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Full Length Research Paper

Concrete Technology in a Rapidly Growing Urban Environment – The Case of Dar es Salaam City

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ABSTRACT

Concrete is a building material that is used in great quantities second only to our use of water. The ingredient materials of concrete include cement, fine and coarse aggregates plus a reasonable amount of water, and sometimes additives. The construction of various structures like, residential buildings, commercial buildings, hospitals, schools, bridges, etc., needs good quality concrete. Good modern technologies are needed by the construction industry in order to effectively construct buildings which are durable. A study has been done with the main objective of assessing the concrete technologies existing in rapid growing cities in Sub-Sahara Africa like Dar es Salaam, and the challenges faced in attaining good quality constructions. The study was done through site visits, observations, sampling and testing. From the results, it has been found that traditional concrete technologies are still prevailing, while new technologies are starting to be adopted. Also, there is a problem of conformance to the standards. It was therefore recommended that investment in Cement production industries is needed and that regulatory bodies must enforce builders to adhere to the standards in order to yield good quality constructions.

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INTRODUCTION

Importance of Concrete Construction Projects in Fast Growing Cities

The construction industry needs cement for making concrete and other cement-based materials for constructing various structures like, residential buildings, commercial buildings, bridges etc. Cement is the key ingredient material for making concrete as well as the foundation of any construction project. Concrete is the widely used construction material more than any other man-made material. Concrete is a composite material that consists of cement, fine and coarse aggregates. Water is added to initiate chemical reactions with cement which binds the aggregates into the concrete matrix. The production of good quality cement results in good quality concrete structures.

The quality of concrete ingredient materials influences the quality of the concrete to be produced, because however good the design and workmanship may be, if there is no quality control of the concrete materials, the product will be poor quality concrete (Kassim 2010). For this reason, one of the important obligations of materials suppliers is to make sure that the concrete constituent materials are of good quality and conform to the standards. This paper reports on a study done on current cement production capacity and markets, current concrete technologies and challenges facing the construction industry in Dar es Salaam and gives measures for enhancing good quality constructions.

Therefore, the aim of this study is to assess the current state of concrete technology, its progress, achievement and challenges. Based on this major objective with regard to Tanzania, the issues are considered in the study which include the following:

- Assessing the market conditions and demand of cement
- Identifying the current practices of making and casting concrete
- Checking the application of available new technologies of concrete
- Identifying the existing challenges in achieving quality concrete constructions

METHODS AND MATERIALS

The study was carried out by determining the current cement production capacity and markets, visiting various construction sites to check the current concrete technologies employed. Also, non-destructive tests were performed on various concrete structural elements at sites, sampling of fresh concrete for preparation of specimens, and conducting laboratory tests on the concrete specimens from sites. In additional to that, laboratory studies were carried out on self-compacting concrete.

Available and prospective cement industries in Tanzania

Currently, there are twelve independent and competing cement producing industries, these are Tanzania Portland Cement Company Ltd (TPCC) also known as Twiga Cement. The company was established in 1966 and its major stakeholder is Heidel Berg Cement owning 67.3%. Its quarry and factory offices are located at Wazo Hill area on the outskirts of Dar es Salaam city. The second industry is Tanga Cement, also known as Simba Cement (Chrispin 2014, Lars Kamer 2022), which opened its factory in 1980 in Pongwe within Tanga municipality. The third industry is Mbeya Cement Company Ltd located in Mbeya region in the Southern highlands which boarders with Zambia. The Mbeya Cement factory produces a cement brand known as Tembo. The fourth industry is Rhino Cement Industry located at Kimbiji – Kigamboni within the suburbs of the city of Dar es Salaam. The fifth one is Camel Cement Industry with its plant at Mbagala within the city of Dar es Salaam. The sixth one is in Mtwara in the south of Tanzania known as Dangote Industries (T) Ltd. with a production capacity of 1.5mil Tons/year using gas as the fuel, and the seventh one is in Shinyanga region in the northern Lake Victoria zone. In all these industries, the adopted standard for cement quality is the BS EN 197 (2010). Other cement industries include, Kilimanjaro Cement Limited, Lee Building Materials Limited, ARM Cement Tanzania Limited, Sinoma and Hengya Cement Tanzania (In development), Mtwara Cement Limited (https://en.wikipedia.org/wiki/List_of_cement_manufacturers_in_Tanzania - cite_note-5) and finally is Kisarawe Cement Company Limited.

Production Capacity, Demand and Market Prices of Cement

Tanzania's cement production reached 6.5 million tons (mt) in 2021, 16% more than in 2020 when the estimated cement market demand in Tanzania reached 5.9 million tons, including exports. The cement industry in Tanzania includes six integrated plants and several grinding facilities with a production capacity of around 11 million tons. Tanzania's largest cement producers are Tanzania Portland Cement (Twiga), Tanga Cement (Simba), and Dangote Cement. Dangote, Africa's leading cement producer, estimated Tanzania's total market sales to reach 6.2 mt in 2021 (Figure 1). It also noted that Tanzania's per capita cement consumption of around 50kg per annum is well below the global average and low even for Africa. Nonetheless, it indicated that the improving performance of the Tanzanian economy has fueled strong growth in cement demand and the prospects remain favorable, given the linear relationship between economic growth and cement consumption (Lars Kamer, 2022). The prices of cement in this year of 2022 vary from 6.52 US$ in Dar es Salaam, and about 9.13 US$ in Kigoma which is at a distance of around 1500 km west of Dar es Salaam. Due to the fall of Tanzania Shilling of around 2300 TShs for 1 US$, the cement prices are substantial high. If the prices were low (say 5 US$), then more people would afford to buy and use it in their constructions. According to sub-Sahara Africa data, the country's per capita cement consumption is 50 kg per person compared to 70 kg per person in Sub-Sahara African countries. The challenges to the cement industries include the escalating cost of power/energy, and also the power shortage problem. The other problem is importation of cement from abroad like India, Egypt and Pakistan which is relatively cheaper when compared with the local cement.

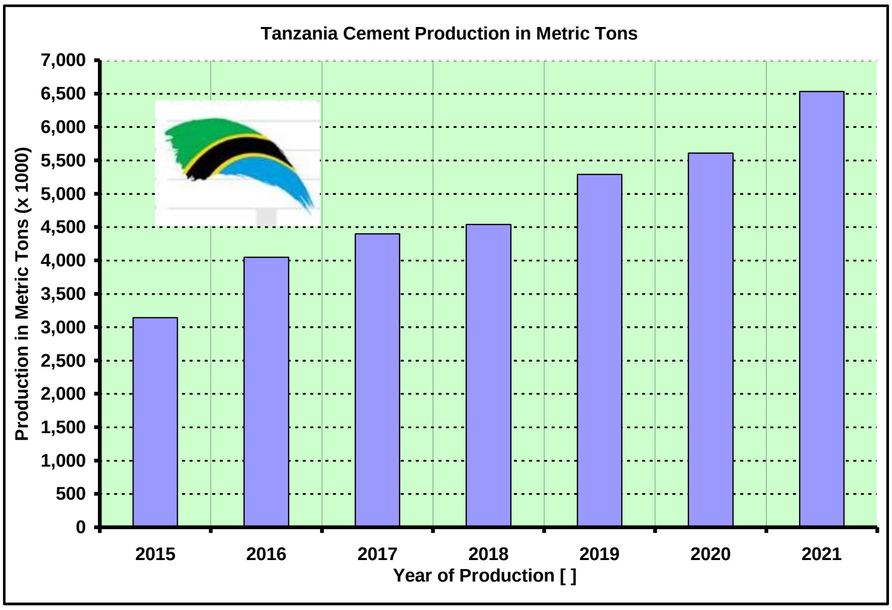

Figure 1: Tanzania Cement Production (Lars Kamer; 2022; www.tanzaniainvest.com/cement).

Existing Technologies in Making and Casting Concrete

The prevailing method of batching concrete ingredients is by volume using buckets and or pans. The most common ratios for concrete mixes production are as given in Table 1. In this case, it can be seen that the amount of water is not established, so it is left to the leader of the concreting gang to decide on the correct amount of water for each mix. In around 35% of the visited sites, it was observed that the concreting gang people do not have proper knowledge with regard to the influence of water on the strength of concrete. Also, the size of coarse aggregates at some sites was not considered as some were more than 25mm and even above 32mm for normal slabs, beams and columns of commercial and residential buildings.

The transportation of Concrete can be done by a variety of methods and equipment. The precaution to be taken while transporting concrete to the final casting place is to maintain the homogeneity obtained at the time of mixing. The popular methods adopted for transporting fresh concrete in our cities include (i) Mortar Pans, (ii) Wheel barrow or Hand cart (iii) Crane, Bucket and rope way and iv) Dumpers. More details on the most applied methods are found in the sections below:

Table 1: Common concrete mixes

No.	Ratio: (Cement: Sand: Coarse aggregates)	Achievable concrete grade
1	1: 3: 6	C15: Mass or plain concrete
2	1: 2: 4	C20: Structural reinforced concrete
3	1: 1.5: 3	C25: Structural reinforced concrete
4	1: 1: 2	C30: Structural reinforced concrete

Mortar Pan

The use of mortar pan for transportation of concrete is one of the common methods adopted in this country. It is a labor-intensive method. In this case, concrete is carried in small quantities in pans or small containers. While this method minimizes the segregation to some extent, it suffers from the disadvantage that it exposes greater surface area of concrete to drying conditions. This results in loss of water, particularly, in hot weather conditions. It is to be noted that each mortar pan must be wetted prior to use and it must be kept clean during the entire operation of concreting. Mortar pan method of conveyance of concrete can be adopted for concreting at the ground level, but below or above the ground level (Figure 2) it is difficult as it may lead to concrete segregation.

Figure 2: Typical appearance of mortar pan.

Crane and Bucket

A crane and bucket is one of the right equipment for transporting concrete above ground level. Cranes can handle concrete in high rise construction projects and are becoming familiar in construction sites in big cities. Cranes are fast versatile to move concrete horizontally as well as vertically along the boom and allows the placement of concrete at the exact point. Cranes carry skips or buckets containing concrete. Skips have discharge door at the bottom whereas buckets are tilted for emptying. For a medium scale job the bucket capacity may be $0.5m^3$. For discharging the concrete, the bucket may be tilted or sometimes, the concrete made to discharge with the help of a hinged bottom. The operation for controlling the gate may be done manually or mechanically. Concrete is to be discharged from the smallest height possible and should not be made to freely fall from heights above 1.0m.

Emerging New Technologies in Making and Casting Concrete

Concrete can be produced using different new technologies currently available; these include ready mix concrete and self-compacting concrete. The application of these types of concrete is still at low level in our country. Some details and examples on each method are explained below:

Ready Mix Concrete (RMC)

Ready-mix concrete is a type of concrete that is batched and mixed in a factory or batching plant, according to the set requirements, and then delivered to a construction site, by truck mounted transit mixers. This results in a precise mixture, allowing specialty concrete mixtures to be developed and implemented at construction sites. This type of concrete is sometimes preferred over on-site concrete mixing because of the precision of the mixture and reduced volume of work at site. However, using a pre-determined concrete mixture reduces flexibility, both in the supply chain and in the actual components of the concrete. Ready Mixed Concrete is bought and sold by volume, usually expressed in cubic meters. RMC can be custom-made to suit different applications.

Ready mixed concrete companies are required to equip themselves with up-to-date equipment, such as transit mixer, concrete pump, and Concrete Batching Plant in order to control batching, mixing, transportation and pouring. Ready Mix Concrete has the following advantages to customers (Gaikwad and Thakur 2019)

- Better quality concrete is produced. Site mix can produce higher compression strength with less water than standard batching methods.

Figure 3: Structure made fro RMC at UDSM.

- Elimination of storage space for basic materials at site. Standard batch plant needs more room for its operation than site-mix trucks. Also, the required time is greatly reduced.
- Wastage of basic materials is avoided. With a site-mix truck, there is less waste and wash out. This is better for the environment.
- Labor associated with production of concrete is eliminated.

Despite the advantages of ready-mix concrete, it was observed that only five contractors; one local and four foreign firms, are employing this latest technology.

Others are not yet possibly because of lack of awareness and the investment required

The disadvantages of ready-mix concrete are;

- The materials are batched at a central plant, and the mixing begins at that plant, so the traveling time from the plant to the site is critical over longer distances. In Dar es Salaam, the problem of traffic jam for some sites hinders smooth transportation of ready-mix concrete. This forces the casting to be done in the night.
- Concrete's limited time span between mixing and setting means that ready-mix should be placed within 90 minutes of batching at the plant. Modern admixtures can modify this time span precisely, however, the
- amount and type plus cost of admixture added to the mix is very important.
- It can also lead to unemployment of laborers on site because it is not a labor-intensive approach.

Self-Compacting (Consolidating) Concrete (SCC)

Self-Compacting Concrete, or Self-Consolidating Concrete, is described as a highly workable concrete that needs little to no vibration during placement. It is nominally considered a concrete mix of exceptional deformability during casting, which still meets resistance to segregation and bleeding. Inadequate vibration of normally consolidated concrete in heavily congested areas has led to surface defects and inadequate bond with the rebar. Because of its low yield stress during pouring, self-consolidating concrete can fill heavily reinforced areas under its own weight, without applying any vibrator.

Self-compacting concrete offers many advantages for contractors, ready-mix concrete producers, and precast concrete fabricators. Some of its advantages include:

- Reduced vibration effort and noise during placing, and it can fill complex forms with limited accessibility
- Rapid pumping of the concrete and has uniform distribution in areas of closely bunched reinforcement, and it reduces labor and construction time.
- Uniform and compact surface with less voids and minimum need for rubbing and patching. It improves aesthetics of flatwork with less effort

SCC Study at the University of Dar es Salaam

The objective of the study was to assess the effectiveness of GLENIUM ® 114 admixture as an additive in concrete that can cause self-compacting property (Hamis B, 2012). The study was achieved through comparing the tensile and compressive strength values of self-compacting and normal vibrated concrete specimens tested after 7 and 28 days of standard curing. A mix design was established resulting into the required amounts of concrete ingredients. The Superplasticizer; GLENIUM® 114, being a water-reducing admixture that causes a significant increase in flowability with little effect on viscosity was used at the recommended dosage rate of 0.8 to 2.5 litre per 100kg of total cementitious material.

After mixing, the fresh concrete was subjected to slump and flow tests. The obtained results showed that the spread diameters as well as the slump height were increasing with the increase in the water-cement ratios as indicated in Figure 4 and Table 2. Concrete cube specimens were then prepared and tested for the compressive strengths at the ages of 7 and 28 days.

Figure 4: Slump and flow of concrete.

Table 2: Slump and flow test

W/C ratio	0.4	0.45	0.5	0.56
Spread diameter SCC [mm]	550	562	570	583
Slump NVC [mm]	59	62	67	78

From the test results, it was observed that SCC yielded higher strength values for both 7- and 28-days age tests. Also, it was noted that the higher is the w/c ratio, the lower is the strength. The compressive strength for normal concrete varied from 38 to 42 N/mm2 while for self-compacting concrete it varied from 39 to 62 N/mm2. The tensile strength of the concretes was found to be between 2.72 and 3.0 N/mm² for NVC while for SCC it was 2.75 to 3.65 N/mm². These results show that the assessed admixture was suitable for production of self-compacting concrete.

Examples and Challenges in Attaining Good Quality Concrete Constructions

The Collapsed 16 stories building in Dar es Salaam

This building depicted in Figure 5 collapsed while under construction process on 29th March 2013 at 8.30 am killing 36 people. The Government formed a probe team combining the Engineers Registration Board (ERB), Contractors Registration Board (CRB), and Architects and Quantity Surveyors Board (AQRB) and members from other Government institutions and local Government. The team sought for a consultant who performed the investigation, after which he reported as detailed below:

Visual observations

After visiting the scene of the fatal event, the following observations were made:

- Concrete lumps from rubbles looked to be weak – reflecting poor concrete mix ratio
- Reinforcement bars were corroded, the phenomenon which gives implication of poor compaction of concrete and improper water-cement ratio.
- The actual plan of the existing basement on site was different from the design drawings.
- Orientation of columns directions were altered from the original design.
- Aggregates used for retaining walls, slabs and beams look soft coral rock while that for basement foundation and columns was strong granite rock of origin.
- Some rotten timber elements were seen at the collapsed building – giving indication that probably rotten formwork was mixed with fresh formwork.

In addition to the above observations, the physical layout of the building was checked for the arrangement of columns, number of columns, and depth of foundation if they were matching with the original design. The observation revealed the following:
The sizes of columns at the basement level were reduced from 300mm to 230mm thick.

- The lift shaft did not start at the basement level because no starter bars were seen
- The number of reinforcement bars used in the columns at the basement level was fewer when compared to the structural drawing, e.g., one column in the drawing showed 12Y25 but on site it was 10Y25.

Figure 5: Collapsed building rubbles.

Test results

To ascertain on the quality of materials that were used to construct the collapsed building, samples were taken from the rubbles. The samples included concrete cores, cement-sand masonry blocks and reinforcement steel. The samples and their respective test results obtained are discussed as follows:

Concrete cores plus cement sand blocks

Four concrete cores were taken from columns and raft foundation and send to Tanzania Bureau of Standards (TBS) laboratory for testing. Such members were chosen because they are critical building elements which can cause direct and fast failure of a building if they are weak. The test results indicated that out of the four cores, only one met the specification of fcu = 25N/mm² (BS 8110, 1997) while the rest were below the standard. The individual strength test values were 34.4 N/mm^2, 6.8, 18.2 and 22.2 N/mm^2. This implies that at most times concrete mix ratios and casting were very poor. Also the tested cement–sand blocks had their strength varying from 2.6 to 3.1N/mm^2. The BS 5628 (1985) stipulates that, for load bearing walls the minimum compressive strength should be equal or more than 5.0 N/mm^2 and for non-load bearing walls it should be at least 2.8 N/mm^2. This means that the blocks were unfit to be used for load bearing and some partitioning walls.

Tests on reinforcements

The reinforcement bars were sampled by cutting direct from the rubbles of the collapsed building at the site. Four samples of reinforcement steel were taken to TBS laboratory for testing. The obtained results are presented in Table 3, thus:

Table 3: Reinforcement steel test results

S/N	Diameter mm	Yield strength N/mm²	Specifications to BS 4449: 2005	Observed Carbon content %	Specification for Carbon content %	Remarks
1	25	425	500			failed
2	20			0.6045	0.24	failed
3	16	374	500	0.3986	0.24	failed
4	12	402	500			failed

From Table 3 above, it can be seen that the yield strengths of the steel bars was below the specification according to BS 4449 (2005). Since the failure in yield stress is significant and carbon content is high, this reinforcement was not supposed to be used in the work. Any overloading of the structure could bring a sudden brittle failure of the reinforcement and hence cause catastrophe failure of the structure.

Challenges in Meeting the Standards: Contractors Performance, Consultants, and Regulatory Bodies

For the purpose of checking how the quality of concrete conforms to the standards, three types of data were collected. The first type was data collected from reputable materials laboratories in Dar es Salaam, the second type was data collected from test results done by the author using non-destructive tests on site, and third was test results from sampled concrete cubes and reinforcing steel specimens taken from various on-going construction sites within the city of Dar es Salaam. The obtained results are hereby summarized in the subsections below:

Concrete strength test results from DIT and TBS Laboratories

Data from various sites were sampled among many available data for buildings which were still in the construction stage. Hence sites L and D which had a design strength of concrete grade C20 (CP 110, **1972**) were first sampled. On analyzing the results as shown in Figure 6, it was found that the mean compressive strength values were 19.9N/mm^2 and 18.8 N/mm^2 respectively, being below the standard. The general trend shown in Figure 6 indicates that the compressive strength of concrete does not meet the requirements of strength value of concrete grade C20.

Concrete strength results From Non-Destructive Tests at Sites

In order to have first-hand data, non-destructive tests on the hardened concrete were done to different buildings using the Rebound Hammer method. The obtained results from sites E and F were analyzed as presented in Figure 7 where there are four graphs; two showing the specification strength values of 20 N/mm^2 and 30 N/mm^2, and the achieved strengths with regard to the two concrete grades from tested beams, slabs and columns. With regard to Site E and specified strength of concrete grade C20, all

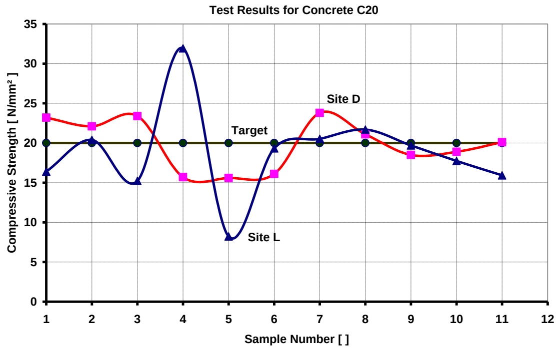

Figure 6: Test results collected from DIT and TBS Laboratories.

12 test results obtained are below the standard. After interviewing confidentially on adherence to the specifications, the foremen responded that they did not send any sample for testing in any laboratory. For site F, the design strength was fcu = 30 N/mm^2 (Mwingizi, 2019). The obtained results showed that out of twelve test points, a half of the test results values were below the standard.

Strength test results from sampled concrete cubes made at sites

Although non-destructive tests were done, still there was a need to sample fresh concrete from various construction sites, prepare the cube specimens, cure and test them after reaching an age of 28 days. For this reason, a total of 30 cube concrete specimens were taken from five different sites, 6 from each, herein named as Sites Q, T and U for concrete grade C20, and Sites R and S (refer Fig. 8) for concrete grade C25.

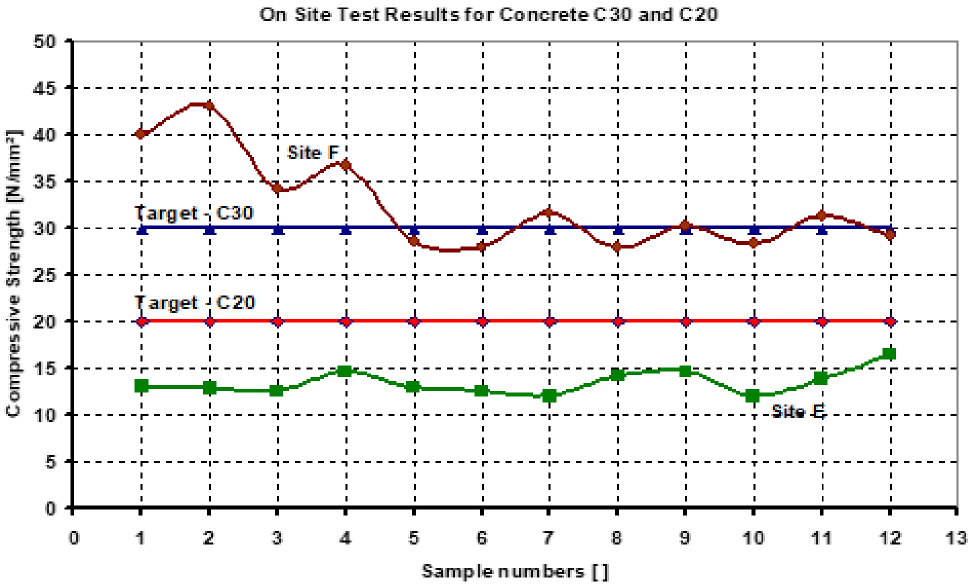

Figure 7: Compressive strength of concrete from Sites E and F.

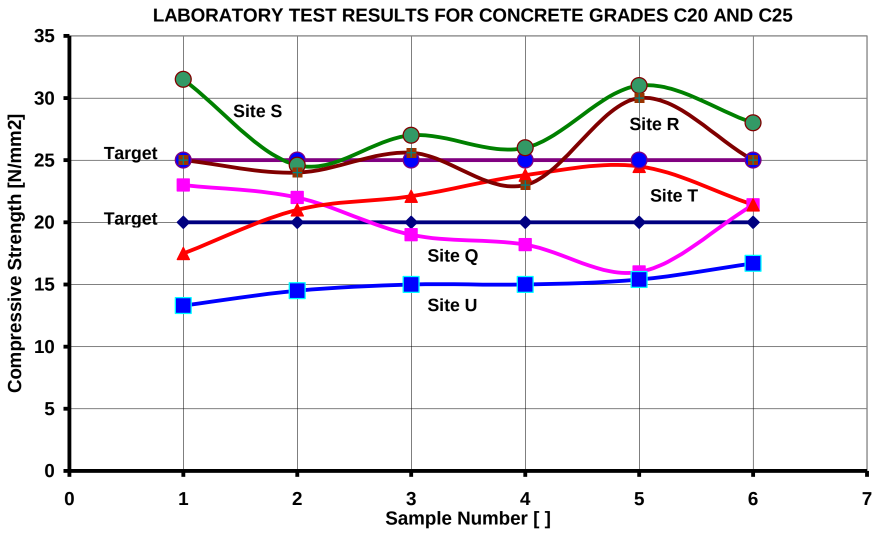

Figure 8: Compressive strength of concrete for sites S and R (C25), Q, T and U (C20).

The molds for making the specimens were taken from the Structures and Building Materials Laboratory, University of Dar es Salaam. On the second day they were taken to a curing tank in the University laboratory. Curing was done for 21 days in water then the specimens were left to dry for 7 days. After reaching an age of 28 days, all specimens were tested for their respective compressive strength. The obtained results were then analyzed and plotted as shown in Figure 8.

Referring to Figure 8, it can be seen that at Site U, there was no any control on mixing concrete ingredients and water was randomly added to the fresh concrete without any measure. It was also found that there was no any supervising engineer. Samples from Site T had good results since 5 cubes out of 6 samples showed good results while only one value fell below the target grade of C20. At site T, it was observed that proper mixing practices and supervising engineer were present. Also, the water cement ratio was controlled in order to acquire good quality concrete as also advocated by Ashraful, et al (2016). At site Q, 50% of the results were below the standard while the rest 50% conformed to the specification of concrete grade C20. The analyzed results from Site R have shown that four samples passed while two samples failed. From Site S, only one sample had a strength value below the specifications for concrete grade C25 (BS 8110, 1997). At these sites, it was observed that there were proper mixing practices and there were site engineers who were controlling the processes; e.g. water cement ratio in order to produce good quality concrete.

Various Structural Strength Investigation Results

In additional to sampling of concrete from various construction sites, another observation was done by the author after being involved in structural strength investigations for some buildings as depicted in Table 5 and Table 6. In Table 5, shown is the concrete strength test results (Makunza and Momanyi 2012), (Makunza, 2013, 2020) of concrete cores taken form four different sites where by the design strength of concrete was grade C20. As viewed in the table, all samples failed completely. There is no even a single value which reached a strength of 20 N/mm^2. The concrete matrix had significant voids, which means there was inadequate compaction of the fresh concrete and less amount of cement especially in the 4th building.

Table 4: Concrete cube strength test results - grade C20 (Makunza, 2013)

S/N	Building Description	Concrete strength specified in contract	Average strength of concrete cores	Condition of voids in concrete cores	Remarks
1	6 Stories - 1	20 N/mm^2	15.9 N/mm^2	Medium	Fail
2	6 Stories - 2	20 N/mm^2	17.6 N/mm^2	Medium	Fail
3	6 Stories - 3	20 N/mm^2	18.7 N/mm^2	Medium	Fail
4	2 Stories - 4	20 N/mm^2	9.8 N/mm^2	Medium to many	Fail
5	4 Stories -5	20 N/mm^2	16.8 N/mm^2	Medium	Fail

Table 5 shows the ranges of compressive strengths of concrete cores drilled from three different multistory buildings in Dar es Salaam. From the obtained test results, it can be seen that the quality requirements were not met at all, for in each case, the compressive strengths are too low in comparison to the target grade of C25. The cores showed medium to many voids and more fines in the concrete matrix. This means that there was improper control of mixing the concrete ingredients and there was poor compaction of the poured fresh concrete.

Table 5: Concrete cube strength test results - grade C25

S/N	Building Description	Concrete strength specified in contract	Average strength of concrete cores	Amount of voids in concrete	Remarks
1	12 Stories	25 N/mm^2	18 N/mm^2	Medium	FAIL
2	13 Stories	25 N/mm^2	8.4-22 N/mm^2	Medium to many	FAIL
3	6 Stories	25 N/mm^2	5.6 – 14.6 N/mm^2	Medium to many	FAIL

Strength of Reinforcement Steel

At five other sites, 3 steel bar samples were taken from each site and tested at the Structures and Building Materials Laboratory of the University of Dar es Salaam. The steel samples were designated as high yield steel with fy = 460N/mm2. After testing, it was revealed that five specimens did not reach the specifications for steel grade 460 as illustrated in Table 6.

Table 6: Steel strength Test results; f_y = 460N/mm^2

S/N	Building description	Specification for steel strength	Reinforcement steel test results
1	12 Stories	460 N/mm^2	350 N/mm^2
2	13 Stories	460 N/mm^2	314 N/mm^2
3	6 Stories - A	460 N/mm^2	349 N/mm^2
4	6 Stories - B	460 N/mm^2	274 N/mm^2
5	6 Stories - C	460 N/mm^2	364 N/mm^2

In addition to the above sampling, 50 steel bars were tested for their yield strength at the Structures and Building Materials Laboratory of the University of Dar es Salaam. The specification for the structural steel was that the yield strength shall be fy = 460 N/mm^2. As seen in Figure 9, the obtained test results indicated that the structural steel bars were medium to high yield steel. Some of this steel would offer less resistance against the applied design loads as 36% of it had a yield strength less than 460 N/mm^2.

DISCUSSION ON THE FINDINGS

The following challenges have been observed when conducting the study on Concrete Technology in a Rapidly Growing Urban Environment – the case of Dar es Salaam:

Cement and Concrete Technology

The high cost of cement and shortage of cement distribution in some places lead to dominance of traditional construction technologies, and normal methods of casting concrete. Modern concrete technologies such as ready mix and self-compacting concretes are still emerging. Also, the GLENIUM ® 114 admixtures seemed to behave well in making the concrete attains self-compacting property.

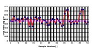

Figure 9: Yield strength of reinforcement bars.

Also, a visual assessment of concrete cores from one Standard Railway Bridge was carried out for 12 cores. It was observed that the amount of concrete ingredients was not up to standard of 1:2+ with respect to the grade of concrete of C40. Out of the 12 cores, only 3 conformed to the specifications while the other 9 failed as seen in Table 7.

Table 7: Visual Assessment of Concrete Cores for a Bridge (Makunza, 2020)

S/N	Sample	Max/min	Agg Max	Voids Content			Honey comb	Rate of compaction	Estimated matrix aggregates ratio	
		mm	mm	Small	Medium	Large				
1	DL-1	210/204	19.5	Nil	Very few	Very few	NIL	Vey good	2:1	Not OK
2	DL-2	197/172	9.5	Very few	Very few	Very few	NIL	Very good	1:1	Not OK
3	DL-3	212/205	19.5	Very few	Very few	Very few	NIL	Good	1:2	OK
4	DL-4	220/211	19.5	Very few	Very few	Very few	NIL	Good	1:2	OK
5	DL-5	176/170	19.5	Very few	Very few	Very few	NIL	Very good	3:1	Not OK
6	DR-1	243/239	19.5	Very few	Very few	Very few	NIL	Good	1:2	OK
7	DR-2	245/237	19.5	Very few	Very few	Very few	NIL	Very good	1:1	Not OK
8	DR-3	198/190	19.5	Very few	Very few	Very few	NIL	Good	2:1	Not OK
9	WL-1(i)	260/257	9.5	Very few	Very few	Very few	NIL	Very good	3:1	Not OK
10	WL-1(ii)	70/62	9.5	Very few	Very few	Very few	NIL	Good	3:1	Not OK
11	WL-1(iii)	87/82	19.5	Very few	Very few	Very few	NIL	Very good	5:1	Not OK
12	WR-5	265/255	9.5	Very few	Very few	Very few	NIL	Good	1:1	Not OK

Shortage of engineers at sites

There was shortage of supervising Engineers at constructions sites in (9) nine sites out of (24) twenty-four projects. Failure to Test Steel and Concrete Samples. Two projects out of twenty-four which was 8.33% of all, revealed that the contractors did not test their sample materials such as structural steel, and concrete specimens in both fresh and hardened states.

Quality of reinforced concrete

The study revealed that, projects utilizing concrete grade C20 had more failures because the majority of these multi-storey buildings are owned and constructed by private people or individuals. In this category most, developers are not employing qualified engineers to supervise the construction works of their multi-story buildings.

Lack of contractors and consultants engaged in the projects

The personnel from continuing projects when interviewed confessed that the projects are executed without a registered contractor, but the client and consultant had agreed to use a certain contractor's name in executing the project. The gang leaders from concreting groups are the ones who supervise the construction works and decide on the mix ratios for the concrete. About 58.33% of projects assessed had one consultant only, though among the sites inspected there was no resident engineers to oversee the construction works.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

It has been observed that there is sufficient amount of cement in Tanzania and that traditional methods of casting concrete are still dominant while application of new technologies for concrete works such use of ready-mix concrete and self-compacting concrete are just emerging. The investigation results on the on-going construction projects for multi-storey buildings in Dar es Salaam have revealed that there was poor supervision of reinforced concrete structures and less adherence to the design specifications as stipulated in the structural drawings/contract documents.

- From the results of this study, it is concluded that
- The demand of cement in Tanzania is met as the current production is relatively higher than the demand. However, the cost of cement is relatively high to the extent that low-income people cannot afford to buy it sufficiently for constructing a complete house.

The causes of achieving poor quality concrete include the following:

- Cheating practices at sites, whereby the batches for sampling cube specimens were properly prepared by having the correct mix ratio, but for other batches the mix ratios were below the standard.
- There were few technical personnel in the Works Department at the Municipals, hence inadequate as compared to the volume of inspecting the construction works in the city of Dar es Salaam.

Recommendations

Basing on the obtained results and the conclusions made above, it is recommended that:

- Builders are advised to start using new technologies for concrete making and casting.
- It is suggested that the government of Tanzania should subsidize the energy price so that the cost of locally produced cement becomes low. Such action will make the cement prices to be affordable by many people, and the local industries will be able to compete with the imported cement from abroad.
- Each part of the project team must execute its obligations as per the established contract and specifications.
- On each day of casting concrete, an engineer must be at site to ensure quality control of concrete
- To reduce poor quality concrete constructions of multi-storey buildings, the Contractors Registration Board (CRB), the Engineers Registration Board (ERB), the Institute of Engineers (IET) and the National Construction Council (NCC) should enforce the contractors and the engineers to conform to the standards.
- The Municipal Councils should insert inspection fee as part of application of Building Permits, say 200-300 US$ per floor to cover for extra costs to be incurred for the salaries of additional building inspectors.
- The Municipal Councils should establish by-laws for penalizing those who fail to conform to the specifications.

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