Challenges of the Quality of Reinforced Concrete Buildings In Dar es Salaam

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Abstract

In Dar es Salaam, most of the buildings are constructed using reinforced concrete due to non – availability of other durable materials and the strength and protection concrete provide against aggressive weather conditions. Despite of these advantages, still reinforced concrete constructed buildings in Dar es Salaam are facing quality problems which are mainly caused by lack of national building codes and standards, design deficiencies such as lack of design details and accuracy, unsatisfactory quality of concrete ingredients, inappropriate construction technology, lack of quality control measures and inadequate supervision on construction sites.

Keywords: reinforced concrete, quality, durability, permeability, concrete cover, design deficiency.

1. INTRODUCTION

Reinforced concrete is widely used in the construction of buildings and several other types of structures in Dar es Salaam due to its relatively lower cost of construction, non-availability of other durable materials, and the strength and protection concrete structures provide against natural disasters and aggressive weather conditions. Reinforced concrete being a fabricated material, its properties are much dependent on the procedures adopted during design and construction. Most of the reinforced concrete constructions in Dar es Salaam are of in-situ concrete which is labor intensive. It has been observed that sometimes the desirable qualities in terms of strength, serviceability, and protection are not achieved particularly when appropriate quality control measures are not adopted during design and construction.

In Dar es Salaam, about 98% of storeyed buildings are constructed using reinforced concrete, and Rubaratuka (2011) established that there are several cases where reinforced concrete structures have shown signs of distress and deterioration before their expected service life. For the last eight years, four cases of reinforced concrete buildings which collapsed, have been noted. For example, in 2008, a ten storey reinforced concrete building collapsed and in March 3013, a sixteen reinforced concrete building collapsed. This has raised questions on the suitability of reinforced concrete as a construction material. Dar es Salaam, which is a commercial city in Tanzania is located along the Indian Ocean and about 6^0 south of the Equator as shown in Figure 1, as a result most of the constructed reinforced concrete buildings are subjected to aggressive environmental conditions.

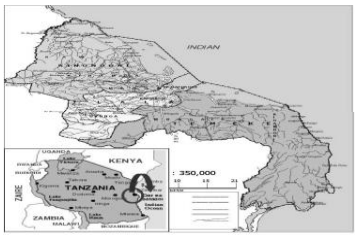


Figure 1 A map of Dar es Salaam City

This paper discusses the challenges of the quality of reinforced concrete building construction in Dar es Salaam and recommendations on how to improve the quality of reinforced concrete buildings are presented.

2. CONSTRUCTION REGULATORY AUTHORITIES IN DAR ES SALAAM

Construction regulatory authorities involved in regulating construction activities in Dar es Salaam are the Engineers Registration Board, the Architects and Quantity Surveyors Registration Board, Contractors registration Board, Public Procurement Regulatory Authority (for public constructions), and the Municipal Councils

(Kinondoni, Ilala and Temeke Municipal Councils)

2.1 Engineers Registration Board

According to the Engineers Registration Act No. 15 of 1997, the Engineers Registration Board (ERB) is responsible for regulating engineering activities in the country such as construction works, Registration of engineers and engineering works, approval of designs, monitoring construction works, etc.. According to the Act which established ERB, all engineers responsible for design and supervision of construction works have to be registered by the board in the categories of professional or consulting engineers. In addition, all engineering designs and construction works have to be registered by ERB.

2.2 Architects and Quantity Surveyors Registration Board

According to the Architects and Quantity Surveyors Act of 2010, The Architects and Quantity Surveyors Registration Board (AQRB) is responsible for approving and regulating architectural and quantity surveying activities, and registration of architects and quantity surveyors.

According to the Act which established AQRB, all architects and quantity surveyors responsible for design and supervision of construction works have to be registered by the board as architects or quantity surveyors. All architectural designs and works have to be registered by AQRB.

2.3 Contractors registration Board

The Contractors registration Board (CRB) is responsible for regulating all construction works and registering contacting companies. According to the Contractors Registration Act of 1997, which established CRB, all construction works have to be carried out by registered contractors and all construction projects have to be registered by the board. It is the responsibility of the board to inspect the projects and ensure that they are carried out according to the law.

2.4 Public Procurement Regulatory

According to the Public Procurement Act of 2011, The Public Procurement Regulatory Authority (PPRA) is responsible for procurement of consultancy services and construction works among others for public constructions.

2.5 Municipal Councils

Municipal Councils are responsible for approving designs, issuing building permits and inspecting and approving the construction works regularly.

3. REINFORCED CONCRETE

Concrete is obtained by mixing cement, fine aggregates, coarse aggregates and water in required proportions. The hardening is caused by chemical action between water and cement due to which concrete grows stronger with age. The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, proportion of the mix and other controls during placing, compacting and curing. In situations where tensile stresses are developed, concrete is normally strengthened/reinforced by steel bars forming a composite construction called reinforced concrete. Reinforced concrete being a fabricated material, its properties are much dependent on procedures adopted during design and construction.

3.1 Design Philosophy

The design of reinforced concrete buildings is based on the assumption of certain properties of concrete such as strength, but the actual strength of concrete produced is a variable quantity. Sources of variability include variation in mix ingredients, changes in concrete making and placing, poor workmanship, unprofessional conduct by team members, testing procedures, etc. The variability of concrete can be minimized through quality control.

3.2 Quality of Reinforced Concrete

The purpose of quality control is to measure and control the variations of those operations which affect the strength and durability of concrete namely batching, mixing, formwork design and construction, placing, compaction and curing. A good quality concrete can be obtained by effectively controlling both human (effective supervision and good workmanship) and non – human (materials/ingredients used in concrete production) factors.

The quality of reinforced concrete can be defined using strength, durability and serviceability as the main criteria for measuring the quality of construction in one form or another. Adhering to the recommended design and construction procedures, it

is ensured that a constructed facility will have an acceptable service life to function as per intended use without significant maintenance cost.

4. INVESTIGATION OF THE QUALITY OF REINFORCED CONCRETE BUILDINGS

Investigation of the quality of reinforced concrete buildings in Dar es Salaam involved the following methodology: (i) review of designs of constructed reinforced concrete buildings, (ii) determining the quality of concrete ingredients and steel reinforcement at different construction sites, and (iii) assessment of construction technology and determining the quality of constructed structural components of the building.

5. CHALLENGES OF THE QUALITY OF REINFORCED CONCRETE BUILDINGS

Investigations carried out for designs of selected reinforced concrete buildings, and constructed buildings in Dar es Salaam have established the following main causes for unsatisfactory quality of reinforced concrete buildings: (i) design deficiencies, (ii) unsatisfactory quality of concrete ingredients and steel reinforcement, (iii) inappropriate construction technology, and (iv) unsatisfactory site supervision.

5.1 Design Deficiencies

5.1.1 Lack of national codes and some standards

Design of reinforced concrete building structures is guided by codes of practice and standards, which provide extensive provisions for concrete and reinforcement. Since reinforced concrete is a fabricated material, the codes give detailed procedures for checking the quality of the concrete during and after its placement in the construction. For construction, the codes provide requirements, and recommend guidelines and practices.

Design provisions and factors in the codes are primarily based on the statistical information, professional experience and construction practices in their regions of application. These codes are regularly revised and updated as and when more information becomes available regarding materials, design procedures, and construction practices. Therefore, the safety, strength, and durability levels stipulated in a code can be achieved only if the recommended design and construction provisions of the codes and standards have been applied judiciously. Partial application of these provisions may not yield the intended quality in the constructed facility.

In the absence of a national code of practice, the design and construction of most of reinforced concrete structures are carried out using foreign codes, namely British Standards, which in some cases are not directly applicable to our conditions. In most cases, designs of structural components are carried out using material and load partial safety factors which depend on certain conditions prevailing in the countries of the origin of respective codes and standards which are not the same as in Tanzania. For example, some of the partial safety factors for materials and loadings for British Standards (BS 8110-1-1997) and South Africa Building Standards (SABS 0100-1 & SABS 0160-1989) are shown in Table 1 below.

Table 1: Comparative partial safety factors

Item	BS8110-1-1997	SABS 0100-1
Reinforcement	1.05	1.15
Shear strength without shear reinforcement	1.25	1.40
Dead Load	1.4	1.2*
Dead Load in isolation		1.5*

Application of these factors in design of structural members in Tanzania, in some cases, may not be appropriate and may affect the quality and durability of structures. Also, the recommended minimum concrete covers for adequate durability of structures differ in different codes as shown in Table 2 below and its application may have different impacts on the durability of structures.

Table 2 : Recommended minimum concrete cover

Code	Minimum concrete cover (mm) for conditions of exposure				
	Mild	Moderate	Severe	Very severe	Extreme
SABS 0100-2	20	30 – 40	40 – 50	50 - 60	60 – 70
BS 8110-1 1997	20 - 25	20 – 35	25 -40	30 - 50	50

Absence of national codes and standards has resulted to the use of various codes and standards for design and construction of reinforced concrete structures in Dar es Salaam and in Tanzania.

5.1.2 Lack of design details and inaccuracy

It has been observed that design details provided for reinforced concrete building structural members are inadequate especially for connections of beams, columns and foundations. For some projects, soil investigation is not carried out as a result design of foundations is based on assumptions which do not take into account the appropriate soil conditions. Some buildings are constructed without expansion joints, foundation beams, etc. For some buildings, the provided concrete covers are inadequate as a result premature deterioration of structural components has been observed.

5.2 Quality of Concrete Ingredients

While in many projects the cement used comply to the required standards as shown in Table 3, sometimes the quality of water, fine and coarse aggregates used is not satisfactory.

Table 3 Test results for cement

Sample Indication	**Soundness (mm)**	**Setting time (min.)**		**Fineness (cm^2/g)**	**Strength (N/mm^2)**		**Loss in Ignition %)**
	Expansion	**Initial**	**Final**	**Sp surface**	**2 days**	**28 days**	
Twiga Cement 42.5 N	1.0	79	139	2742	13.7	43.5	2.45
Simba Cement 32.5R	1.0	151	352.1	2455	21.7		0.7
Requirements EN 197-1:2000							
42.5 N	≤ 10	≥ 60	≤ 600	2275	≥ 10	≥ 42.5	≤ 5 (TZS727:2002)
32.5R	≤ 10	≥ 75	≤ 600	2295	≥ 10	≥ 32.5	≤ 5 (TZS727:2002

Depending on the source, water used for construction, contains chloride to a slight degree of aggressiveness (slightly less than 300 mg/l. Rubaratuka (2008) noted that fine and coarse aggregates contain impurities slightly above the recommended limit of 3% mainly due to improper storage as shown in Figure 2 and also coarse aggregates are not washed before mixing.

Although the tensile strength of steel reinforcement is adequate as shown in Table 4, but sometimes steel reinforcement used show signs of rust and are used without being treated as shown in Figure 3. This state accelerates the initiation of reinforcement corrosion which eventually affects the strength and durability of reinforced concrete buildings.

Figure 2 Improper storage of aggregates at a construction site in Dar es Salaam

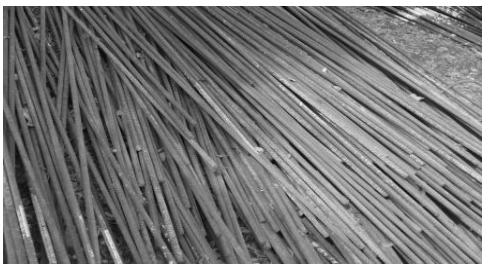


Figure 3 Steel reinforcement with signs of rust

5.3 Poor Construction Technology

Investigations carried out at different construction sites in Dar es Salaam have revealed that poor workmanship is partly a result of lack of adequate skilled labourers, qualified and committed technical staff and lack of proper tools and equipment required to undertake concrete works as follows.

Table 4 Test results for steel reinforcement

Sample	Yield Stress (N/mm^2)	Tensile Stress (N/mm^2)	f_t/f_y	Elongation (%)
1Y8	512.9	591.5	115	25
2Y8	509.6	588.3	115	25
1Y12	553.2	637.3	115	18
2Y12	557.6	641.7	115	18
1Y16	573.3	670.1	117	19
2Y16	570.2	675.5	118	20
1Y20	611.0	684.0	112	19
2Y20	611.5	688.0	113	17
1Y25	595.1	658.1	111	13
2Y25	596.6	659.8	111	13
REQUIREMENTS FOR TENSILE TEST BS 4449:1997				
Steel GR 460	Specified characteristic strength 460 N/mm^2		≥ 110	≥12

5.3.1 Batching and Mixing

It was observed that at many construction projects, the mix design is not carried out as a result concrete produced is variable and do not attain the required design strength as shown in Table 5. Lack of proper supervision at the construction sites has resulted to batching not being carried out correctly as a result concrete with high w/c ratio (greater than 0.5) is normally used hence resulting to production of permeable reinforced concrete with a lower strength [2].

Mixing of concrete ingredients is also not adequately carried out and sometimes small concrete mixers are used leading to production of concrete which is not uniform and with variable strengths as shown in Table 5.

Table 5 Compressive strengths for concrete cubes

Concrete Grade	Sample	Compressive strength (N/mm^2)	Target Compressive Strength (N/mm^2)
25	1	26.0	31.6
	2	17.4	
	3	27.4	
30	1	25.6	38.2
	2	25.2	
	3	23.0	
40	1	41.1	48.2
	2	27.8	
	3	40.8	

5.3.2 Form and False works

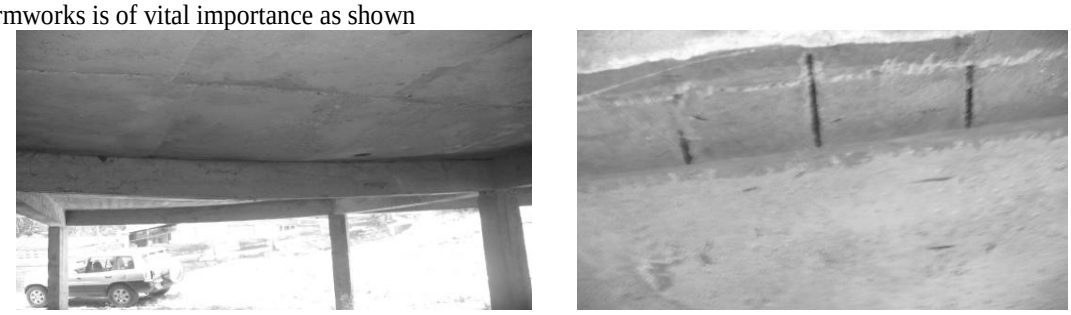
For concrete to harden and achieve the required shape, form and false works plays a vital role. To minimize the cost of form and false works, wooden props and planks of different sizes and strength are widely used in Dar es Salaam. In many projects, form and false works are not designed and erected properly (see Figure 4) as a result they deform, get distorted hence affecting the alignment of concrete members and concrete cover as shown in Figure 5.

(a) (b)

Figure 4 Timber formwork for building construction

To avoid such defects, proper erection of

formworks is of vital importance as shown



(a) (b)

Figure 5 (a) Deflected reinforced concrete slab (b) Reinforced concrete slab with inadequate concrete cover

in Figure 6.

Figure 6 Formwork for a column

5.3.3 Placement of concrete

Investigations carried out at different sites in Dare s Salaam revealed that concrete is poured instead of being placed. Further, it has been established that lack of compaction equipment/vibrators lead to compaction being carried out using timber pieces hence resulting to inadequate compaction and concrete members with voids, honeycomb (see Figure 7) which are permeable.

Figure 7 A reinforced concrete beam – column joint with honeycomb

It has been established that most of the labourers involved in concrete works do not have relevant knowledge, experience and skills for concrete works as a result the constructed concrete members do not have adequate concrete cover as shown in Figure 8 for a pad foundation base under construction.

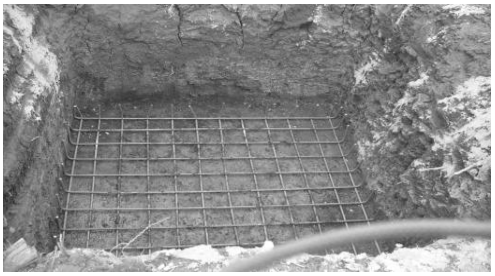


Figure 8 Reinforcement for a pad foundation base

5.3.4 Curing

Despite the importance of curing on the strength and quality of concrete, it has been observed that curing is not carried out properly on many sites. The most recommended wet curing is not fully adhered to as shown in Figure 9 where columns are partially covered by sacks hence resulting to non uniform curing.

Figure 9 Curing of reinforced concrete members

5.3.5 inadequate supervision

Investigations carried at different construction sites in Dar es Salaam, have revealed that some supervising consultants do not provide adequate supervision as a result some contractors are not adhering to design specifications as well as to good construction practices. Figure 10 shows a building which was still under construction but already loaded prematurely with cement sand blocks.

Figure 10 A building frame subjected to premature loading

Further, it has been established that designs for some buildings and supervision of construction works are undertaken by technicians instead of qualified professional engineers. Some of the contractors are carrying out construction works without employing qualified engineers. Also, it was observed that some of the construction works are carried out by labourers under the supervision of technicians and not by registered construction companies. Testing the quality of and strength of materials at some of the sites is not carried out as a result the quality of works is not checked.

6. IMPROVING THE QUALITY OF CONCRETE

To ensure that reinforced concrete buildings are designed and constructed according to the required standards and specifications, the following measures have to be implemented.

6.1 Appointment of Consultants and Contractors

Appointment of consultants for designing the buildings and supervising the construction works as well as contractors for undertaking construction works has to be based on the lowest evaluated bid instead of the lowest bid as stipulated in the Public Procurement Act. This will ensure that qualified, experienced and competent consultants and contractors with adequate technical and financial capability are engaged to undertake the works.

6.2 Enhanced role of Regulatory Authorities

The regulatory authorities must ensure that the designs and construction works are undertaken by competent and qualified registered consulting and construction firms. Municipal Councils have to employ qualified architects and engineers to ensure that proper checking and approval of designs is carried out and also to ensure that the construction works are properly inspected and monitored. In case, the Municipal Councils have no internal expertise and in house capacity, then they have to engage engineering and architectural firms to carry out the required services and ensure that the works are constructed as per the specifications.

6.3 Improving workmanship and Supervision.

There is a need to intensify professional training of technical personnel (artisans, technicians, engineers, architects, etc.) in the construction industry in order to meet the demand of the increased volume of construction works. Further, contractors have to be urged to engage skilled labourers and professional engineers to undertake the works.

Contractors under the supervision of consultants must always test concrete ingredients to ensure that quality materials are used as per specifications. Where possible, ready mix concrete has to be used in order to produce quality concrete works. Proper equipment and tools such as concrete mixers, compactors and vibrators must be used during the construction works and proper curing of concrete has to be undertaken.

6.4 Develop and adoption of national standards

National building codes and standards have to be developed and adopted for design and construction works in order to ensure that the designed and constructed structures are capable of withstanding local environmental conditions.

6.5 Mode of Payment of consultancy fees

The current practice for payment of consultancy fees whereby about 70% is paid for pre contract consultancy services and the remaining 30% paid for post contract consultancy fees has to be reviewed to ensure that more fees is paid for post contract consultancy services. This will encourage consultant to provide adequate supervision during the construction stage.

7. CONCLUSIONS

The quality of designs and construction of reinforced concrete buildings in Dar es Salaam is still a challenge mainly due to design deficiencies, lack of national building standards, inadequate monitoring of construction works by the regulatory authorities, lack of quality control for concrete ingredients as well as steel reinforcement, lack of appropriate construction technology and inadequate supervision of the works.

Therefore, challenges of quality of reinforced concrete buildings will be reduced/minimized by staffing the regulatory authorities with qualified technical personnel, developing and adopting national building standards, application of appropriate construction technology and enhancing supervision of construction works.

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