

Risk Assessment of Design Components of Building Construction

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Abstract. Lack of designer's knowledge of construction safety risks and HSE personnel's knowledge of structural designs and means and methods of construction have been highlighted as significant barriers to the implementation of design for construction safety. These barriers often result in poor collaboration among designers and HSE personnel in addressing safety issues that lead to accidents and frequent work stoppages. This study explored the ability of HSE officers, engineers and superintendents to recognize and assess risk associated with constructing structural components of a building (foundation, columns, walls, beams and roofs). The objective was to determine how consensus is risk perceived among the three groups of field personnel. The paper used a quantitative methodology that evaluates safety risks related to performing construction activities to supports designers to carry out construction designs using a risk assessment-based approach. The methodology compares cumulative risks of five designs and ranks the severity level of each design. The methodology also compares risk perception among HSE personnel, engineers and superintendent. Using this method of risk assessment will identify significant risks during design stage and highlight them in advance. Thus, a range of risk elimination or mitigation measures will be implemented before and during construction. The study was done with a survey questionnaire, and 40 construction field personnel (12 HSE, 14 superintendents and 12 engineers) were asked to evaluate risk's level of severity and time of exposure for each activity. Data collected were analysed with SPSS Statistics using descriptive statistics, general linear models (Multivariate) and Bivariate correlations (Pearson and Spearman). The results of the analysis showed that roof construction was perceived to have the highest risk followed by beam, foundation, wall and column. The differences in risk perceptions among the respondents were found to be non-significant statistically.



1. Introduction

Despite increasing efforts over the years to address occupational safety and health in the construction industry, injuries and fatalities continue to be an issue plaguing the industry (Cheng, 2010). The industry has the highest fatality rates among all industrial and service sectors, and this has been of great concern to stakeholders and international organizations. Construction safety has always been the responsibility of contractors and is addressed during construction stage alone (Behm, 2005). This has not been adequate to address the alarming rate of injuries and fatalities in the industry (Cameron, 2008). It has been realized through research that addressing construction safety during the design stage and the involvement of all key players of construction projects in the entire construction and safety process is highly likely to increase the effectiveness of safety and health of workers (Gambatese, 2008). Lack of designer's knowledge of construction safety risks (Toole, 2006) and HSE personnel's knowledge of structural designs and means and methods of construction (Goh, 2016) are significant barriers to the implementation of design for construction safety. These barriers often result in poor collaboration among designers and HSE personnel to address safety issues which lead to accidents and frequent work stoppages (Goh, 2016). Risk assessment and quantification is an appropriate method of identifying risks associated with constructing structural elements and activities (Dharmapalan, 2014). This can be achieved by the ability of field personnel to perceive risk and implement practical risk assessment and management practices (Banaitienè, 2011), through their knowledge of construction designs processes and safety.

Formal identification of hazards and assessing risk in construction is one of the fundamentals for successful safety management (Carter, 2006; Trethewy, 2003). The findings of Carter and Smith (2006) indicated that current hazard identification levels in construction projects are far from ideal due to knowledge and information barriers and also process and procedures barriers. Goh and Abdul-Rahman (2013) identified the lack of knowledge on risk assessment and management and the costs associated with implementing the process as significant barriers in Malaysia. Chileshe and Kikwasi (2014), in Tanzania, also identified lack of knowledge, experience and coordination between parties as critical barriers to implementing practical risk assessment and management. Effective risk assessment, quantification and management and full collaboration or coordination between field personnel are essential for project success. However, lack of one and other parties' knowledge among the project players hinders the effectiveness of addressing construction safety and collaboration. Not only contractors but also all other parties (engineers, architects, superintendent, HSE personnel, contractors, owners etc) involved can influence construction safety (Behm, 2005; Gambatese, 2008; Toole, 2017). Behm (2005). Gambatese (2008) linked 42% of construction fatalities in the US to designs. There have been few studies that evaluate risk assessment and quantification through construction field personnel, for example Hallowell & Gambatese (2009) and Dharmapalan & Gambatese (2014).

This study aims to present the concept of designing for construction safety through risk evaluation during the design stages of projects. The objective was to assess and quantify risk associated with constructing structural components and determine the risk perception differences between construction field personnel (engineers, HSEs and superintendents). This will aid the evaluation of the personnel's level of knowledge and ability to perceive risk of construction activities.

2. Method

The research addresses two research questions; what are the safety risk values associated with structural components when they are constructed using the identified construction activities and how significant are the differences in risk perceptions between field personnel. A focus group discussion coupled with field survey-analytical research method, was employed to achieve the research aim and objectives. The method of focus group discussion and field survey serves as an assessment tool for measuring safety risk level of structural elements and also provides a consistent basis for comparisons of risk perception and knowledge among field personnel. A survey questionnaire was developed to collect the data required for this study. It was developed through the modification of a validated questionnaire used by Dharmapalan and Gambatese (2014), a case study of a multi-storey building,

where they used building construction books to identify design features and major construction activities. This questionnaire was used because the two concepts are similar, and was modified because the case studies used were different, which means components and activities may also be different. After its development, the questionnaire was further reviewed and modified by the supervisor and several times by academic professionals at UTM and construction and safety personnel at the NIOSH Institute. It was then taken to experts with wealth of experience in civil, structural and construction engineering in three large construction companies for further input, verification and validation. Forza (2002) indicated that industry experts should be involved in verifying and validating questionnaires related to industrial works. According to Forza (2002), this will aid simplifying the questionnaire for proper understanding of its content by the respondents.

Base on the process of developing, reviewing, modifying, verifying and validating the questionnaire, five components were identified (namely: footing & foundation, column, wall, beam and roof) as well as five major construction activities for each component. Respondents were asked to indicate the percentage of time spent on performing each activity and also to rate the risk severity level for each activity. Four risk severity levels were identified and used: Near miss (1), Low severity (2), Medium Severity (3) and High severity (4). The risk severity levels were based on the ability of the worker involved in the accident to return to work.

2.1. Instrument Reliability and Validity

Cronbach's alpha of reliability analysis is used to test the internal consistency of a survey and must be greater than 0.7 for validity and reliability (Forza, 2002). This was used test 15 respondents' initial data of all 5 components, foundation, column, wall, beam and roof, and the values found were 0.841, 0.894, 0.904, 0.886 and 0.895 respectively, all values greater than 0.7, thus indicating high reliability.

3. Data Collection

Data were collected through focus group discussion and survey study, and the researcher was involved in three 15 minutes focus group discussions with three developers to discuss the purpose and significance of the study and the content of the questionnaire. The purpose of the discussion was to explain the research background further, gather information or input from respondents and explain the instructions on how to fill the questionnaire to ensure data validity. Respondents were urged to use their personal experience, knowledge and judgement in assessing each activity. The questionnaires were distributed by the researcher to the panels of professionals and field experts in construction. The use of questionnaire as data collection method in the construction project has been justified by Amaratunga et al. 2002. The target respondents are industrial experts such as Health and Safety Executives, Engineers and Superintendents. The use of target respondents in management research is supported by Forza, 2002. Their duties were to use their knowledge and experience in construction and safety, critically observe the design elements and activities and indicate the time spent to perform each activity and tick the risk severity levels associated with the activities.

To calculate the unit risk of specific construction activity, the four-grade scales used to rate the risks were multiplied by the time spent to perform the activities to convert the severity rate into numerical values. The calculation of unit risk is based on the method proposed by Brauer, 1994. He developed calculation of risk matrix based on probability of an event and severity of an event. Probability of an event is characterized as frequent, occasional and remote, while, severity of an event is classified as catastrophic, critical, marginal and negligible. The summation of all five unit risks of each component gives the cumulative risk for that component.

4. Results

There were 45 respondents in the panels that participated in the survey, but 5 of the questionnaires were unusable as a result of incomplete survey. The study used data from 40 questionnaires filled accordingly resulting in a response rate of 90%. Respondents' experience was the most important of their demographics because the research and risk assessment was based on human knowledge and

perception. The respondents were 12 engineers, 14 HSEs and 14 Superintendent. On average, 50% of the respondents had over 5 years of experience working in the construction industries as safety officers, engineers and superintendents. The cumulative risks for all components are shown in Table 1. Roof construction carries the highest risk value followed by beam construction. This could be as a result of the work at height involved in the process. Falls are major construction accidents caused by working at height. Chong and Low (2014) indicated that falls from height are among the leading causes of death in the construction industry. Yuen (2017) reviewed case studies of accident resulting from falls and revealed that these accidents were the top contributors of all workplace fatal injuries.

Table 1. Cumulative risk ranking of components

Components	Engineers		Superintendents		HSEs		Overall	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Foundation	199.17	4	221.79	5	236.79	2	220.25	3
Column	190.42	5	230.17	4	212.14	4	212.13	5
Wall	206.25	3	233.93	3	210.36	5	217.38	4
Beam	227.50	2	247.14	1	230.36	3	235.38	2
Roof	280.00	1	242.86	2	259.59	1	259.75	1

A one-way MANOVA was performed to examine the potential discrepancies among the participants' perceptions of risks, and the result is illustrated in Table 2. Wilks' lambda demonstrates the amount of variance accounted for in the dependent variable by the independent variable; the smaller the value, the more significant the difference between the groups being analyzed.

Table 2. Wilks' Lambda Test Results (MANOVA)

Effects	Value	F	Hypothesis df	Error df	Sig
Profession	0.606	1.594 ^b	10	56	0.132
Experience	0.664	1.275 ^b	10	56	0.267
Education Level	0.735	0.933 ^b	10	56	0.511

The results of the one-way MANOVA shown in Table 2 revealed no significant differences among respondents' perceptions of risks. The result for participants' professions was observed to be (Lambda (10, 56) = 0.606, $p = 0.132 > 0.05$). Similar results were observed for the respondents' experiences (Lambda (10, 56) = 0.664, $p = 0.267 > .05$) and education levels (Lambda (10, 56) = 0.735, $p = 0.511 > 0.05$). The Pearson correlation and Spearman's coefficient (rho) is used to showing the strength of a linear relationship between two parametric and non-parametric variables respectively. Table 3 gives the relationship between risk perceptions between the three groups of respondents. There is an indication of a strong relationship between the three pair groups (engineers – HSEs, Engineers - Superintendent and HSEs – Superintendent). Pearson shows a score of 71.1 % correlation between engineers and HSEs and between engineers and superintendents. HSEs and superintendents' score is 50.3%. For Spearman's Rank coefficient, the scores are 67.1%, 58.8% and 37.6% for engineers and HSEs, engineers and superintendents and HSEs and superintendents respectively.

Table 3. Pearson's correlation and Spearman's Rank coefficient

Pair Group	Mean Scores		
	Pearson's Correlation	Spearman's Rank Coefficient	Sig
Engineers - HSEs	0.711**	0.671**	0.05
Engineers - Superintendents	0.711**	0.588**	0.05
HSEs - Superintendents	0.503*	0.376	0.05

†.Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed)

5. Conclusion

The study explored the perception or ability of field personnel (HSE, engineers and superintendents) to assess and rate risk associated with construction activities of structural components (foundation, column, wall, beam and roof). The objective was to determine how consensus risk is perceived among the three groups of field personnel and rank the components in terms of cumulative risks. The paper used a quantitative methodology that evaluates safety risks related to performing construction activities to supports designers carry out construction designs using a risk assessment-based approach. The methodology compares cumulative risks of five designs and ranks the severity of the risk of each design. The methodology also compares the risk perception among HSE personnel, engineers and superintendent. Using this method of risk assessment designers will be able to identify significant risks during the design stage and highlight them in advance. Thus, range of risk elimination or mitigation measures will be proposed and implemented before and during construction. The highest degree of correlation occurred between engineers and superintendent implying a strong consensus of risk perception among these two groups and this is followed by engineers and superintendent and finally HSE and superintendent. It can be concluded that there is a certain level of consistency on risk perception among the three groups of respondents and that roof construction is the riskiest among the five design components followed by beam, foundation, wall and column.

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