exchanged between engineer and contractor: [The engineer should share the health and safety specifications for the construction work with the contractor.]	[BA] [The engineer should share information which might affect the health and safety of any employee carrying out construction work.]	[BB] [The engineer should also undertake periodic audits and share the results of the audits.]	[BC] [The engineer should stop the contractor from executing any construction work which is not in accordance to the health and safety plan of the contractor.]	[BD] [Sufficient health and safety information needs to be shared with the contractor to ensure that the work is executed safely where changes are brought about.]	[BE] Briefly discuss, in your opinion, what type of information, with regard to safety, needs to be shared with the contractor by the engineer	[BF] 4. Safe design process
Agree	Agree	Disagree	Strongly Agree	Strongly Agree	Agree	Strongly Agree	Strongly Agree		Know what have to be done in the construction phase and identify all the hazards. For each hazard, consider the different techniques that can be used to reduce the chance of a accident. Discuss the techniques with the contractor and ensure that all the employees are aware of the hazards.
Agree	Agree	Agree	Strongly Agree	Agree	Agree	Strongly Agree	Strongly Agree	Safety issues Safe construction methods	Don't know
Agree	Agree	Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	Strongly Agree	All the information above + Information that would result in safer construction practices. (Hazard identification, safety equipment should be used at all times)	Appoint consultant, Discuss general specifications of building with client, Appoint main contractor, Identify risks, Mitigate risks, Design

## **APPENDIX E: RESULTS TO PART 3 OF QUESTIONNAIRE**

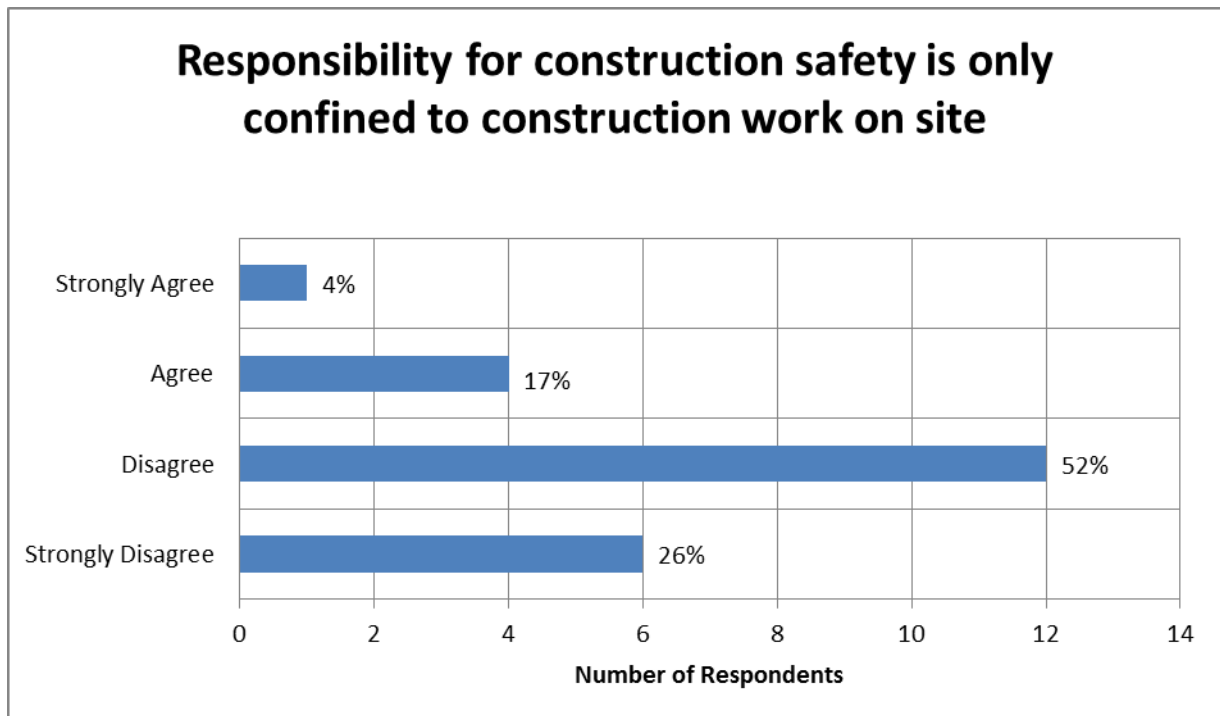


Figure E1: A graph that shows the opinion of the respondents with regard to the following lesson: Responsibility for construction safety is only confined to construction work on site

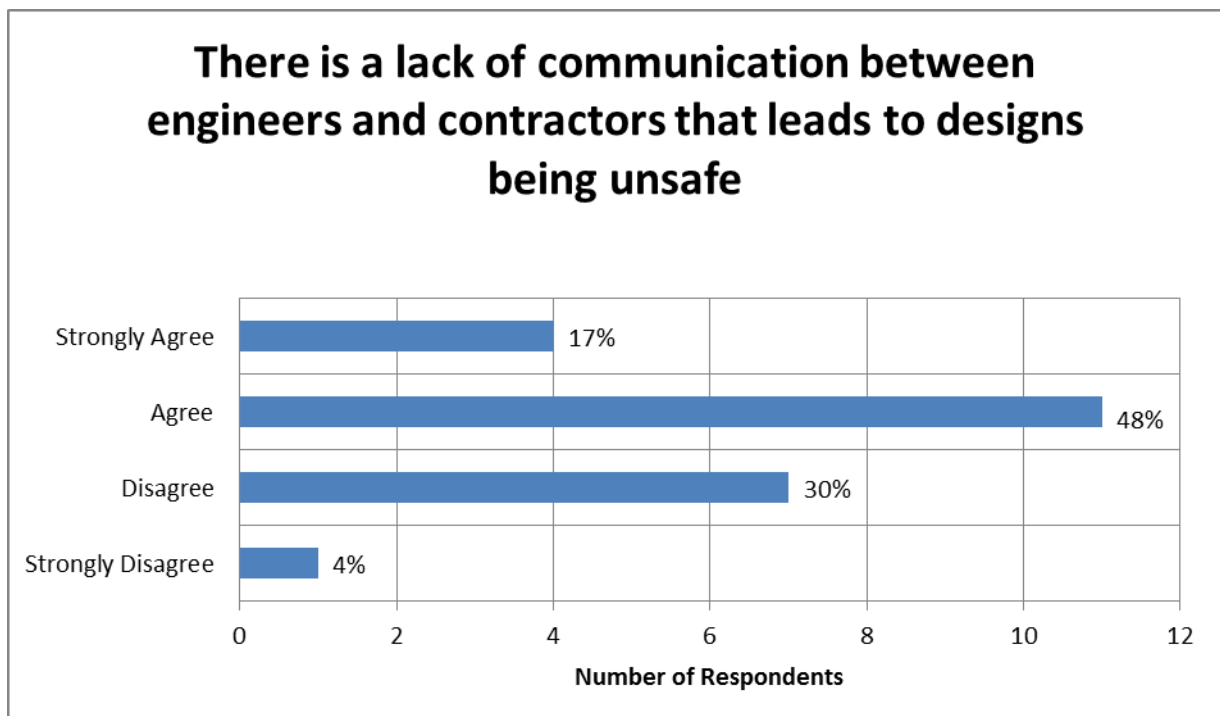


Figure E2: A graph that shows the opinion of the respondents with regard to the following lesson: There is a lack of communication between engineers and contractors that lead to designs being unsafe

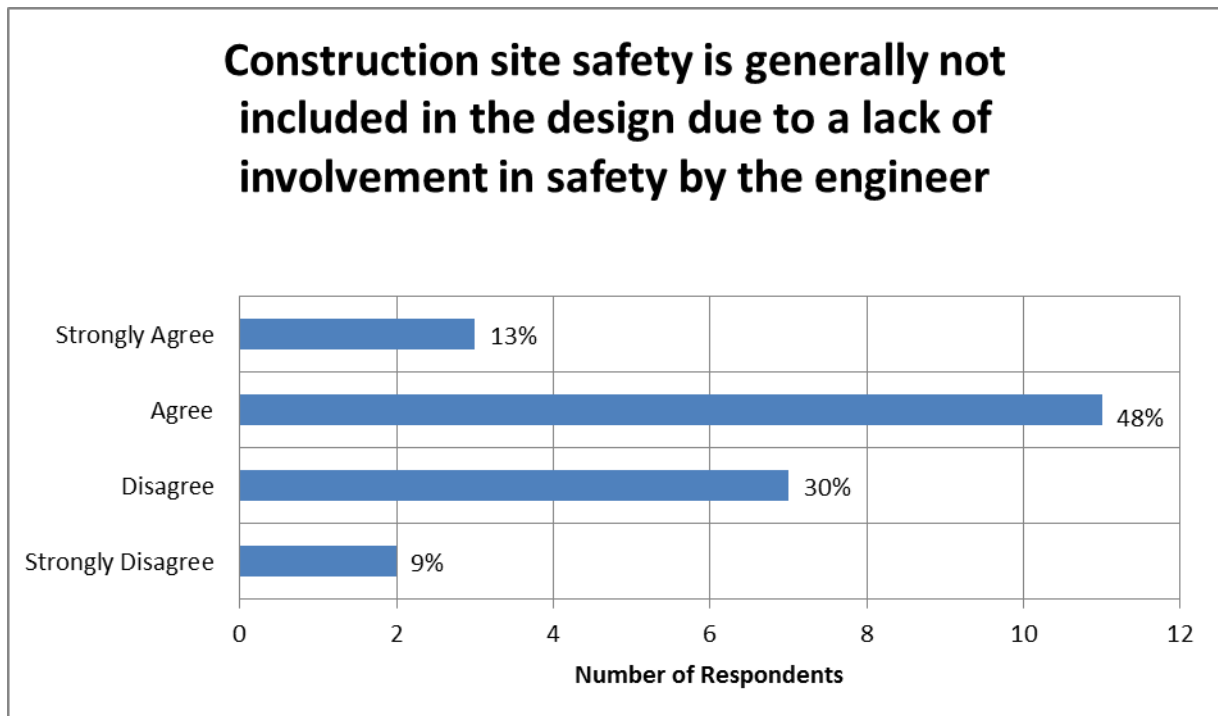


Figure E3: A graph that shows the opinion of the respondents with regard to the following lesson: Construction site safety is generally not included in the design due to a lack of involvement in safety by the engineer

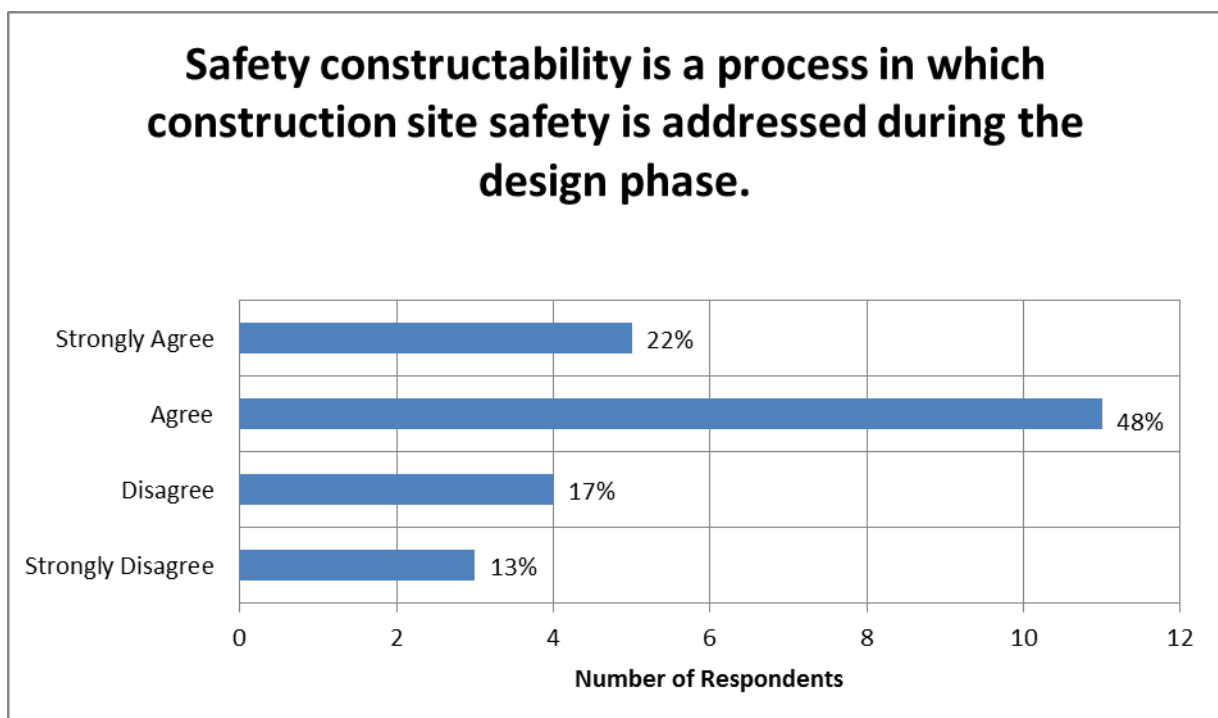


Figure E4: A graph that shows the opinion of the respondents with regard to the following lesson: Safety constructability is a process in which construction site safety is addressed during the design phase

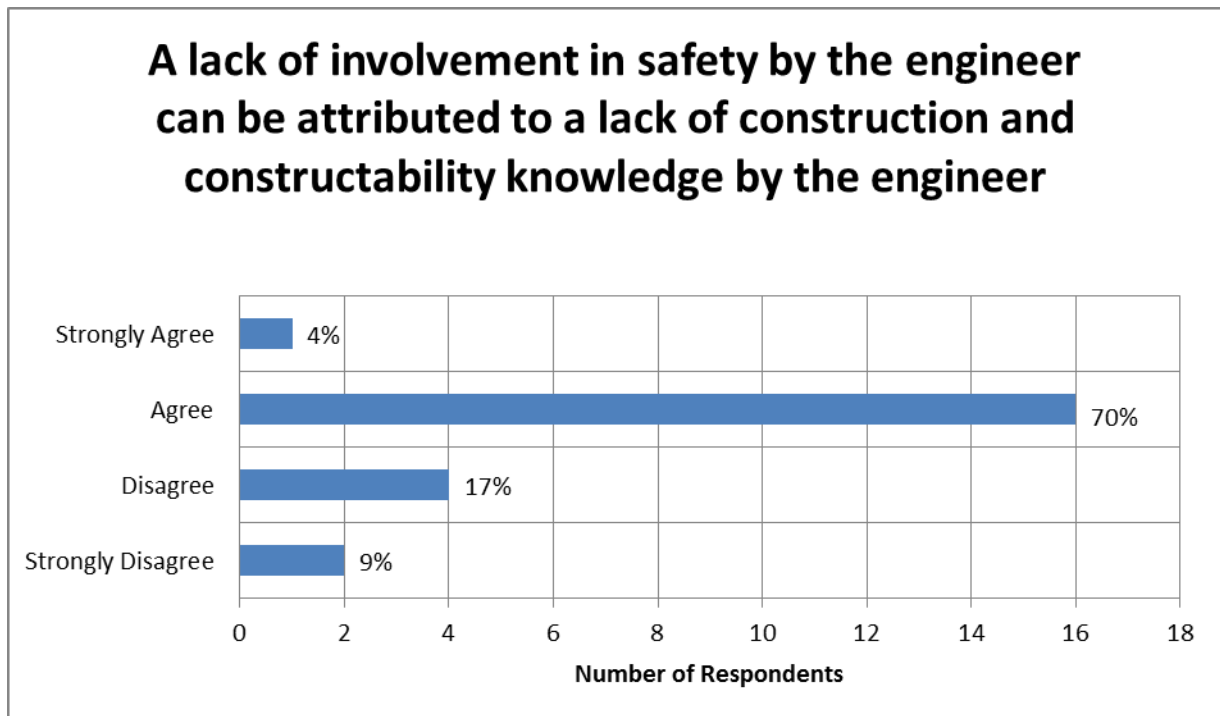


Figure E5: A graph that shows the opinion of the respondents with regard to the following lesson: A lack of involvement in safety by the engineer can be attributed to a lack of construction and constructability knowledge by the engineer

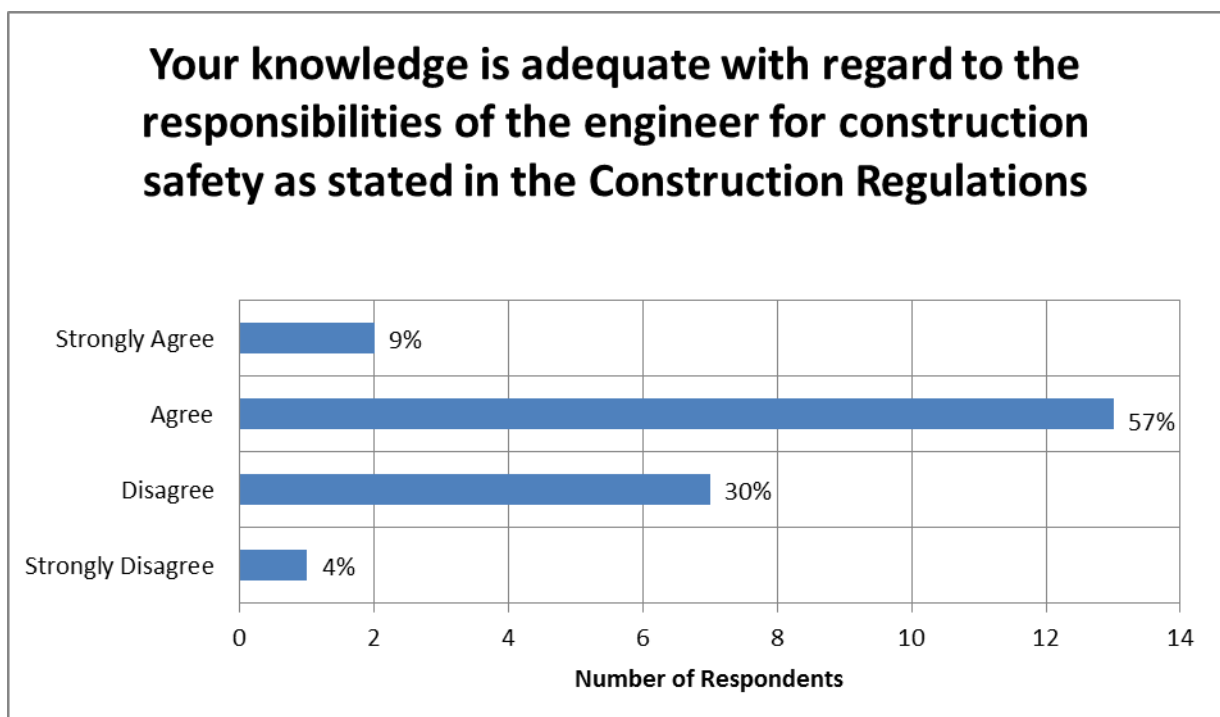


Figure E6: A graph that shows the opinion of the respondents with regard to the following statement: Your knowledge is adequate with regard to the responsibilities of the engineer for construction safety as stated in the Construction Regulations

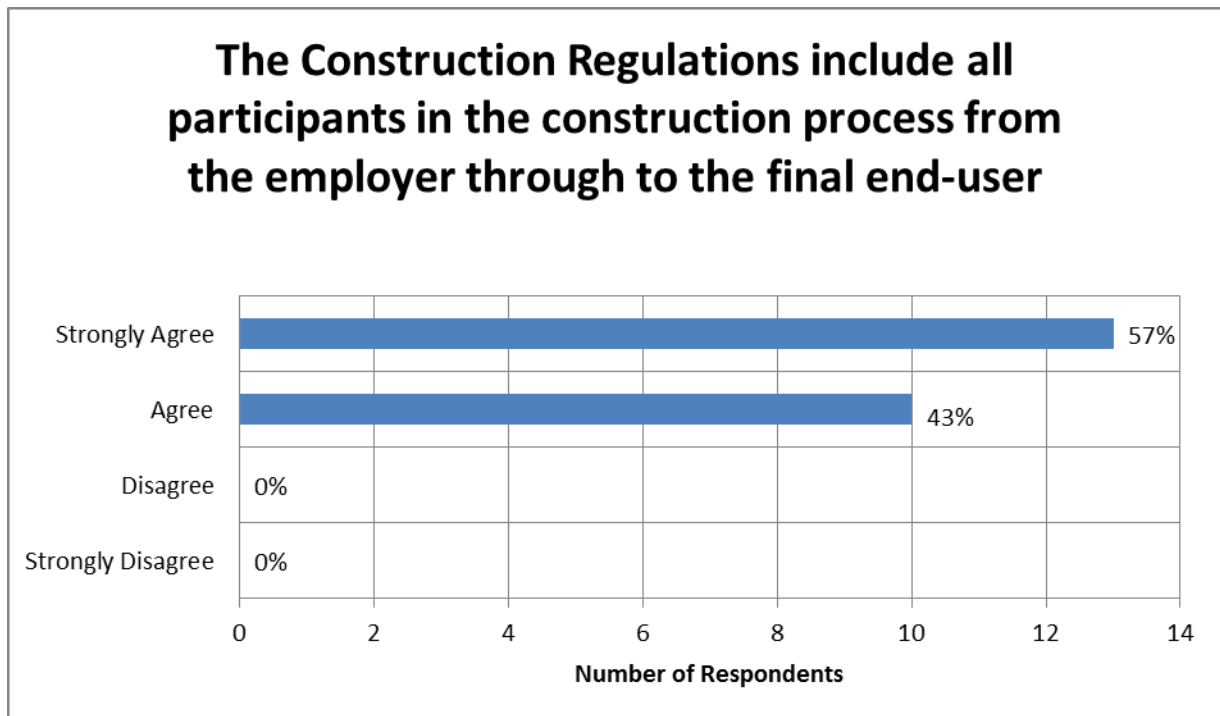


Figure E7: A graph that shows the opinion of the respondents with regard to the following statement: The Construction Regulations include all participants in the construction process from the employer through to the final end-user

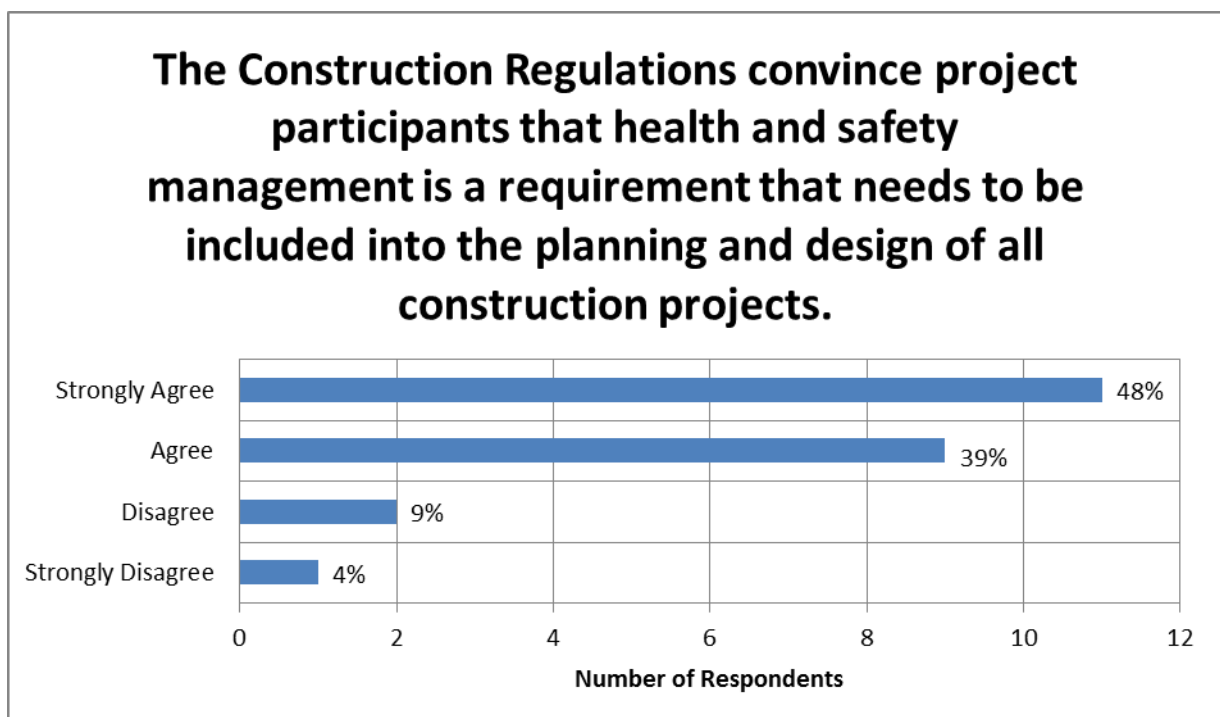


Figure E8: A graph that shows the opinion of the respondents with regard to the following statement: The Construction Regulations convince project participants that health and safety management is a requirement that needs to be included into the early stages

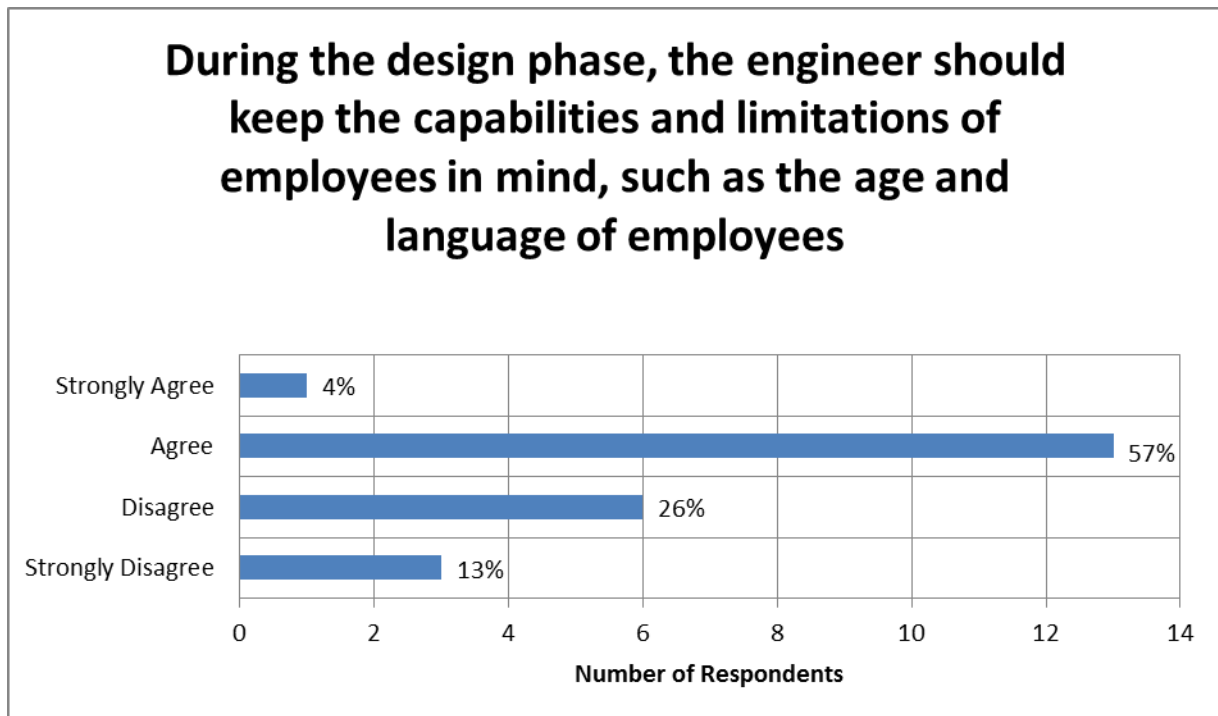


Figure E9: A graph that shows the opinion of the respondents with regard to the following lesson: During the design phase, the engineer should keep the capabilities and limitations of employees in mind, such as the age and language of employees

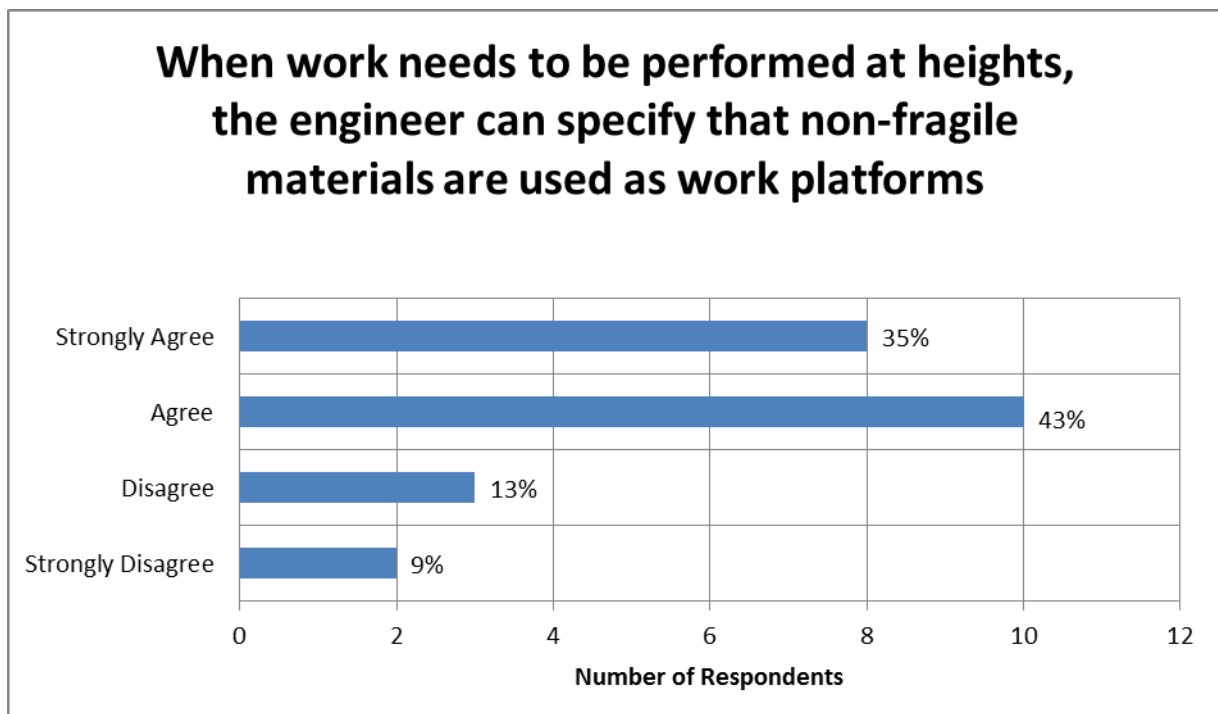


Figure E10: A graph that shows the opinion of the respondents with regard to the following lesson: When work needs to be performed at heights, the engineer can specify that non-fragile materials are used as work platforms

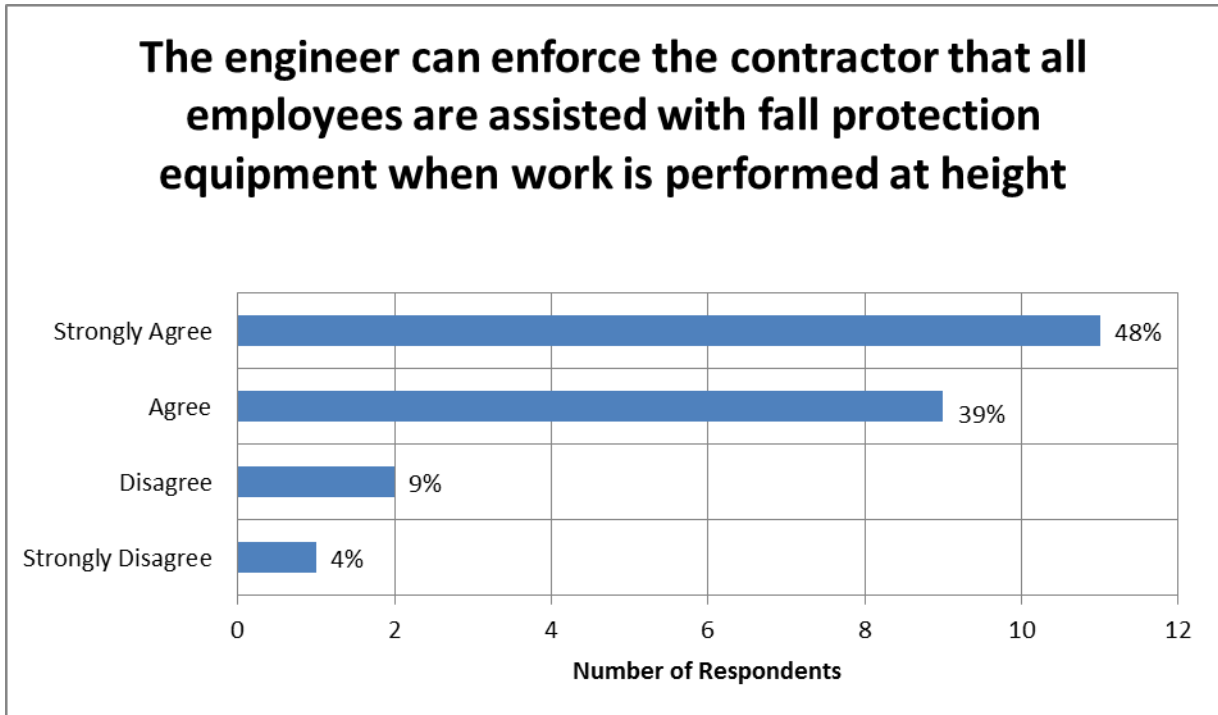


Figure E11: A graph that shows the opinion of the respondents with regard to the following lesson: The engineer can enforce the contractor that all employees are assisted with fall protection equipment when work is performed at height

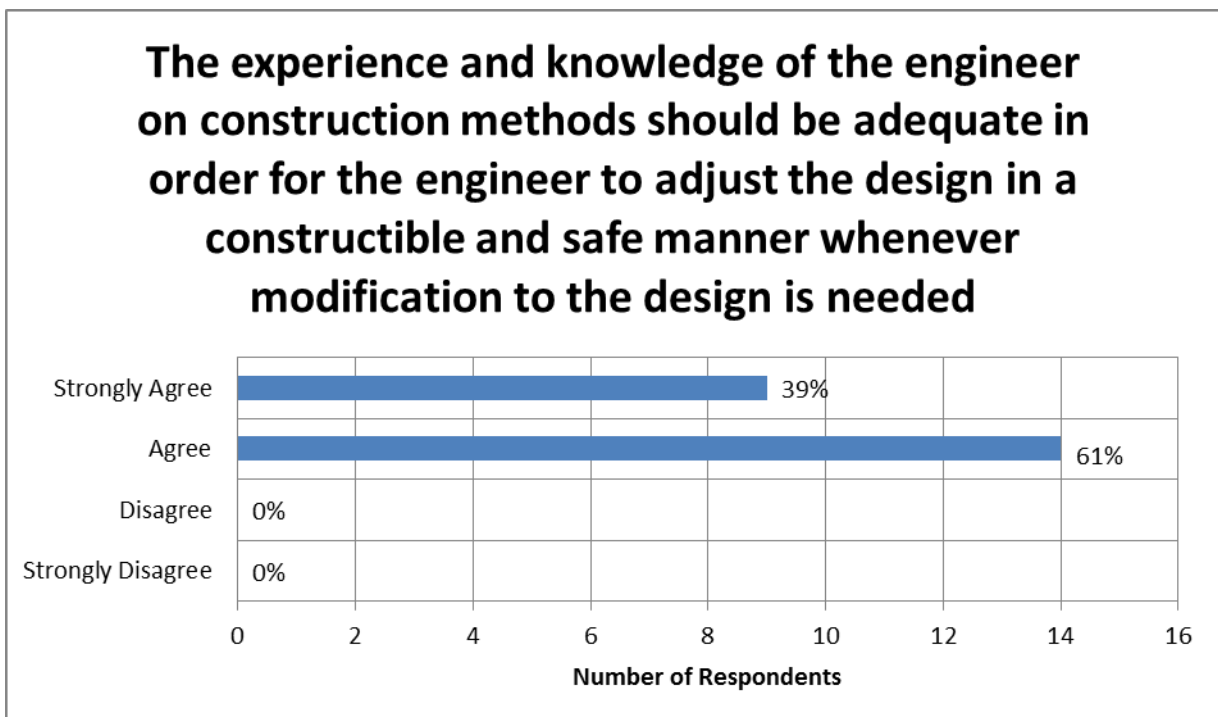


Figure E12: A graph that shows the opinion of the respondents with regard to the following lesson: The experience and knowledge of the engineer on construction methods should be adequate in order for the engineer to adjust the design constructible and safe



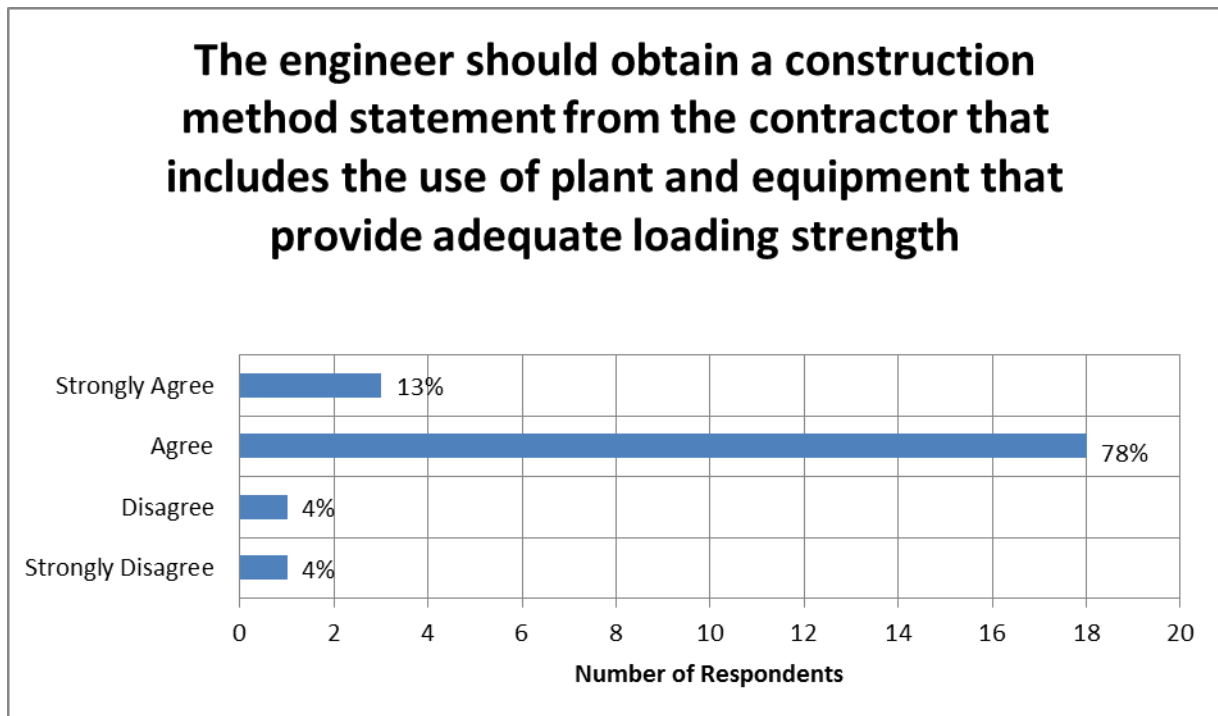


Figure E13: A graph that shows the opinion of the respondents with regard to the following lesson: The engineer should obtain a construction method statement from the contractor that includes the use of plant and equipment that provide adequate loading strength

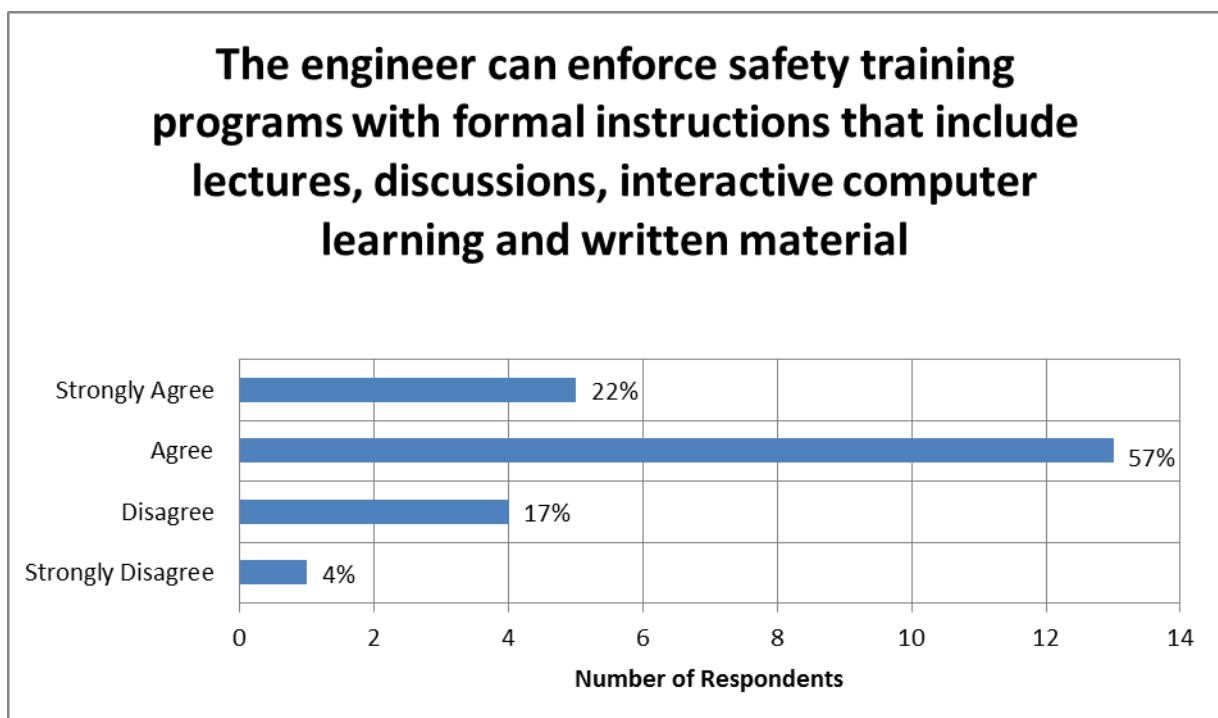


Figure E14: A graph that shows the opinion of the respondents with regard to the following lesson: The engineer can enforce safety training programs with formal instructions that include lectures, discussions, interactive computer learning and written material

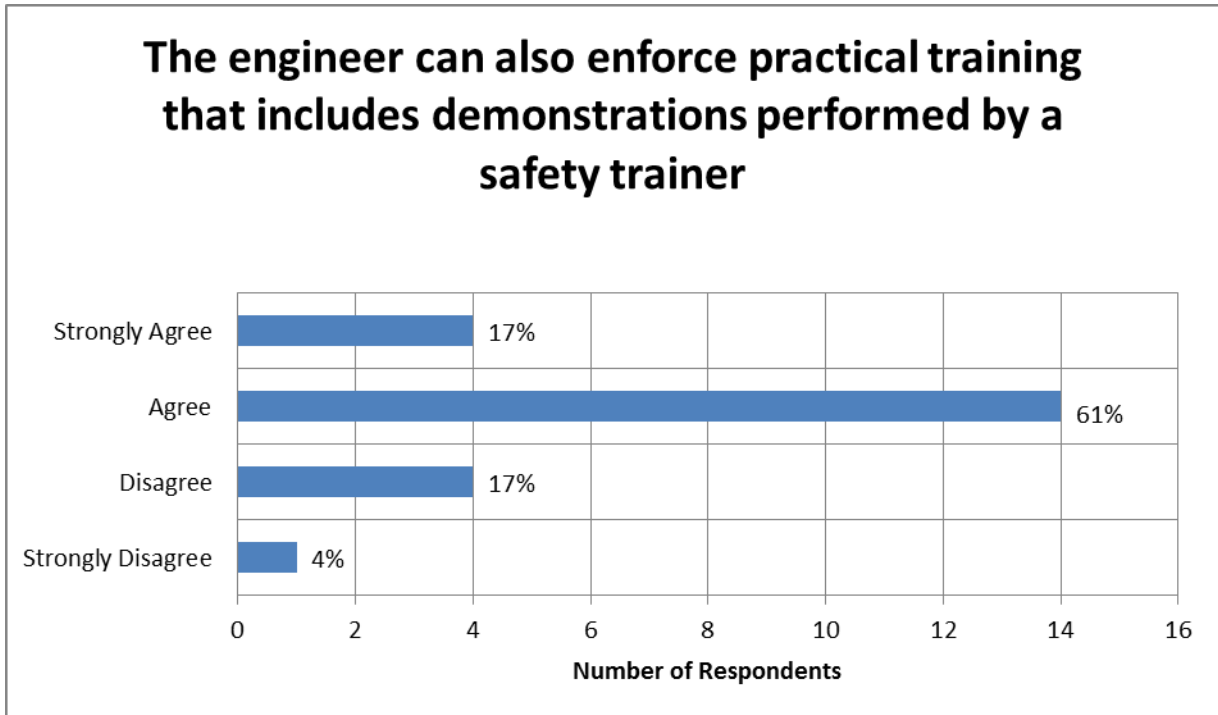


Figure E15: A graph that shows the opinion of the respondents with regard to the following lesson: The engineer can also enforce practical training that includes demonstrations performed by a safety trainer

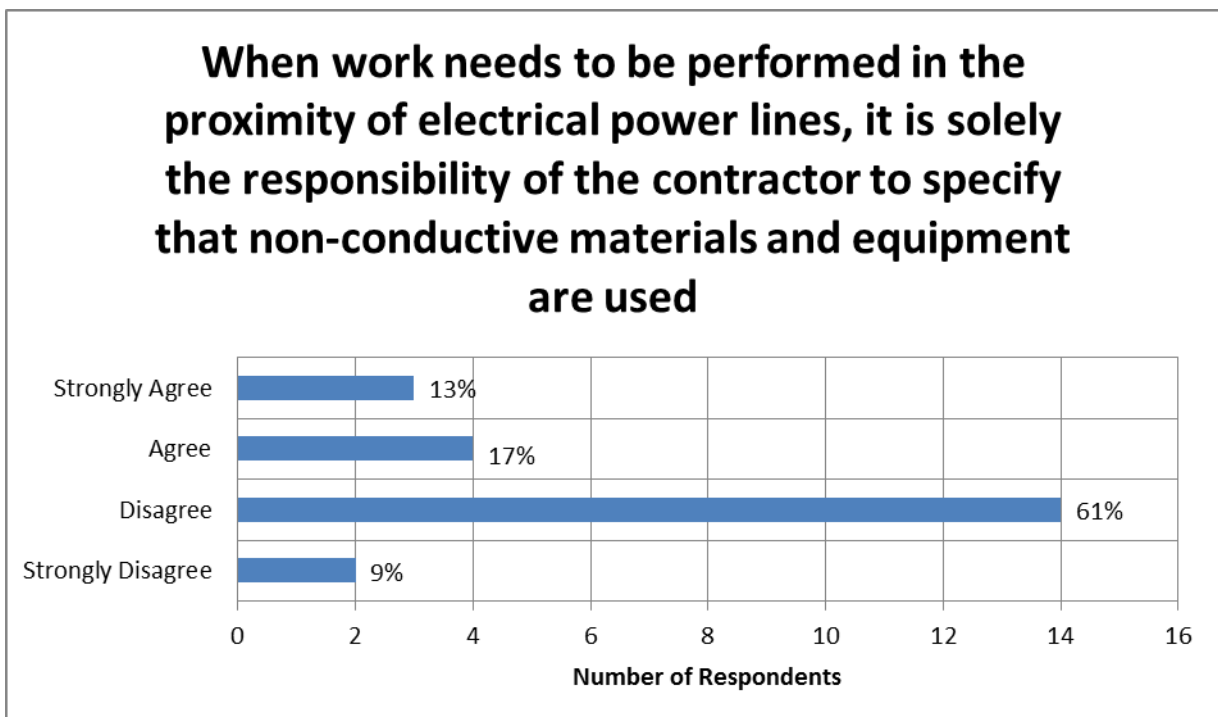


Figure E16: A graph that shows the opinion of the respondents with regard to the following lesson: It is solely the responsibility of the contractor to specify that non-conductive materials and equipment are used near power lines

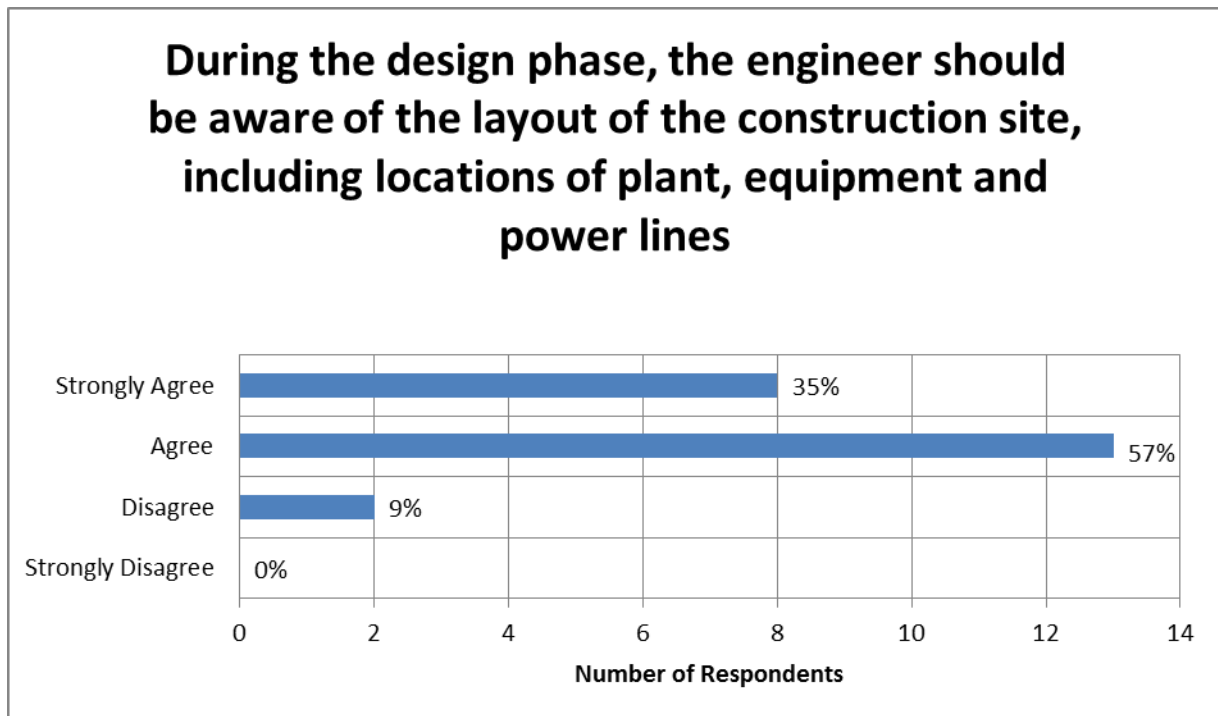


Figure E17: A graph that shows the opinion of the respondents with regard to the following lesson: During the design phase, the engineer should be aware of the layout of the construction site, including locations of plant, equipment, and power lines

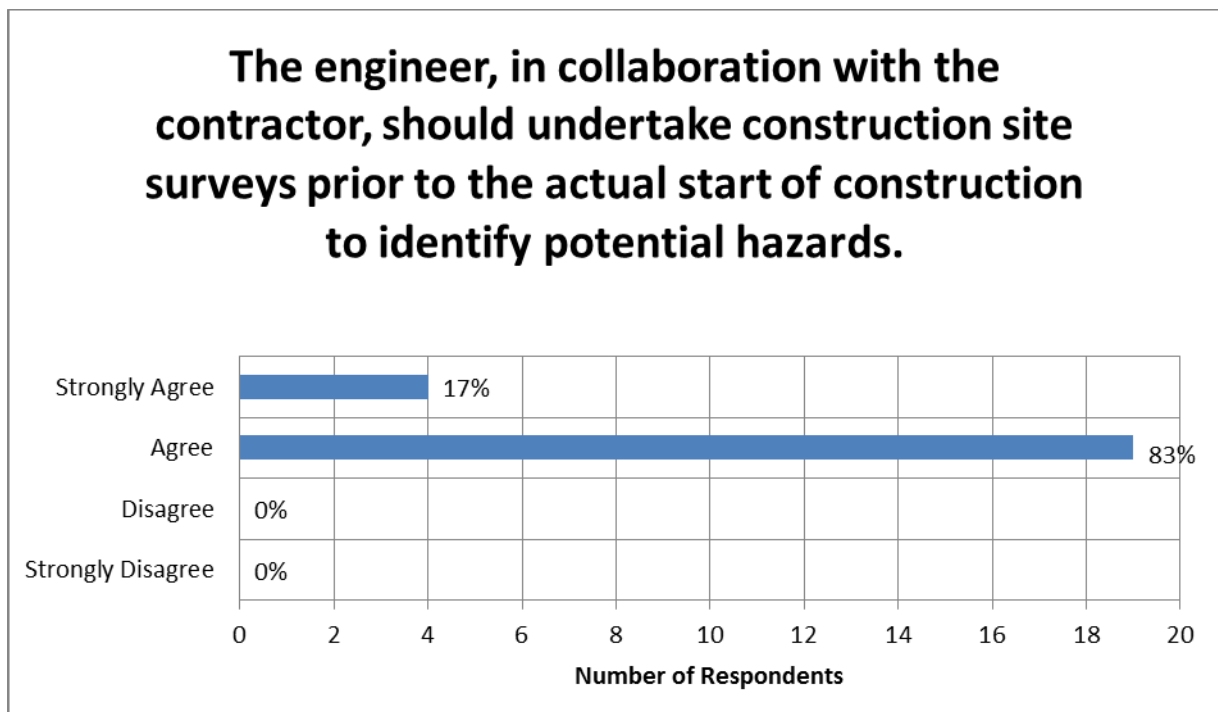


Figure E18: A graph that shows the opinion of the respondents with regard to the following lesson: The engineer, in collaboration with the contractor, should undertake construction site surveys prior to the actual start of construction to identify potential hazards

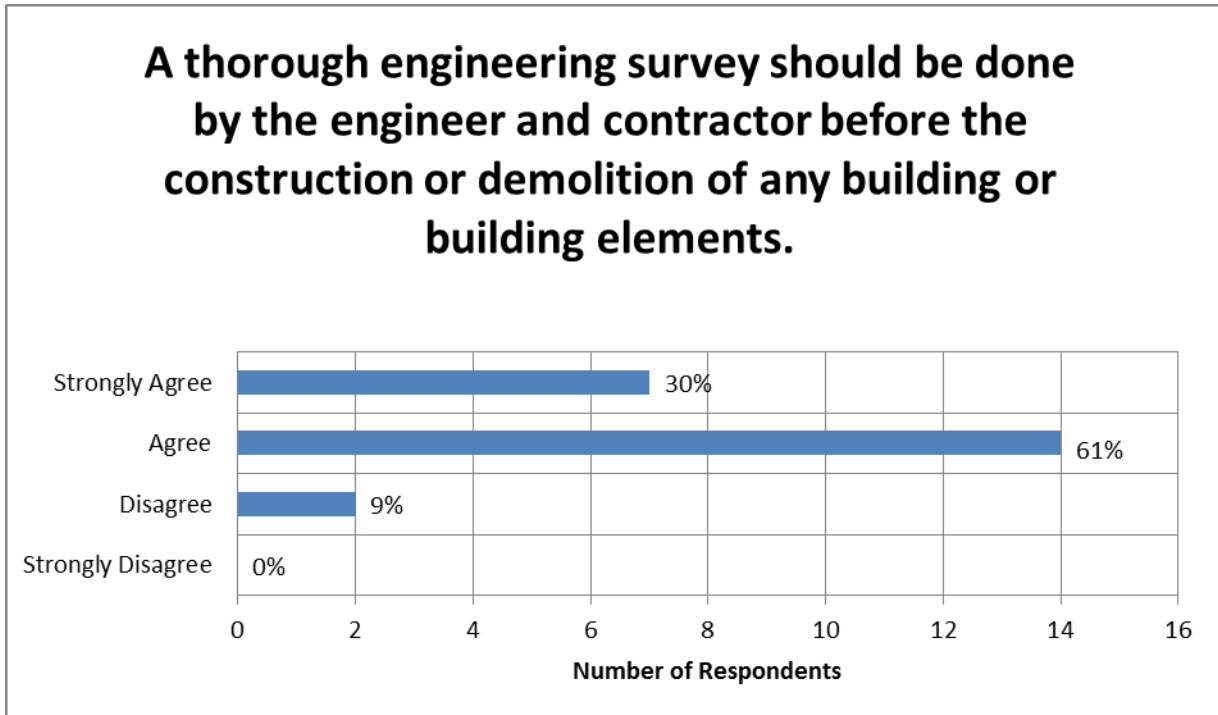


Figure E19: A graph that shows the opinion of the respondents with regard to the following lesson: A thorough engineering survey should be done by the engineer and contractor before the construction or demolition of any building or building elements

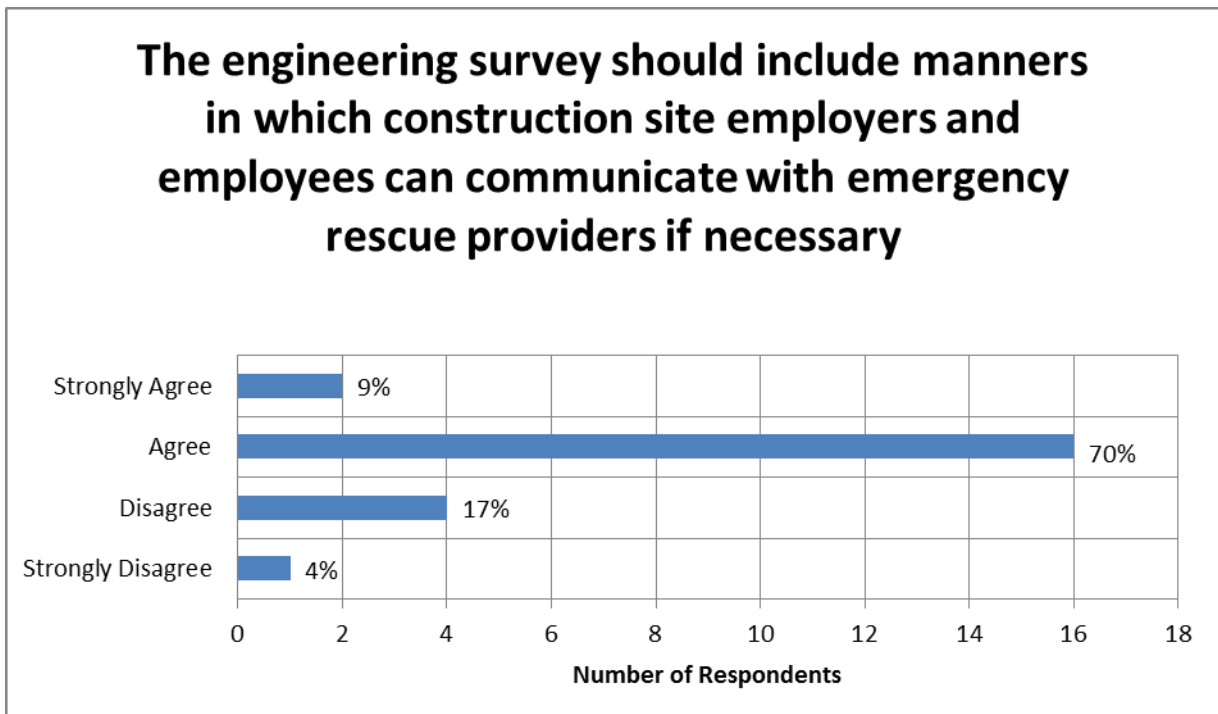


Figure E20: A graph that shows the opinion of the respondents with regard to the following lesson: The engineering survey should include manners in which construction site employers and employees can communicate with emergency rescue providers if necessary

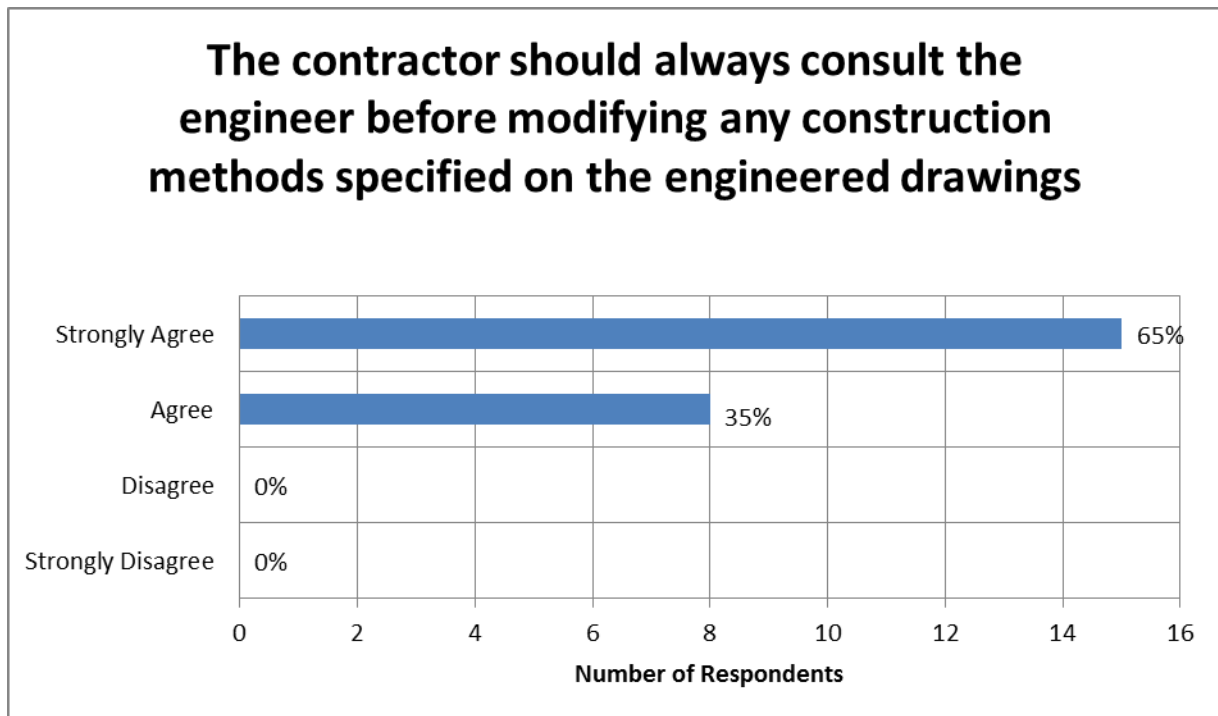


Figure E21: A graph that shows the opinion of the respondents with regard to the following lesson: The contractor should always consult the engineer before modifying any construction methods specified on the engineered drawings

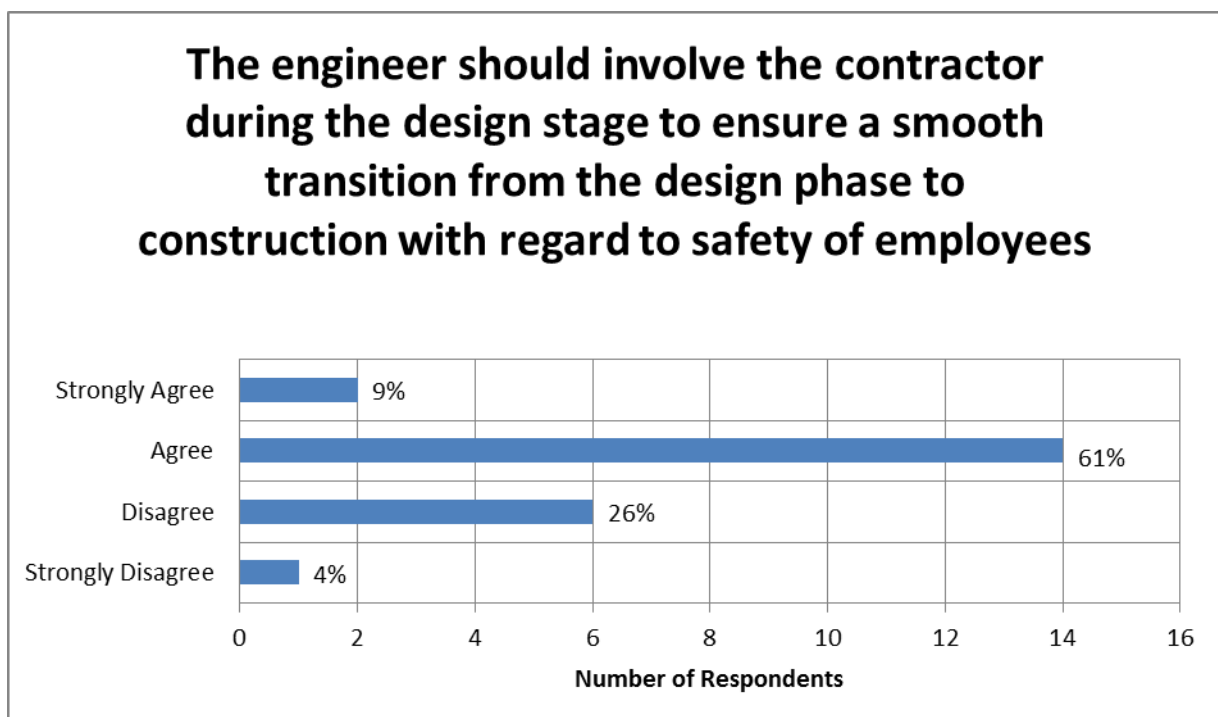


Figure E22: A graph that shows the opinion of the respondents with regard to the following lesson: The engineer should involve the contractor during the design stage to ensure a smooth transition from the design phase to construction with regard to site safety

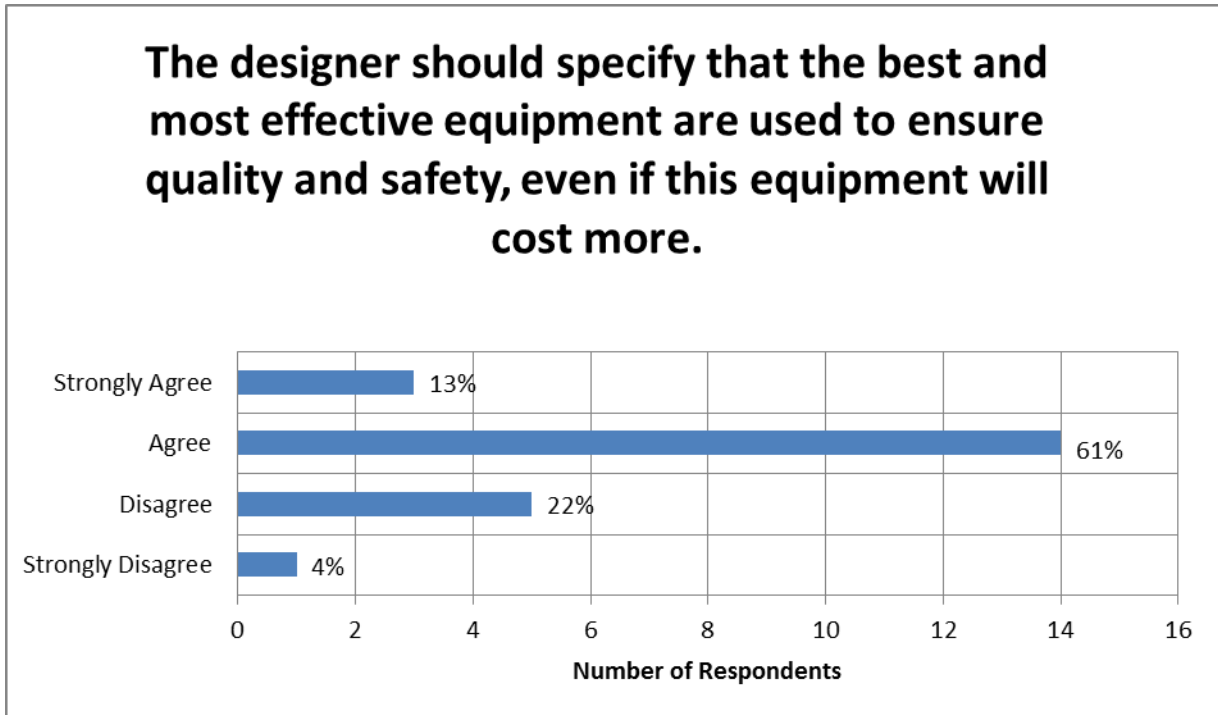


Figure E23: A graph that shows the opinion of the respondents with regard to the following lesson: The designer should specify that the best and most effective equipment are used to ensure quality and safety, even if this equipment will cost more

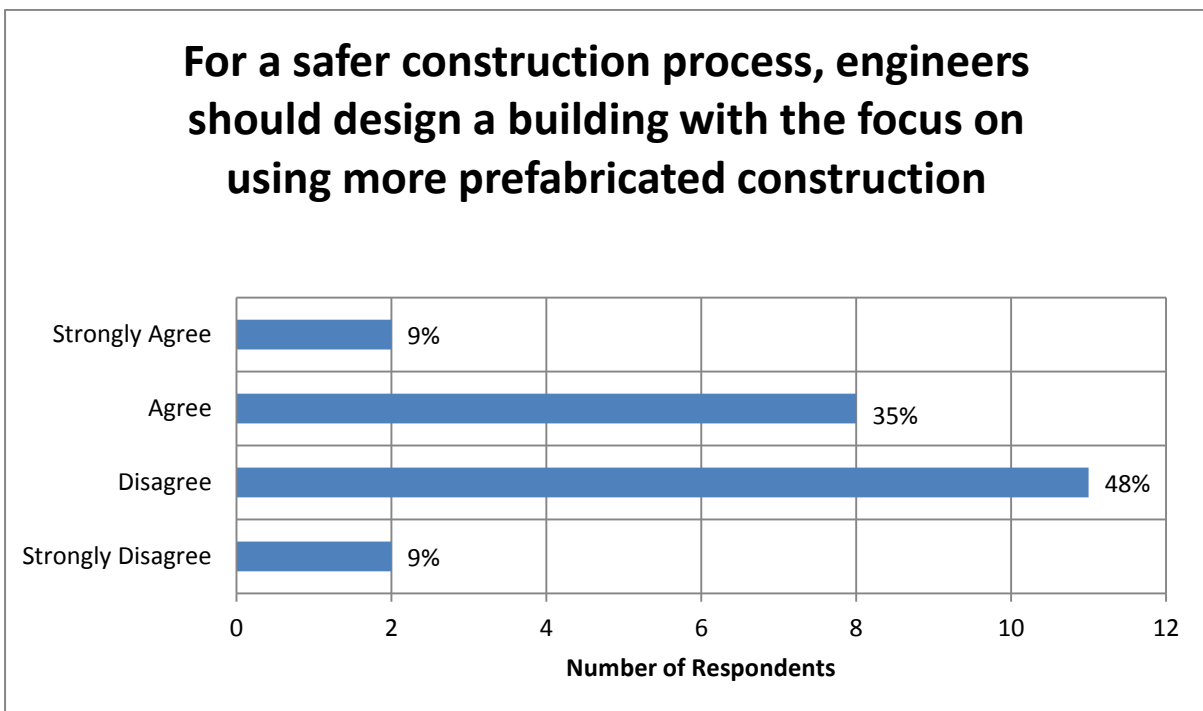


Figure E24: A graph that shows the opinion of the respondents with regard to the following lesson: For a safer construction process, engineers should design a building with the focus on using more prefabricated construction

## **APPENDIX F: RESULTS TO PART 4 OF QUESTIONNAIRE**

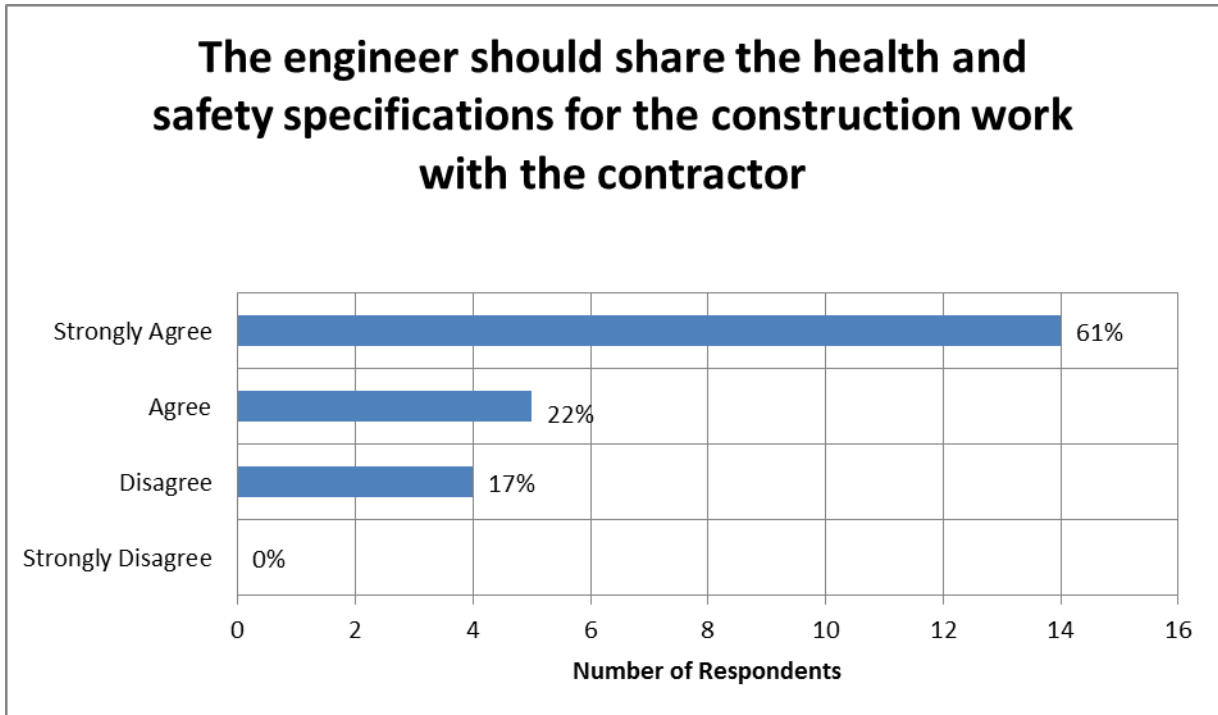


Figure F1: A graph that shows the opinion of the respondents with regard to the following statement: The engineer should share the health and safety specifications for the construction work with the contractor

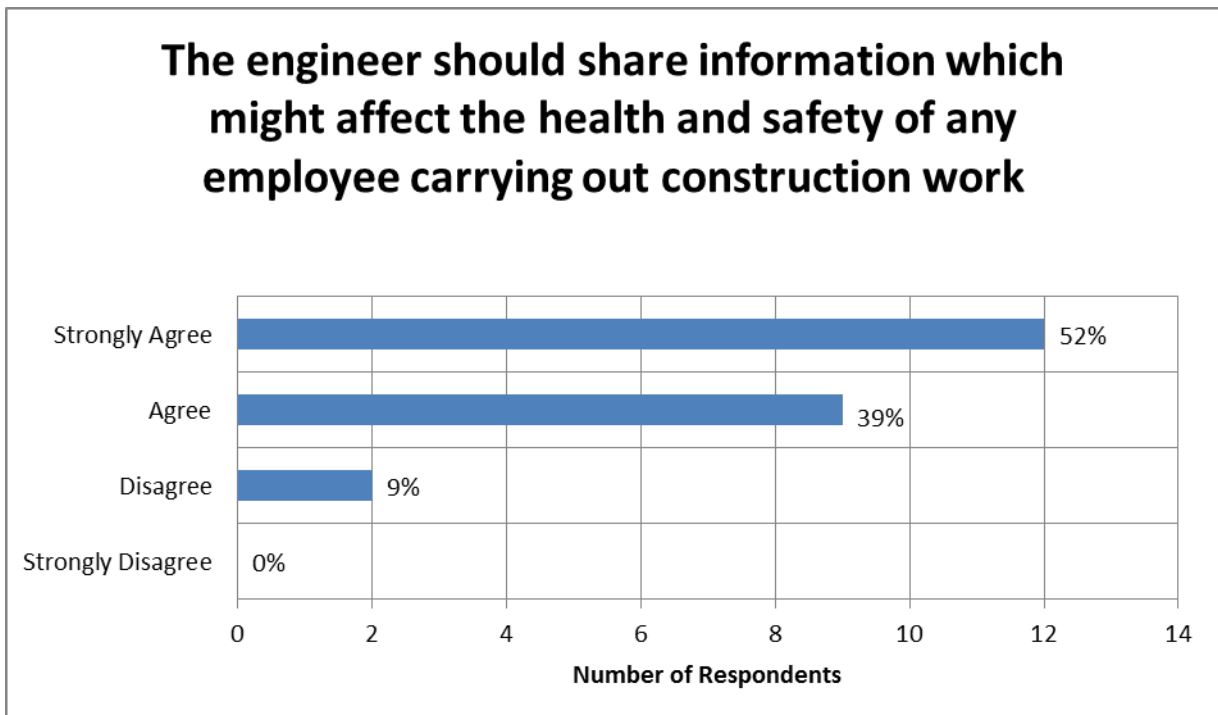


Figure F2: A graph that shows the opinion of the respondents with regard to the following statement: The engineer should share information which might affect the health and safety of any employee carrying out construction work



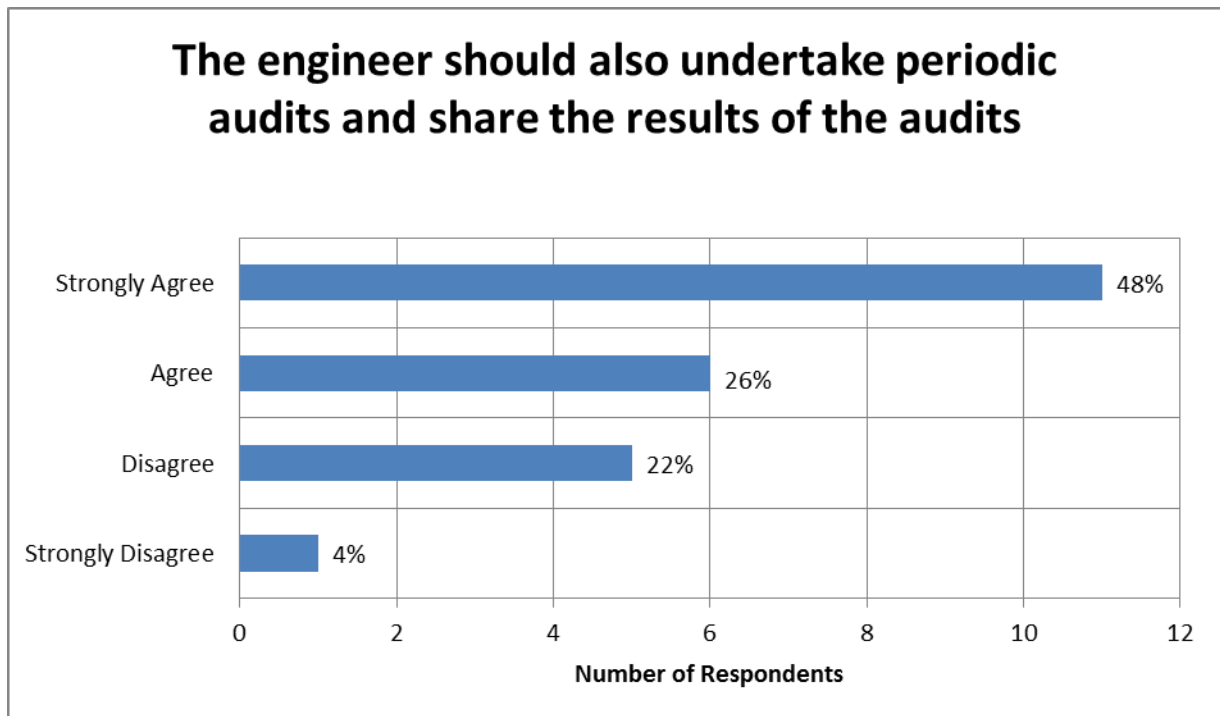


Figure F3: A graph that shows the opinion of the respondents with regard to the following statement: The engineer should also undertake periodic audits and share the results of the audits

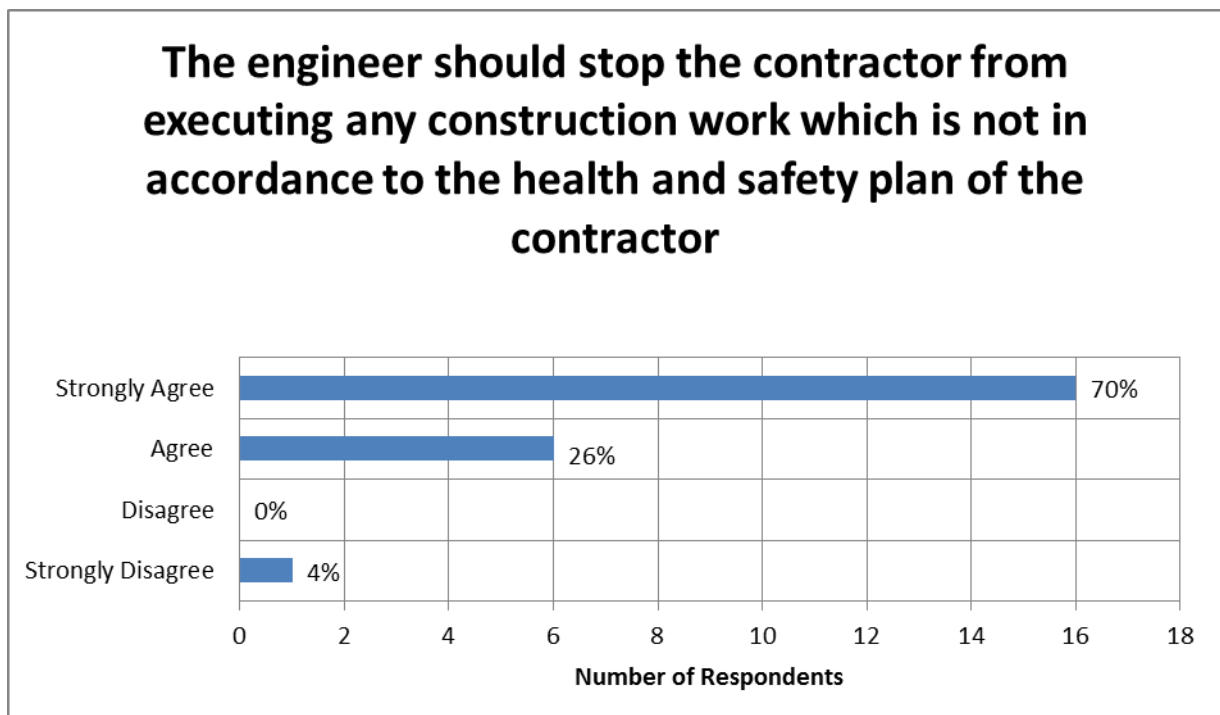


Figure F4: A graph that shows the opinion of the respondents with regard to the following statement: The engineer should stop the contractor from executing any construction work which is not in accordance to the health and safety plan of the contractor

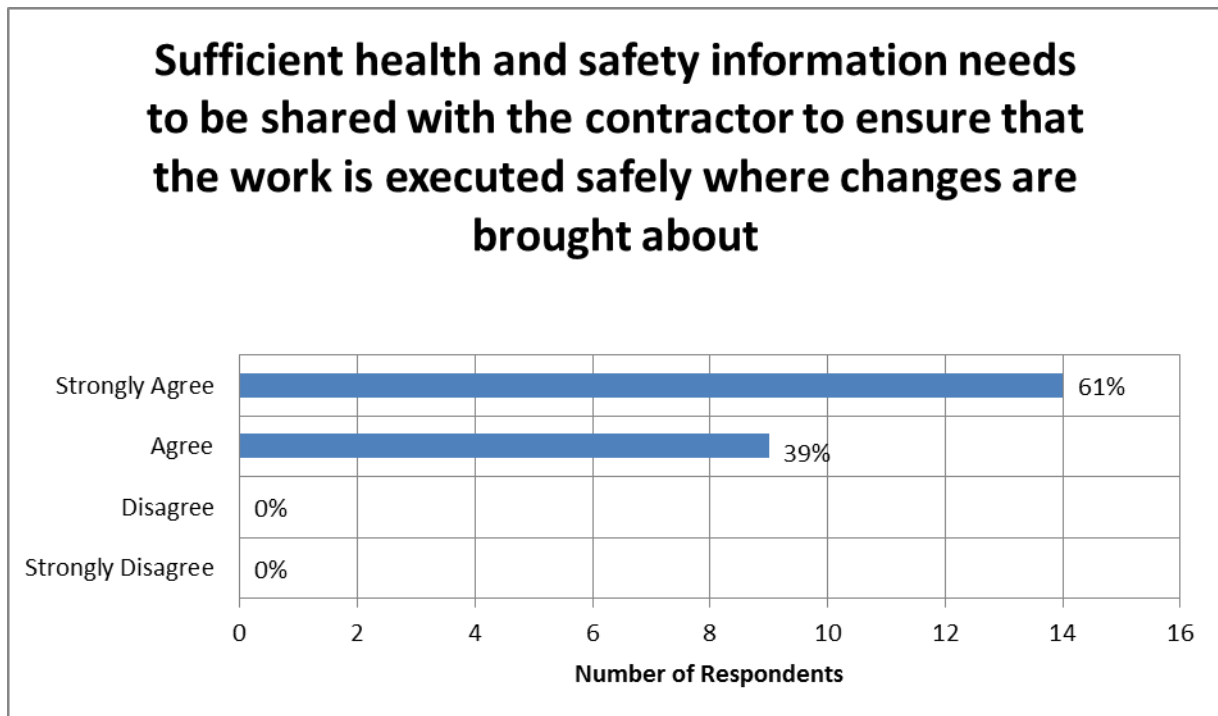


Figure F5: A graph that shows the opinion of the respondents with regard to the following statement: Sufficient health and safety information needs to be shared with the contractor to ensure that the work is executed safely where changes are brought about