CAUSES OF REINFORCED CONCRETE BUILDINGS FAILURE IN DAR ES SALAAM

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Abstract
Over the last three decades population growth has force the demand of housing in Dar es Salaam to be pressing. The quest to meet up with these demands lead to different approaches of realizing housing, as a result building structure of different qualities are constructed. The embarrassing feature of building developmental strive is the failure among the existing structures and those under construction. The cost of these failures in terms of human life and economic waste cannot be over emphasized. Moreover, each building collapse carries along with it tremendous effects that cannot be forgotten by any of its victim. The aim of the study was to examine causes of reinforced concrete buildings failure in Dar es Salaam. The study adopted descriptive research design and data was collected through survey strategy. Contractors and designers involved (78%) in reinforced concrete buildings under construction in Dar es Salaam were interviewed. Data was collected through interview schedule designed in a five points Likert scale. The study found out that poor construction supervision (Mean 4.39), poor quality of concrete (Mean 4.00), overloading due to vertical extension (Mean 3.97) and deficiency in design and working drawings (Mean 3.53) in order of severity are factors that causes 80% of reinforced concrete failure in Dar es Salaam. On the other hand the results found out that poor construction workmanship (Mean 3.13), incompetence of construction team (Mean 2.89), poor construction method (Mean 2.82) and poor quality of reinforcement steel bars (Mean 2.55) in order of severity are factors that causes 20% of reinforced concrete failure in Dar es Salaam Pareto diagram as a total quality management tool is developed to help in improving reinforced concrete building construction in Dar es Salaam.

Key words: *Buildings; construction; failure; quality; reinforced concrete*

1. INTRODUCTION
For centuries building industry has played important role for socio-economic development in many countries (Windapo & Rotimi, 2012). Building serve as place of residence, work, worship etc, therefore they are so essential to human just like air, water and food (Ede, 2010). Globally, construction industry represents $ 3.5 trillion market value and a workforce of around 100 million (El-Mikawi, 2007). Construction contributes between 5 and 10 percent of Gross Domestic Product (GDP) in almost every country (Ofori, 2012). In Tanzania, total value added in the construction industry in 2010 was TShs. 1,187 trillion (NBS, 2013) and contributes 12% to the GDP (NCC, 2017). More than 80% of the world's urban population will be living in the fast-growing cities of developing countries by 2050 (Figueroa, 2014). 29.6% of population in Tanzania lives in urban centre, while 10% live in Dar es Salaam (MoF, 2013). It is projected that about 65 million inhabitants are expected to be living in Tanzanian cities by 2050 (MoLH, 2015). This population growth forces the demand of housing to be more pressing (Figueroa, 2014). The quest to meet up with these demands lead to different approaches of realizing housing and infrastructure, as a result building structure of different qualities are constructed (Makenya & Nguluma, 2007). Buildings that meet required quality add value to the national asset stock and hence its GDP (Windapo & Rotimi, 2012). But when quality of the buildings structure is below requirements, structural failure with its associated consequences is inevitable (Reynolds & Steedman, 1992). Failure of reinforced concrete buildings may result collapse with associated consequences including loss of people's life, injuries to people and loss of property.

Literature has shown that buildings failure among the existing and those under construction in many developing counties are occurring the worst being collapse (Figueroa, 2014, Ayodeji, 2011; Oloyede *et al*., 2010). Tanzania is not exempted from incidents of buildings failure. Between 1987 and 2017 at least five reinforced concrete buildings suddenly collapsed in Dar es Salaam (NCC, 2017; Rubaratuka, 2013; CRB, 2010). Failure and collapse of buildings in Dar es Salaam is attributed to poor quality among other factors (NCC, 2017; NBS, 2013; NCC, 2010). To deal with quality problem facing construction industry, adoption of quality management particularly total quality management (TQM) philosophy and

guiding principles is suggested (Haseeb & Huang, 2013; Abdul-Rahman, 2010; Arditi & Gunaydin, 1997) Argument for this suggestion is based on the findings that, TQM improved quality and productivity in the manufacturing industry (Abdul-Rahman, 2010; Hoonakker *et al.,* 2010; Delgado, 2006). Despite the wealth of literature in construction quality, no enough information is available in the literature about causes of reinforced concrete buildings failure in Dar es Salaam. Causes of building failure in Dar es Salaam represent a significant knowledge gap. Therefore a study was carried out to examine causes of reinforced concrete buildings failure in Dar es Salaam for the purpose of finding practical solution.

2. CONSTRUCTION CHARACTERISTICS

Construction is defined as the mobilization and utilization of capital and specialized personnel, materials and equipments on a specific site in accordance with drawings, specifications and contract document prepared to serve the purposes of the client (NBC, 2013; Delgado, 2006). Construction is a complex system in which several participants each with their own perspectives and interests, are brought together to complete a project plan that typically changes several times during construction, while each tries to minimize the effects of weather, schedule delay and building defects (Hoonakker *et al*., 2010). The many changes can lead to delays in completion of the construction project, complaints about quality and rework (Inuwa, 2014). Construction industry consists traditionally of three primary participants: the owner (client), the designer (consultant) and the contractor (PMBOK, 2000). Owner hires an architect/engineer firm to design the project and the contractor performs the actual construction work normally under supervision of the consultant (architect/engineer). Despite that a common goal of a project is shared, participants differ in what they hope to gain from the construction process. Owner would like to spend as little as possible to get their desired project completed (Delgado, 2006). Designers are in business to provide service to the owner, but their relationship with the contractors is often not clear (Hoonakker *et al*., 2010). Contractors are in business so they attempt to provide the product as drawn by the designer with a focus of maximizing their profit (Delgado, 2006).

2.1 Reinforced Concrete Building Failure

Reinforced concrete building is a structure constructed of composite materials i.e. concrete and reinforcement steel bars. Failure of reinforced concrete buildings has been defined differently by different authors. According to Windapo and Rotimi (2012) building failure can be defined as an unacceptable difference between expected and observed performance of a building structure. Ahzahar *et al*. (2011) described building failures as the condition or fact of not achieving the desired end, it is the termination of the ability of an item to perform an intended or required function. Ede (2010) defined building failure as inability of the building components to perform as expected or required. Structural failure in buildings, in broad terms comes in various forms and degree of severity, the worst of which is a collapse (Oloyede *et al*., 2010). Reinforced concrete building collapse is the ultimate and most serious structural failure (Ahzahar *et al*., 2011). Reinforced concrete building failure occurs when there is a defect in one or more elements of a building caused by inability of the material making up the components of such building element to perform its original function which may finally lead to building collapse (Ayodeji, 2011).

2.2 Reinforced Concrete Buildings Collapse

Reinforced concrete building construction is a dangerous activity that should be carried out with great care (Wanberg *et al*., 2013). Reinforced concrete buildings in some areas have turn to be a danger trap to people (Ayodeji, 2011). Reinforced concrete buildings collapse among the existing and those under construction in many developing counties have occurred (Figueroa, 2014, Windapo & Rotimi, 2012). Table 1 shows cases of buildings collapse in various countries. Tanzania is not an exception from incidents of reinforced concrete buildings failure. Between 1987 and 2017 at least five buildings suddenly collapsed in Dar es Salaam (NCC, 2017; Rubaratuka, 2013; CRB, 2010). Table 2 shows incidence of buildings collapse in Tanzania. Reinforced concrete buildings collapse incidences as shown in Table 2 and the importance of building sector for socio-economic development, highlight the urgency of this study for the purpose of improving building construction process to curb reinforced concrete buildings failure in Tanzania.

Table 1: Cases of Buildings Collapse (Various countries in various years)

Country	Reported cases of buildings collapse	No of Deaths	Injured people
Kenya	17	84	291
Nigeria	92	426	178
Malaysia	1	100	200
Ghana	1	12	78

Bangladesh	1	1100	2500

Source: (Figueroa, 2014; Windapo & Rotimi, 2012)

Failure of reinforced concrete buildings can be caused by a number of factors some of which are natural disaster and human action or inaction (Agwu, 2014). Literature (Figueroa, 2014; Rubaratuka, 2013; Philip *et al*., 2012; Fakere, 2012; Adenuga, 2012; Ayodeji, 2011; Ede, 2010;) have shown that causes of reinforced concrete buildings failure include among others: overloading due to vertical extension; poor construction workmanship; poor quality of reinforcement steel bars; deficiency in building design; poor quality of concrete; poor construction supervision; incompetence of construction teams; poor method of construction; poor quality assurance and control; and poor quality management.

Table 2: Incidence of Buildings Collapse in Tanzania from 1987 to 2017

Collapsed Building	**Location**	**Year**	**No of Deaths**
4 - storey building under construction	Msimbazi Street **Dar es Salaam**	1987	Not known
4 - storey building under construction	Chang'ombe **Dar es Salaam**	2006	4 people
10 - storey building under construction	Mtendeni Street **Dar es Salaam**	2008	3 people
4 - storey completed building and occupied for residential	Sinza Mori **Dar es Salaam**	2013	Not known
16 - storey building under construction	Indira Gandi Street **Dar es Salaam**	2013	36 people

Source: (NCC, 2017; Rubaratuka, 2013; CRB, 2010)

2.3 Total Quality Management Technique for Quality Improvement

To deal with quality problem facing the construction industry in many countries including Tanzania, adoption of quality management particularly total quality management (TQM) philosophy and guiding principles is suggested (Haseeb & Huang, 2013). Total Quality Management (TQM) philosophy is seen as the main framework upon which to initiate the quality improvement efforts (Hoonakker *et al.,* 2010; Lema, 1996). TQM concepts and principles are suggested for quality improvement efforts in the construction industry after successful applications in service and manufacturing industries (Delgado, 2006; Arditi & Gunaydin, 1997).

Pareto diagram is a TQM tool developed from Pareto principles (PMBOK, 2004). The Pareto principle hold that most problems come from relatively few causes or in other words a small proportion of components have the major effect on the outcome (PMBOK, 2004). In quantitative term, Pareto Principle is elaborated that, 80% of the problems come from 20% of the causes (Suarez, 1992). Pareto Principle is generally used to decide where to apply initial effort for maximum effect. The Pareto Principle approach is to identify the problems causing lacks of quality and to rank them from the most important - the 20 per cent of defects causing 80 per cent of quality problems - to the least important (Koch, 1998). Once the 'vital few' sources of off-quality product have been identified, effort is focused on dealing with these issues, rather than trying to tackle all the problems at once (Fellows & Liu, 2008).

Efforts concentrated on enhancing quality in construction process are likely to result in a significant improvement of the end construction product. The notion that prevention is better than cure is very well relevant in reinforced concrete building construction. In recognition of this Oakland and Aldridge (1995 cited in Hoonakker *et al.,* 2010) argued that "*if ever an industry need to take up the concepts of TQM, it is the construction industry"*. Rejecting a defective part in a reinforced concrete building construction need to be taken before the succeeding parts is constructed. If any defects occurred during construction are not fixed and the succeeding parts is constructed before rectification is done, it may cause catastrophic failure.

3. METHODOLOGY

Due to nature of the problem studied, this study adopted survey research strategy among the common research strategies available (Fellows & Liu, 2008). The research was conducted through the exploratory and descriptive research design (McNabb, 2009). A thorough literature review was done to identify causes of reinforced concrete buildings failure of which helped to design research interview schedule. Reinforced concrete buildings under construction in Dar es Salaam were taken as population for the study. Number of reinforced concrete buildings under construction in the area of study could not be found; therefore physical counting was conducted and came up with a number of 70 buildings. Calculated sample size of 59 buildings under construction was randomly selected for data collection (Kothari, 2004).

Interview was conducted in 78% of reinforced concrete buildings under construction. From each reinforced concrete building identified for data collection, two sets of interview schedule were prepared i.e. for contractor and designer (consultant). On the one hand the schedule intended contractors' to indicate causes of building failure by use of 5 points Likert scale, where 1 indicates very low impact while 5 indicates very high. On the other hand the schedule required consultants to rank factors influenced buildings failure in order of severity from one to eight factors provided.

4. RESULTS AND DISCUSSION

Both Contractors and Consultants (designers) ranked poor construction supervision the first among the top three factors affecting reinforced concrete buildings failure in Dar es Salaam. Contractors ranked poor quality of concrete the second factor while consultants ranked overloading the second factor affecting reinforced concrete buildings failure in Dar es Salaam. Contractors ranked vertical extension as the third factor but consultants ranked poor quality of concrete as the third factor affecting reinforced concrete buildings failure in Dar es Salaam. Both contractors and consultants ranked deficiency in building design fourth in the factor affecting reinforced concrete buildings failure in Dar es Salaam. Poor construction workmanship, Incompetence of construction teams, Poor method of construction and Poor quality of reinforcement bars were ranked fifth, sixth seventh and eighth by both the contractors and consultants. Table 3 shows Contractor's assessment on factor affecting RC buildings failure in a Likert scale of 1-5 while Table 4 shows frequency of consultants' assessment on factor affecting RC buildings failure in Dar es Salaam.

Table 3: Contractor's assessment on factor affecting RC buildings failure

Factors affecting RC buildings failure	Mean	Rank
Poor construction supervision	4.39	1
Poor quality of concrete	4.00	2
Overloading due to vertical extension	3.97	3
Deficiency in building design	3.53	4
Poor construction workmanship	3.13	5
Incompetence of construction teams	2.89	6
Poor method of construction	2.82	7
Poor quality of reinforcement bars	2.55	8

Table 4: Consultants' assessment on factor affecting RC buildings failure

S/N	Factors influence building failure	Frequency
1	Overloading due to vertical extension	7
2	Poor construction workmanship	4
3	Poor quality of reinforcement bars	1

S/N	Factors influence building failure	Frequency
4	Deficiency in building design	6
5	Poor quality of concrete	7
6	Poor construction supervision	8
7	Incompetence of construction teams	3
8	Poor method of construction	2

In their ranking, both contractors and consultants agreed that poor construction supervision is the factor highly affects RC building failure in Dar es Salaam. This implies that both the consultants and contractors do not supervise construction as required. In traditional contractual method of project delivery known as design-bid-build, commonly applied in Tanzania, contractors as well as consultants are supposed to supervise the construction works. In the contrary, on one side consultants blamed contractors for not supervising construction works properly; on the other side contractors blamed consultants for not being at site most of the time and therefore not discharging their supervision duty diligently. The purpose of supervision is primarily to ensure that building requirements expressed in the contract documents are correctly interpreted and implemented in construction to the client's satisfaction (Fakere *et al.,* 2012). Tradition method of project delivery commonly applied in Dar es Salaam, design is carried out by architect/structural engineer and construction is carried out by general contractor. In the construction phase both the designer (consultant) and the general contractor are involved. Contractor doing the actual construction while consultant does the supervision work and where necessary give instructions to the contractor on behalf of the client.

One the one hand there is no reason can be provided as to why contractors fails to supervise construction properly, because it is their duty to construct the proposed building to the required design specifications. On the other hand low supervision fee is claimed to be one of the reason for poor construction supervision by consultants in Dar es Salaam and elsewhere in Tanzania. It is claimed by many of the designer that there is no proportionality between time spent for design and the fees paid on one side and time spent for construction supervision and the fee paid on the other side. Giving an example, design that can take relatively short time to complete consume 70% of all consultancy fee payable, while construction which normally takes relatively long time consume only 25% of all consultancy fee payable.

If construction supervision is properly carried out other factors affecting failure of reinforced concrete buildings in Dar es Salaam will be solved. The results have shown that construction supervision is in level one of the factors affecting reinforced concrete buildings failure in Dar es Salaam while the other factors are in level two of cause and effect (Ishikawa) diagram (PMBOK, 2004). Using cause and effect technique, if level one problem (construction supervision) is fixed, also level two problems (poor quality of concrete, overloading caused by improper vertical extension, poor workmanship and poor method of construction) will as well be fixed.

Designers and contractors both ranked deficiency in building design and working drawings fourth in the list of factors affecting failure of reinforced concrete buildings in Dar es Salaam. The contractors assessed the factor as moderately (Mean of 3.53 out of 5 points scale) falling in the fourth rank while consultants ranked it fourth according to their frequency counting. According to this study, architects and structural engineers were regarded as consultants; therefore whoever between architects and structural engineers found at construction site was involved in the interview. Some architect blamed engineers for producing structural drawings without some important details, while most contractors blamed both architects and engineers for producing drawings without some important details. This disparity is considered as negligence. Seriousness and accuracy is required in design and production of working drawings during the reinforced concrete building design.

Looking at the factors affecting failure of reinforced concrete building in Dar es Salaam, they are all human action or inaction. This phenomenon is mostly common in developing countries. The results are in agreement with the results from the studies (Agwu, 2014; Rubaratuka, 2013; Shittu *et al.,* 2013). The results suggest that there is no shortcut for quality management. Most of the time, poor quality reported in Tanzanian construction industry led to broad policy actions

(NCC, 2017) rather than specific actions and therefore same mistakes have being repeated with same results of poor quality of construction process and the construction products.

5. CONCLUSION

Failure of reinforced concrete buildings in Dar es Salaam is caused by a number of factors. All the factors are human action or inaction. The study established that poor construction supervision is the top among the factors affecting failure of reinforced concrete buildings in Dar es Salaam. The other factors affecting failure of reinforced concrete buildings in Dar es Salaam in the in order of severity are: Quality of reinforced concrete materials; Building modification to accommodate more floors than that which it was originally designed; deficiency in design and working drawings. The other group of factors affecting failure of reinforced concrete buildings in Dar es Salaam in the hierarchy of severity include: Poor construction workmanship; Construction team incompetence; Poor construction method and. poor quality of reinforcement steel bars.

6. RECOMMENDATIONS

There is a great potential for quality improvement in the reinforced concrete buildings construction in Dar es Salaam. In today's competitive world, quality improvement is vital for the construction industry. There are not resources to waste, defects rework or failure is not acceptable. As in the manufacturing industry, the construction industry should focus on process quality. TQM philosophy and principles do apply to the construction industry. Pareto diagram as a TQM tool can enable process quality in construction industry. In order to achieve the required quality in reinforced concrete building construction, contractors and consultants should identify the problems causing lacks of quality and to rank them from the most important to the least important. Once the 'factors' causing majority of the problem have been identified, effort is focused on dealing with these factors, first rather than trying to tackle all the problems at once. Specifically the following were identified as factors causing the majority of the problems that need to be fixed first in the order of urgency:

(i) Construction supervision - Proper construction supervision should be carried out and should be done by engaging qualified technical staff.

(ii) Poor quality of concrete – Concrete production should follow required procedure. Both contractors and consultants should supervise construction works by engaging qualified technical staff.

(iii) Overloading due to building modifications - Building owners (clients) particularly the private clients must avoid demanding alterations that may affect structural strength of a building. Contractors and consultant should not entertain alterations without due consideration for design specification provided in the building design.

(iv) Deficiency in design and working drawings – designers should be careful in design and working drawing production to avoid errors. Checks mechanism should be provided at each stage to eliminate errors.

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