Assessment of Production and Quality of Concrete Blocks in Dares Salaam, Tanzania

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Abstract - *The construction sector in Tanzania is growing, however, even with this advancement, there is still a problem of poor technology used in the building and construction industry which lead to production of inferior products. Concrete blocks are among the inferior products that are readily available in this industry. The blocks are produced in large quantities because the technology involved does not require high capital investment. This business is in principle, dominated by small and medium scale producers whose primary purpose is to earn a living income. The producers lack technical skills needed for the production. In most cases, the products do not conform to the local Tanzania Standards. This research focused on investigating the production process of concrete blocks, validated the quality of raw materials used in the production and product properties. The research was conducted in local areas of Kinondoni and Ubungo districts in Dar es Salaam region. It was accomplished in two phases at different intervals to allow observation of any changes. Phase I, involved thirty (30) block sites which constituted 10 block sites from Goba, Boko and Bunju respectively. Phase II involved eleven (11) block sites from Kimara, Goba, Boko and Bunju. In the process, questionnaire and interview were administered to each block site with the purpose of assessing the raw materials and production techniques used by the block producers. Out of the 30 block sites in Phase I, 3 block sites from Goba, 3 block sites from Boko and 3 block sites from Bunju were picked for laboratory testing. In each of these 9 sites, 3 block samples were taken for water absorption test and the other 3 blocks for compressive strength test. In Phase II similar procedure for observation, testing was adopted as in Phase I. Field work observation and results show that majority of the concrete block producers do not follow the standard procedures in the production process. Further, results from laboratory tests indicate that approximately two thirds (above 60%) of the blocks tested for water absorption failed; as they absorbed more than 15% of moisture as specified in the Tanzania Bureau of Standards. The blocks tested for compression resistance failed to reach the structural capacity of 7N/mm² for load bearing blocks and 3N/mm² for non-load bearing blocks.*

Key words: Concrete blocks, Quality, Compressive strength, Water absorption, Moisture content.

1. INTRODUCTION

The construction industry is a sector of the economy that transforms various resources into constructed physical economic and social infrastructure necessary for socio-economic development. It embraces the process by which the said physical infrastructure are planned, designed, procured, constructed or produced, altered, repaired, maintained and finally demolished.

The importance of infrastructure for economic growth is widely recognised, and considerable focus has been placed on construction in recent years. The UNESCO-National Commission of the United Republic of Tanzania, 2010 [1] states that during the period 2002-2008, the construction industry enjoyed an average 10% growth, primarily driven by the developments in the road work, water supply projects, commercial and residential buildings and other land development projects. As part of this commitment the government allocated 13% of the 2010/2011 expenditure budget to infrastructure.

In Tanzania, concrete blocks production technology is common in most of the regions. This technology has been growing due to the availability of quality cement brands produced within the country. The most common type of cement used is Ordinary Portland Cement (OPC) because of its reliability, availability and affordable price.

The management of the construction sector in Tanzania is primarily under the ministry of Infrastructure Development, which is charged with developing a sector capable of meeting construction needs, rehabilitation and maintenance of civil works and buildings. This sector is under the government and is an important link to both economic and social development. The responsibility for the roads fall under the National Roads Agency (TANROADS) which caters for the development, construction, maintenance and repair of trunk and regional roads while urban, district, and feeder roads. The provision of water infrastructure falls under the ministry of water and irrigation while housing sector falls under the ministry of Lands, Housing and Human Settlements. The only government housing agency, National Housing Corporation (NHC) facilitates the provision of serviced land, housing and other buildings in Tanzania for use by members of the public, for residential, business, industrial and other purposes.

The National Construction Industry Policy was approved by the Government in 2003 following recommendations by stakeholders [1]. The policy takes into account of the fact that the realization of the objectives and goals of the identified priority sectors such as education, health, water, agriculture, manufacturing, tourism, mining, energy, construction, land and good governance operates on the availability of reliable, strong and competitive local construction industry which is capable of delivering quality services to its stakeholders.

The 'Small and Medium Enterprises' - SMEs is usually adopted to contrast this sector with large business. As a consequence of the co -existence in Tanzania of formal and informal activities, the SME sector is highly diverse, with structures, problems, growth potential and access to support differing widely between segments. This situation is not exclusive for Tanzania. The various SME policies that are already in place in some Eastern and Southern African countries show similar patterns. SMEs are estimated to contribute 30-35% of the gross domestic product (GDP). The sector consists of more than 1 million business activities engaging 3-4 million persons, that is, about 20 -30% of the labour force. The 1991 National Informal Sector Survey revealed that micro-enterprises employed about 20 percent of the total labour force [2].

Building and construction materials provide an international forum for the dissemination of research and development, in the field of building and construction materials and their application in new project works and maintenance practice. Building materials and technology cover cement, aggregates, water, concrete reinforcement, blocks/bricks and mortars, additives, corrosion technology, ceramics, timber, steel, polymers, glass fibres, recycled materials and by-products, sealants, adhesives. Cement related products include, blocks, bricks, beams, columns, slabs, foundations, mortar, asphalt, roof tiles, floor tiles, box culverts, bridges, drainage basins, barriers, pipes, parking curbs and architectural products(decorative block paving).

This is a period when the pressure is on engineers, architects and contractors to optimize the use of new materials and up-to-date technologies. As such, knowledge on building and construction materials will provide essential information that can help professionals and academicians involved in research on building materials [3].

2. REVIEW ON CONCRETE BLOCKS

Concrete block is a modern technology and the most common method used in the construction of walls by the bedding and jointing of blocks into established bonding arrangements. In this circumstance, the knowledge on constituent materials and production techniques that affect the quality of the block may justify the availability of good quality concrete blocks. This knowledge is essential to producers in order to cope with their career pattern to the diverse expectations of the users. The history of the art of brick making and the craft of bricklaying can be traced back to before 6,000 BC. The use of brick work flourished during the third and fourth centuries, after which the craft suffered a rapid decline until its re-introduction at the end of the fourteenth century. Since then, it has been firmly established, and remains as one of the major building materials [4].

2.1 Invention of cement and technology on concrete blocks production

The invention of Portland cement in 1832 opened the way to pre-cast concrete blocks. In the 1830s, a variety of machines for making concrete blocks were patented in England and the United States. However, the blocks had a disadvantage of weight. A solid block measuring 12 × 9 × 32 inches (30 × 23 × 81 cm) could weigh 180 pounds (82 kg) and require a hand-crane for placement. Builders and inventors were looking for a more convenient, lighter block.

Harmon S Palmer of Chattanooga, Tennessee, patented a machine to make a solid concrete block in 1889. In 1899, he patented a 'machine for moulding hollow concrete building blocks' that, together with his 1901 patent for a 'concrete wall for buildings', was the start of modern concrete blocks [5]. Solid Concrete blocks had been used as early as 1832 by the builder William Ranger of Brighton, England, who patented his version as 'Ranger's Artificial Stone'. Subsequently a number of other, but more or less sporadic uses of concrete block occurred, such as a lighthouse in Jersey in 1874, designed by Sir John Coode, and similar lighthouses in Australia at Jervis Bay (1897-9) and Cape Byron (1901.) [6].

As for concrete blocks mechanization, the power tamping method is reported to have been introduced in the United States in the 1920s. Steam curing was first suggested in the United States in 1908, and had become standard by the 1940s. In 1934 the Joltcrete machine was developed by Louis Gelbman and the Stearns Manufacturing Company of Adrian, Michigan, to make three blocks simultaneously and nine blocks a minute. By 1940 most aspects of manufacture were automated. There were now 6,600 manufacturers in the United States, mainly because it was uneconomical to ship either the blocks or the raw materials to long distance [6].

Block is a masonry unit which by usage in its normal function exceeds the actual dimensions specified for a brick, that is 337.5 x 225 x 112.5 mm, but no dimension should exceed 650mm nor should the height exceed either its length or six times its thickness according to BS 6073, 1981. Concrete blocks are classified as dense aggregate concrete blocks that are produced as solid or hollow blocks. They are usually made by local contractors, special concrete blocks producers, or small and medium block producers. [7].

2.2 Basic requirements for concrete blocks

The basic requirements for concrete blocks are individual components or materials that work together in the production of the block. These constituents when mixed in correct proportions will yield a good quality of concrete block. The materials are cement, sand and water.

Cement can be explained as any substance which acts as a binding agent for materials. Natural cement (Roman Cement) is obtained by burning and crushing the stones containing clay, carbonates of lime and some amount of carbonate of magnesia. The clay content in such stones is about 20 to 40 percent [8].

Sand is an important building material used in the preparation of mortar and concrete. Sand particles consist of small grains of silica ($Si0_2$). It is formed by the decomposition of sand stones due to various effects of weather. According to BS 5930 (1981) [9] the size of grains, sand is classified as fine (particle size between0.20-0.060), coarse (particle size between 2-0.020) and medium (particle size between 0.060-0.20). Sand passing through a screen with clear opening of 1.5875mm is known as fine sand. It is generally used for masonry works. Sand passing through a screen with clear opening of 3.175mm is known as coarse sand. The finer the material, the more will be the increase in volume for a given moisture content. This phenomenon is known as bulking of sand.

The water that is fit for construction is that which is clean and free from any deleterious matter. Water plays a role in determining the strength and workability of concrete blocks. It is responsible for the hydration of cement that is used as a binder material. The optimum moisture content (OMC) for moulding depends on the materials being used, quality of vibration, and moulding equipment. Generally, the coarser the particles are graded and the greater the compaction effort, the lower will be the OMC.

2.3 Concrete production and technology

According to Skat [10], concrete block construction has become important and a valid alternative to fired clay bricks. The essential ingredients of concrete are cement, aggregate (sand, gravel) and water. Concrete blocks are produced in a large variety of shapes and sizes. They can be produced manually or with the help of machines. Production can be carried out in the open, the process is simple and equipment does not require high capital investment [11]. According to Skat [10]. Preparation of materials is necessary in order to achieve a good quality concrete block.

The estimation of the proportionate mix of the materials is known as batching. This involves two methods and those are weight batching and volume batching [4]. According to Khanna [12], batch mixers are of three main types: tilting, in which the drum tilts to discharge its contents and non-tilting, which is emptied by means of a chute. With these mixers the required quantities of materials are placed in a revolving drum which is completely discharged after each mix; the drum is fitted with blades which turn over the materials. For normal works there is little to choose between the two above-mentioned types of batch mixers. Hand-mixing should be done on a clean paved area or a water-tight platform.

For moulding, hand operated machines should be used as instructed by the manufacturer. The mould of a powered machine should be filled until approximately six to eight cycles of compaction are required to bring the compacting head to its stop. Too little or poor compaction should be avoided as it results in highly reduced strengths [11].

Compaction done by the use of approved standard machine is preferred, but hand compaction can also be used when the blocks are manually produced using metal moulds. In either case, what is essential is that the desired and approved strength must be attained [13].

Curing is the process of maintaining a satisfactory moisture content and a favourable temperature in the blocks, to ensure complete hydration of the cement and development of required strength [11]. It is normally sufficient to cover blocks with plastic sheeting to prevent moisture loss (or to spray blocks with water, provided block surfaces do not dry out and the water does not freeze).

2.4 Quality control

Three aspects should be monitored to ensure quality masonry units: strength, dimensions and shrinkage [10]. Quality of blocks should be controlled so that strengths are adequate (to avoid breakages and rejection by users) and mixes are as economical as possible. The compressive strength of a concrete block largely depends upon: (i) the water/cement ratio (ii) the quantity and characteristics of cement (iii) the degree of compaction obtained in the mix (iv) Curing (v) the age of a concrete block.

The length and width of the units are determined by the mould and should not vary greatly. However, the height can vary and should be monitored using a simple gauge. Concrete masonry units shrink slightly after manufacture. In order to avoid this happening in the wall, blocks should be allowed to dry out for at least seven days before use.

2.5 Laboratory tests on concrete blocks

The tests that are crucial are tests on aggregate and concrete blocks. The tests conducted include Sieve Analysis, impurities in sand, bulk density, moisture content and compressive strength.

3. METHODOLOGY

The present research applied both qualitative and quantitative approaches. Descriptive design included; literature review, non-participant observations, interviews and, close and open ended questionnaires. Field work was conducted to assess and evaluate the materials and the production techniques employed by concrete block makers in Boko, Bunju, Goba and Kimara in Kinondoni and Ubungo municipals. From the field, randomly selected sand cement blocks from the sample size were taken to a laboratory for compressive strength and water absorption tests. The blocks tested were those aged from 14 days and above. The results were then compared to the provided standards by the Tanzania Bureau of Standards (TBS) in Tanzania.

4. DATA COLLECTION, ANALYSIS AND DISCUSSION

4.1 Introduction

In this study data were collected from different site locations of the four areas namely Goba, Boko, Bunju and Kimara in Dar es Salaam. Test results obtained from specimens were analysed and the quality assessed. The analysis based on the results from questionnaires, observations and laboratory tests.

Table 1: Study areas of in Kinondoni Municipal, Dar es Salaam (Phase I)

Study Area	Sample size	Distributed questionnaires	Returned questionnaires	TOTAL
BOKO	10	10	10	10
BUNJU	10	10	10	10
GOBA	10	10	10	10
TOTAL				**30**

4. 2 Raw materials

In the field, it was noted that pit sand and river sand were the common types used in the production process. Most pit sand used were a mix of soft sand (sand which contains silt and smooth when compressed by hand) and sharp sand (sand which is coarse when compressed by hand). Some sand was very clean, while another was contaminated with organic impurities and some clay particles.

At the site, the sand was not tested for availability of any impurities or sieved to remove any deleterious materials. It was used directly for production and this consequently caused presence of deleterious matter, thus, reducing the binding ability of cement to the fine aggregates.

Ordinary Portland cement (OPC) with strength 42.5N was the common type used in the block production process. The cement brands used were both local and imported.

Type and source of water used varied with the location of the sites. Some of the sites used drilled well water delivered in water bowsers and other sites used tap water. The water was not tested before its use in blocks production. Majority of the sites in Goba used drilled well water and water bowser delivery due to scarcity of tap water in the area; while Boko and Bunju areas used tap water.

4. 3 Production technology

The method of batching used in most sites was volume batching. However, this method was not performed accordingly, most of the workers were not accurate with the number of spades used in a given batch. In concrete blocks production the proposed mix ratios are 1:6, 1:8 and 1:10. With these ratios one is certain to obtain good compressive strength results due to good cement binding with aggregates. As for the mix ratio, the workers had no standard figure, hence, they used their own experience as in Table 2

Table 2: Concrete blocks produced per bag of cement

Study area: Goba		
Sample ID	Mix Ratio Used (Blocks / bag)	Equivalent Ratio (cement:sand)
1	37	1:30
2	37	1:30
3	34	1:20
4	35	1:20
5	37	1:30
6	33	1:20
7	37	1:30
8	34	1:20
9	35	1:20
10	37	1:30

Table 3: Concrete blocks produced per bag of cement

Study area: Boko		
Sample ID	Mix Ratio Used (Blocks / bag)	Equivalent Ratio (cement:sand)
11	28	1:20
12	32	1:22

13	31	1:20
14	35	1:23
15	30	1:20
16	30	1:20
17	32	1:22
18	33	1:22
19	30	1:20
20	30	1:20

Table 4: Concrete blocks produced per bag of cement

Study area: Bunju		
Sample ID	Mix Ratio Used (Blocks / bag)	Equivalent Ratio (cement:sand)
21	30	1:20
22	33	1:20
23	32	1:20
24	35	1:20
25	37	1:30
26	31	1:20
27	32	1: 22
28	32	1:22
29	30	1:20
30	30	1:20

4.3.1 Mixing of materials

Pan mixer that was used in all sites. These machines had an approximate of 0.5-0.6m^3 capacity with a sluice gate at the base for ejecting the mix after it has been mixed.

4.3.2 Moulding of concrete blocks

Powered motorised vibration machine was used for the moulding and compaction of concrete blocks. They produced concrete blocks at a faster rate and with defined dimensions.

4.3.3 Water cement (w:c) ratio used

The workers had no fixed figure for water-cement ratio that was used during production. They used exprience in determining the workability of the mix, therefore variation in the consistency of water content in every batch produced. Water cement ratio has a major role in the workability, compaction and porosity of the concrete block.

4.3.4 Compaction method

The concrete block producers used a motorised vibration machine to achieve the compaction required for concrete blocks. But even with the use of this machine, it was still difficult to attain the standard compaction required because most of the blocks were compacted in different lengths of time.

4.3.5 Curing of blocks

The curing process was conducted after the manufacturing of concrete blocks. Most sites used water pipes for curing. This method was easy to conduct and not time consuming. The duration of the curing process varied from one site to another.

Table 5: Curing of concrete blocks

Study area: Goba			
Sample ID	Curing process	Curing duration (days)	Drying duration (days)
1	Water pipe	1-3	1-3
2	Water pipe	1-3	4-6
3	Water pipe	4-7	1-3
4	Water pipe	1-3	4-6
5	Water pipe	1-3	1-3

6	Water pipe	4-7	4-6
7	Water pipe	4-7	1-3
8	Water pipe	1-3	4-6
9	Water pipe	1-3	1-3
10	Water pipe	4-7	1-3

Table 6: Curing of concrete blocks

Study area: Boko			
Sample ID	Curing process	Curing duration (days)	Drying duration (days)
11	Water pipe	4-7	4-6
12	Water pipe	4-7	1-3
13	Water pipe	4-7	4-6
14	Water pipe	4-7	14
15	Water pipe	4-7	4-6
16	Water pipe	4-7	7
17	Water pipe	4-7	1-3
18	Water pipe	4-7	4-6
19	Water pipe	4-7	7
20	Water pipe	4-7	4-6

Table 7: Curing of concrete blocks

Study area: Bunju			
Sample ID	Curing process	Curing duration (days)	Drying duration (days)
21	Water pipe	4-7	1-3
22	Water pipe	4-7	1-3
23	Water pipe	1-3	1-3
24	Water pipe	4-7	1-3
25	Water pipe	4-7	1-3
26	Water pipe	4-7	1-3
27	Water pipe	1-3	1-3
28	Water pipe	4-7	4-6
29	Water pipe	4-7	1-3
30	Water pipe	4-7	1-3

4.3.6 Stacking of blocks

In most of production sites they stacked their blocks in an open space so that they can dry and be cured, and the blocks were arranged on top of the other.

Figure - 1: Stacking of concrete blocks at Bunju area

4.3.7 Stock piling of aggregates

All sites had aggregates stocks piled in an open space. Being in an open space, the aggregates were contaminated with other deleterious materials.

4.3.8 Cement storage

Cement was stored in bags and kept in a cool dry space with no moisture connection, so that the cement strength was maintained.

4.4 Laboratory test and results

A number of experiments were performed to test the materials used in the production and the output products (concrete blocks). The tests include;

(i) Sieve analysis

(ii) Water absorption test

(iii)Dimension checking

(iv) Weighing and

(v) Compressive strength.

4.4.1 Sieve analysis

In this test samples were selected from from Goba and Bunju area.

A sample of one (1) kilogram was then poured to the sieves and properly shaken for about 5-6 minutes. The quantity of the particles retained on each sieve was determined and the results are as in Table 8.

Table 8: Particle size distribution for fine aggregates

Sieve size(mm)	5.00	4.00	2.36	1.18	0.60	0.425	0.300	0.20	0.15	0.075
Goba Samples	Percentage finer (%)									
Sample 1	100	99.1	95.8	86.8	78.1	64.6	49.2	33.1	10.4	4.3
Sample 2	100	98.5	94.6	87.5	79.4	65.7	51.2	35.6	11.9	2.1
Average	100	98.8	95.2	87.2	78.8	65.2	50.2	34.4	11.2	3.2

Table 9: Particle size distribution for fine aggregates

Sieve size(mm)	5.00	4.00	2.36	1.18	0.60	0.425	0.300	0.20	0.15	0.075
Boko Samples	Percentage finer (%)									
Sample 1	100	99.6	96.8	92.3	79.1	65.1	50.9	34.3	12.7	6.1
Sample 2	100	98.9	95.3	88.1	78.2	66.4	52.0	35.1	11.8	4.5
Average	100	99.3	96.1	90.2	78.7	65.8	51.5	34.7	12.3	5.3

Table 10: Particle size distribution for fine aggregates

Sieve size(mm)	5.00	4.00	2.36	1.18	0.60	0.425	0.300	0.20	0.15	0.075
Bunju Samples	Percentage finer (%)									
Sample 1	100	99.4	98.3	94.8	70.3	63.1	47.4	36.3	11.7	4.4
Sample 2	100	98.0	91.5	89.6	71.4	62.6	40.2	32.9	10.1	2.6
Average	100	99.1	94.9	92.2	70.9	65.2	43.8	34.6	10.9	3.5

Results from the sieve analysis comply with British standard (BS) 882 [14] which approves the fine aggregates to be used for production process. All six samples met the grading requirements.

4.4.2 Water absorption

The water absorption test was performed in order to observe the behaviour of the concrete blocks under extreme wet condition. In this test block samples were soaked for a period of 48 hours and the amount of water absorbed by each sample was recorded. According to the Tanzanian standards (TZS 283: 2002(E))[15], the amount of water a block sample absorbs should not be exceed 15% maximum. However for very good blocks the value should not be more than 12% (Table 11).

Table 11: Water absorption results for concrete blocks

Study area: Goba						
Sample ID	Dimensions L×W×D mm	Volume L×W×D (10^6) (mm^3)	Weight of block before immersion (W_D)(kg)	Weight of block after immersion (W_W)(kg)	Change in weight W_W - W_D	Water absorption %
1A’	460×130×230	13.8	24.55	27.47	2.92	11.9
1B’	460×130×230	13.8	24.00	26.95	2.95	12.3
1C’	460×130×230	13.8	23.65	26.87	3.22	13.6
2A’	460×130×230	13.8	23.60	27.07	3.47	14.7
2B’	460×135×230	14.3	22.90	26.83	3.93	17.2
2C’	460×135×230		23.90	27.58	3.68	15.4

3A'	460×130×230	13.8	22.70	26.55	3.85	16.9
3B'	460×130×230	13.8	23.55	27.29	3.74	15.9
3C'	460×130×230	13.8	23.65	27.20	3.55	15.0

Table 12: Water absorption results for concrete blocks

Study area: Boko						
Sample ID	Dimensions L×W×D Mm	Volume L×W×D (10^6) (mm^3)	Weight of block before immersion (W_D)(kg)	Weight of block after immersion (W_W)(kg)	Change in weight W_W - W_D	Water absorption %
14A'	460×135×225	13.5	22.25	26.29	4.00	17.9
14B'	460×135×230	14.3	23.00	26.63	3.63	15.7
14C'	460×135×230	14.3	22.90	26.99	4.00	17.5
15A'	460×130×225	13.5	22.70	26.75	4.00	14.9
15B'	460×130×225	13.5	22.90	26.85	3.95	17.2
15C'	460×130×225	13.5	22.50	26.65	4.15	18.4
16A'	460×130×230	13.8	24.10	27.21	3.11	12.9
16B'	460×130×2×30	13.8	23.90	26.86	2.96	12.4
16C'	460×130×230	13.8	23.50	27.05	3.55	15.1

Table 13: Water absorption results for concrete blocks

Study area: Bunju						
Sample ID	Dimensions L×W×D mm	Volume L×W×D (10^6) (mm^3)	Weight of block before immersion (W_D)(kg)	Weight of block after immersion (W_W)(kg)	Change in weight W_W - W_D	Water absorption %
27A'	460×135×230	14.3	24.45	27.15	2.7	11
27B'	460×135×230	14.3	24.00	26.55	2.55	10.1
27C'	460×135×230	14.3	23.10	26.41	3.31	14.3
28A'	460×130×235	14.0	22.15	25.82	3.67	16.5
28B'	460×130×235	14.0	23.30	26.42	3.12	13.4
28C'	460×130×230	13.8	22.75	26.80	4.00	17.6
29A'	460×130×230	13.8	23.10	26.22	3.12	13.5
29B'	460×130×230	13.8	24.85	27.36	2.51	10.1
29C'	460×130×230	13.8	23.00	26.26	3.26	14.2

As results from the Tables show, most of the concrete blocks produced by the small producers have high water absorption percentage. The blocks with a higher water content than 15% can be observed in Table 14 and Table 16.

Table 14: Average results for water absorption for Goba area

Study area: Goba									
Sample ID	1A'	1B'	1C'	2A'	2B	2C'	3A'	3B'	3C'
Water absorption (%)	11.9	12.3	13.6	14.7	17.2	15.4	16.9	15.9	15.0
Average (%)	12.6			15.8			15.9		

Table 15: Average results for water absorption for Boko area

Study area: Boko									
Sample ID	14A'	14B'	14C'	15A'	15B'	15C'	16A'	16B'	16C'
Water absorption (%)	17.9	15.7	17.5	14.9	17.2	18.4	12.9	12.4	15.1
Average (%)	17.0			16.8			13.5		

Table 16: Average results for water absorption for Bunju area

Study area: Bunju									
Sample ID	27A'	27B'	27C'	28A'	28B'	28C'	29A'	29B'	29C'
Water absorption (%)	11	10.1	14.3	16.5	13.4	17.6	13.5	10.1	14.2
Average (%)	11.8			15.8			12.6		

The average from Tables 17, 18 and 19 show that, two thirds of each area has blocks that have higher water absorption of more than 15%. Thus, two thirds of the blocks produced from each area failed in water absorption test.

4.4.3 Compressive strength test

A total 3 block producers were picked from each study area of Goba, Boko and Bunju respectively (in Phase I of study).

The compressive test was subdivided into two phases. The first phase was the dry compressive strength of concrete blocks that was determined directly after the acquiring of blocks. The second phase was the wet compressive strength of concrete blocks after 48hours. The results are shown in Tables 17 to 25.

Table 17: Dry compressive strength results for Goba area

Study area: Goba						
Sample ID	Dry mass (kg)	Dimensions L×W×D) mm	Compression area (L×W)mm²	Density Kg/m³	Load 10⁴ N	Compressive strength N/mm²
1A	25.15	460×135×230	62100	1760.80	18.0	2.90
1B	24.65	460×130×230	59800	1792.80	13.5	2.26
1C	24.95	460×130×2×30	59800	1814.00	14.0	2.34
2A	23.85	460×130×220	59800	1812.90	12.0	2.00
2B	23.60	460×130×225	59800	1754.00	10.5	1.76
2C	22.90	460×135×225	62100	1654.00	6.0	0.97
3A	26.50	460×155×225	71300	1651.90	11.0	1.54
3B	28.75	460×155×230	71300	1753.20	19.0	2.66
3C	27.75	460×155×230	71300	1692.20	13.5	1.89

Table 18: Wet compressive strength results for Goba area

Study area: Goba						
Sample ID	Dry mass (kg)	Dimensions (L×W×D) Mm	Compression area (L×W) mm²	Density Kg/m³	Load 10⁴ N	Compressive strength N/mm²
1A'	24.55	460×130×230	59800	1785.00	9.5	1.59
1B'	24.00	460×130×230	59800	1745.00	7.5	1.25
1C'	23.65	460×130×230	59800	1719.50	8.0	1.34
2A'	23.60	460×130×230	59800	1715.90	5.0	0.84
2B'	22.90	460×135×230	62100	1603.30	5.5	0.89
2C'	23.90	460×135×230	62100	1673.30	7.0	1.13
3A'	22.70	460×130×230	59800	1650.40	4.0	0.67
3B'	23.55	460×130×230	59800	1712.20	5.5	0.92
3C'	23.65	460×130×230	59800	1719.50	5.0	0.84

Table 19: Dry compressive strength results for Boko area

Study area: Boko						
Sample ID	Dry mass (kg)	Dimensions (L×W×D) Mm	Compression area (L×W) mm²	Density Kg/m³	Load 10⁴ N	Compressive strength N/mm²
4A	23.00	460×135×225	62100	1646.10	6.0	0.97
4B	23.35	460×135×225	62100	1671.10	5.5	0.89
4C	23.80	460×135×225	62100	1703.30	6.0	0.97
5A	22.20	460×130×225	59800	1650.00	5.5	0.92

5B	23.15	460×130×225	59800	1720.60	4.5	0.75
5C	23.30	460×130×225	59800	1731.70	4.0	0.67
6A	25.25	460×130×230	59800	1835.80	11.5	1.92
6B	24.00	460×130×230	59800	1745.00	7.0	1.17
6C	24.45	460×130×230	59800	1777.70	8.5	1.42

Table 20: Wet compressive strength results for Boko area

Study area: Boko						
Sample ID	Dry mass (kg)	Dimensions (L×W×D)Mm	Compression area (L×W) mm²	Density Kg/m³	Load 10⁴ N	Compressive strength N/mm²
4A’	22.25	460×135×225	62100	1592.40	4.0	0.64
4B’	23.00	460×135×230	62100	1610.30	4.5	0.72
4C’	22.90	460×135×230	62100	1603.30	4.5	0.72
5A’	22.70	460×130×225	59800	1687.10	4.0	0.67
5B’	22.90	460×130×225	59800	1702.00	2.5	0.42
5C’	22.50	460×130×225	59800	1672.20	3.5	0.59
6A’	24.10	460×130×230	59800	1752.20	6.5	1.09
6B’	23.90	460×130×230	59800	1737.70	6.0	1.00
6C’	23.50	460×130×230	59800	1708.60	5.0	0.84

Table 21: Dry compressive strength results for Bunju area

Study area: Bunju						
Sample ID	Dry mass (kg)	Dimensions (L×W×D) Mm	Compression area (L×W) mm²	Density Kg/m³	Load 10⁴ N	Compressive strength N/mm²
7A	24.55	460×135×225	62100	1757.00	13.5	2.17
7B	24.45	460×135×225	62100	1749.90	12.0	1.93
7C	23.00	460×135×225	62100	1646.10	14.0	2.25
8A	25.35	460×130×240	59800	1766.30	5.5	0.92
8B	24.00	460×130×235	59800	1707.80	7.0	1.17
8C	23.30	460×130×235	59800	1658.00	4.5	0.75
9A	25.30	460×130×230	59800	1839.50	6.0	1.00
9B	24.10	460×130×230	59800	1752.20	7.5	1.25
9C	24.80	460×130×230	59800	1803.10	6.5	1.10

Table 22: Wet compressive strength results for Bunju area

Study area: Bunju						
Sample ID	Dry mass (kg)	Dimensions (L×W×D) Mm	Compression area (L×W) mm²	Density Kg/m³	Load 10⁴ N	Compressive strength N/mm²
7A’	24.45	460×135×230	62100	1711.80	9.0	1.45
7B’	24.00	460×135×230	62100	1680.30	9.0	1.45
7C’	23.10	460×135×230	62100	1617.30	7.5	1.21
8A’	22.15	460×130×235	59800	1576.20	9.0	0.67
8B’	23.30	460×130×235	59800	1658.00	6.5	1.10
8C’	22.75	460×130×230	59800	1654.10	3.5	0.59
9A’	23.10	460×130×230	59800	1679.50	4.5	0.75
9B’	24.85	460×130×230	59800	1806.70	5.5	0.92
9C’	23.00	460×130×230	59800	1672.20	7.0	1.17

The summary of the average compressive strength of the concrete blocks has been tabulated as follows

Table 23: Average compressive strength of Goba area

Study area: Goba									
Sample ID	1A	1B	1C	2A	2B	2C	3A	3B	3C
Dry strength	2.90	2.26	2.34	2.00	1.76	0.97	1.54	2.66	1.89
Average	1.83			1.42			2.03		
Wet strength	1.59	1.25	1.34	0.84	0.89	1.13	0.67	0.92	0.84
Average	1.39			0.95			0.80		

Table 24: Average compressive strength of Boko area

Study area: Boko									
Sample ID	4A	4B	4C	5A	5B	5C	6A	6B	6C
Dry strength	0.97	0.89	0.97	0.92	0.75	0.67	1.92	1.17	1.42
Average	0.94			0.78			1.50		
Wet strength	0.64	0.72	0.72	0.67	0.42	0.59	1.10	1.00	0.84
Average	0.69			0.56			0.98		

Table 25: Average compressive strength of Bunju area

Study area: Bunju									
Sample ID	7A	7B	7C	8A	8B	8C	9A	9B	9C
Dry strength	2.17	1.93	2.25	0.92	1.17	0.75	1.00	1.25	1.10
Average	2.12			0.95			1.12		
Wet strength	1.45	1.45	1.21	0.67	1.10	0.59	0.75	0.92	1.17
Average	1.37			0.79			0.95		

It can be noted that the average compressive strengths of both dry and wet concrete blocks (Table 20 to 25) are below $3N/mm^2$. The Tanzania Standards specifies that all load bearing blocks should have a minimum strength of $7N/mm^2$ and for non-load bearing blocks the minimum strength per block is $3N/mm^2$.

4.5 Laboratory procedures conducted for the study

4.5.1 Block weighing and dimension checking

All the blocks that were to be tested were weighed in order to facilitate computation of density and water absorption.

4.5.2 Failure modes of concrete blocks under compression test

This part captured different failure modes that were portrayed by concrete blocks when subjected to compressive loading under a predetermined speed required for a block compression.

Figure - 2: Failure mode of concrete block after loading.

4.6 Data and Results from Phase II of the study

Table 26: Dry compressive strength results for Kimara Baruti area

Site N0. 1 Study area: Kimara Baruti						
Sample ID	Dry mass (kg)	Dimension (LxWxD) mm	Compression area (LxW) Mm²	Density (kg/m³)	Load 10^4N	Compressive strength (N/mm^2)

1D	25.09	457x125x225	57125	1952.05	10.2	1.8
1E	24.45	457x125x226	57125	1893.84	9.1	1.6
1F	24.63	458x129x230	59082	1812.51	9.4	1.6

Table 27: Wet compressive strength results for Kimara Baruti area

Site N0. 1 Study area: Kimara Baruti							
Sample ID	Original Dry mass (kg)	Wet mass	Dimension (LxWxD) mm	Compression area (LxW) Mm^2	Density (kg/m^3)	Load 10^4N	Compressive strength (N/mm^2)
1A	25.22	27.72	458x125x231	57250	2020.40	6.8	1.2
1B	25.78	28.24	457x129x236	58953	2029.77	4.7	0.8
1C	23.85	26.81	457x126x230	57582	2024.33	5.8	1.0

Table 27b: Water absorption for Kimara Baruti area

Sample ID	Original Dry mass (kg)	Wet mass	Dimension (LxWxD) mm	Compression area (LxW) Mm^2	Density (kg/m^3)	Water absorption (%)
1A	25.22	27.72	458x125x231	57250	2020.40	9.91
1B	25.78	28.24	457x129x236	58953	2029.77	9.54
1C	23.85	26.81	457x126x230	57582	2024.33	12.41

Table 28: Dry compressive strength results for Kimara Suka area

Site N0. 2 Study area: Kimara Suka						
Sample ID	Dry mass (kg)	Dimension (LxWxD) mm	Compression area (LxW) Mm^2	Density (kg/m^3)	Load 10^4N	Compressive strength (N/mm^2)
2D	26.11	462x131x235	60522	1835.80	13.3	2.2
2E	26.03	458x127x233	58166	1920.65	9.3	1.6
2F	25.04	458x126x235	57708	1846.42	8.7	1.51

Table 29: Wet compressive strength results for Kimara Suka area

Site N0. 2 Study area: Kimara suka							
Sample ID	Original Dry mass	Wet mass	Dimension (LxWxD) mm	Compression area (LxW) Mm^2	Density (kg/m^3)	Load 10^4N	Compressive strength (N/mm^2)
2A	25.22	28.56	463x133x235	61579	1973.59	3.0	0.5
2B	26.15	29.07	461x132x234	60852	2041.52	12.1	2.0
2C	25.01	28.04	458x128x232	58624	2061.65	5.9	1.0

Table 29b: Moisture absorption for Kimara Suka area

Sample ID	Original Dry mass	Wet mass	Dimension (LxWxD) mm	Compression area (LxW) Mm^2	Density (kg/m^3)	Water absorption (%)
2A	25.22	28.56	463x133x235	61579	1973.59	13. 2
2B	26.15	29.07	461x132x234	60852	2041.52	11.2
2C	25.01	28.04	458x128x232	58624	2061.65	12.1

Table 30: Dry compressive strength results for Bunju A Kwajumbe area

Site N0. 3 Study area: Bunju A Kwajumbe						
Sample ID	Dry mass (kg)	Dimension (LxWxD) Mm	Compression area (LxW) Mm^2	Density (kg/m^3)	Load 10^4N	Compressive strength (N/mm^2)
3D	24.09	455x126x232	57330	1811.20	5.1	0.9
3E	24.74	457x126x233	57582	1843.98	10.3	1.8
3F	23.91	457x126x231	57582	1797.55	5.8	1.0

Table 31: Wet compressive strength results for Bunju A Kwajumbe area

Site N0. 3 Study area: Bunju A Kwajumbe							
Sample ID	Original Dry mass	Wet mass	Dimension (LxWxD) Mm	Compression area (LxW) Mm²	Density (kg/m³)	Load 10⁴N	Compressive strength (N/mm²)
3A	24.87	27.76	455x126x236	57330	2051.76	5.7	1.0
3B	24.46	27.39	459x127x231	58293	2034.06	2.9	0.5
3C	24.90	27.86	452x126x234	56952	2090.53	2.8	0.5

Table 31b: Water absorption for Bunju A Kwajumbe area

Sample ID	Original Dry mass	Wet mass	Dimension (LxWxD) Mm	Compression area (LxW) Mm²	Density (kg/m³)	Water absorption (%)
3A	24.87	27.76	455x126x236	57330	2051.76	11.6
3B	24.46	27.39	459x127x231	58293	2034.06	12.0
3C	24.90	27.86	452x126x234	56952	2090.53	11.8

Table 32: Dry compressive strength results for Bunju A area

Site N0. 4 Study area: Bunju A						
Sample ID	Dry mass (kg)	Dimension (LxWxD) Mm	Compression area (LxW) Mm²	Density (kg/m³)	Load 10⁴N	Compressive strength (N/mm²)
4D	25.12	458x131x230	59998	1820.35	7.2	1.2
4E	22.98	456x128x228	58368	1726.79	5.2	0.9
4F	23.63	455x125x230	56875	1806.40	10.2	1.8

Table 33: Wet compressive strength results for Bunju A area

Site N0. 4 Study area: Bunju A							
Sample ID	Original Dry mass	Wet mass	Dimension (LxWxD) Mm	Compression area (LxW) Mm²	Density (kg/m³)	Load 10⁴N	Compressive strength (N/mm²)
4A	23.76	26.21	456x128x228	58368	1969.51	2.9	0.5
4B	24.39	27.15	457x130x229	59410	1995.61	2.9	0.5
4C	24.54	27.13	457x128x231	58496	2007.76	1.8	0.3

Table 34: Dry compressive strength results for Bunju area

Site N0. 5 Study area: Bunju area						
Sample ID	Dry mass (kg)	Dimension (LxWxD) Mm	Compression area (LxW) Mm²	Density (kg/m³)	Load 10⁴N	Compressive strength (N/mm²)
5D	23.63	458x132x230	60456	1699.40	3.0	0.5
5E	23.57	460x132x228	60720	1702.52	3.0	0.5
5F	24.43	458x128x227	58624	1835.79	5.9	1.0

Table 35: Wet compressive strength results for Bunju area

Site N0. 5 Study area: Bunju area							
Sample ID	Original Dry mass	Wet mass	Dimension (LxWxD) Mm	Compression area (LxW) Mm²	Density (kg/m³)	Load 10⁴N	Compressive strength (N/mm²)
5A	23.97	26.61	458x129x228	59082	1975.40	2.9	0.5
5B	24.34	26.70	459x128x228	58752	1993.21	2.9	0.5
5C	23.35	27.09	460x131x226	60260	1989.17	2.4	0.4

Table 36: Dry compressive strength results for Boko Dovi area

Site N0. 6 Study area: Boko Dovi						
Sample ID	Dry mass (kg)	Dimension (LxWxD) Mm	Compression area (LxW) Mm^2	Density (kg/m^3)	Load 10^4N	Compressive strength (N/mm^2)
6D	25.30	458x129x232	59082	1845.77	12.9	2.2
6E	24.12	454x128x230	58112	1804.61	9.3	1.6
6F	24.77	458x130x232	59540	1793.20	8.3	1.4

Table 37: Wet compressive strength results for Boko Dovi area

Site N0. 6 Study area: Boko Dovi							
Sample ID	Original Dry mass	Wet mass	Dimension (LxWxD) Mm	Compression area (LxW) Mm^2	Density (kg/m^3)	Load 10^4N	Compressive strength (N/mm^2)
6A	24.88	27.32	455x127x230	57785	2055.60	5.8	1.0
6B	25.35	27.79	457x129x231	58953	2040.66	7.1	1.2
6C	24.41	24.41	455x127x233	57785	1812.99	5.8	1.0

Table 38: Dry compressive strength results for Boko Mskitini area

Site N0. 7 Study area: Boko Mskitini						
Sample ID	Dry mass (kg)	Dimension (LxWxD) Mm	Compression area (LxW) Mm^2	Density (kg/m^3)	Load 10^4N	Compressive strength (N/mm^2)
7D	22.65	460x128x230	58880	1672.52	5.3	0.9
7E	22.40	460x127x228	58420	1681.71	5.8	1.0
7F	23.38	460x127x231	58420	1732.49	7.0	1.2

Table 39: Wet compressive strength results for Boko Mskitini area

Site N0. 7 Study area: Boko Mskitini							
Sample ID	Original Dry mass	Wet mass	Dimension (LxWxD) Mm	Compression area (LxW) Mm^2	Density (kg/m^3)	Load 10^4N	Compressive strength (N/mm^2)
7A	22.77	25.71	460x129x230	59340	1883.76	2.9	0.5
7B	23.35	26.18	460x128x229	58880	1941.63	2.9	0.5
7C	24.46	26.91	460x128x230	58880	1987.09	2.9	0.5

Table 40: Dry compressive strength results for Banda la Mbao area

Site N0. 8 Study area: Banda la Mbao						
Sample ID	Dry mass (kg)	Dimension (LxWxD) Mm	Compression area (LxW) Mm^2	Density (kg/m^3)	Load 10^4N	Compressive strength (N/mm^2)
8D	23.69	455x127x231	57785	1774.75	2.9	0.5
8E	24.06	455x126x230	57330	1824.68	6.9	1.2
8F	24.11	460x130x232	59800	1737.83	5.4	0.9

Table 41: Wet compressive strength results for Banda la Mbao area

Site N0. 8 Study area: Banda la Mbao							
Sample ID	Original Dry mass	wet mass	Dimension (LxWxD) Mm	Compression area (LxW) Mm^2	Density (kg/m^3)	Load 10^4N	Compressive strength (N/mm^2)
8A	22.61	25.82	457x129x228	58953	1920.95	2.9	0.5
8B	23.78	26.85	455x127x230	57785	2020.23	11.6	2.0
8C	24.30	27.65	456x127x232	57912	2057.97	17.4	2.9

4.7 Discussion

4.7.1 Water absorption

The concrete blocks produced in all four areas of Kinondoni and Ubungo municipals show that two thirds of the blocks failed in the water absorption test. In observing the average values in Tables 17, 18, and 19, more than 50% of the concrete blocks absorbed water above 15% in Phase I. The trend for properties of the blocks tested is the same for phase II, however, per cent of moisture absorption is lower (Tables 27b, 29b and 31b).

4.7.2 Compressive strength

The Tanzania Bureau of Standards (TBS) specifies that the compressive strength of concrete blocks is $3N/mm^2$ for non-load bearing blocks while for load bearing blocks the minimum strength is $7N/mm^2$. Results from the study show that concrete blocks produced around the areas of Goba, Boko, Bunju and Kimara do not meet the minimum strength required for construction purposes.

4.7.3 Quality of concrete blocks

The results and observation from the study reveal that the blocks produced do not really meet the desired quality. Concrete block production is an engineering science that requires technical know-how and knowledge during the production. To produce good quality of these blocks the following factors should be considered:

(i) Cement should comply with Standard and specification. Strength class should be 42.5N or higher because the concrete must develop strength in a defined period. (ii) Sand particles will pass through a sieve with 4.75-mm square openings. They should be clean, not contain organic matter and should not contain more than a very small fraction of clay (iii) Water that is fit for human and animal drinking is suitable. River and borehole water may be used.

4.7.4 Trial mixes

Trial mixes are recommended and are aimed to find a mix that will produce blocks that have an acceptable texture and are strong enough but as cheap as possible. Because cement is more expensive than aggregates, the lower the cement content the cheaper the block.

Strength of well cured blocks depends on (i) aggregate: cement ratio (ii) degree of compaction (iii) type and size of block. And the degree of compaction depends on (i) overall grading of the aggregates (ii)particle shape of aggregates (iii) aggregate: cement ratio (iv) Water content (iv) Compactive effort.

4.8 Quality control

The study reveals poor quality control. There are three aspects that should be monitored to ensure quality of concrete block units i.e., strength, dimensions and shrinkage.

(a) Strength: Quality of blocks should be controlled so that strengths are adequate (to avoid breakages and rejection by users) and mixes are as economical as possible.

(b) Dimensions: The length and width of the units are determined by the mould and will not vary greatly. However,

(c) Shrinkage: Concrete masonry products shrink slightly after manufacture. In order to avoid this, blocks should be allowed to dry out, at least seven days after curing and before being used for construction.

5. CONCLUSION

The following conclusions are presented based on the analysis and discussion of concrete blocks produced in Kinondoni and Ubungo districts, Dar es Salaam;

(1) There is no quality control tests performed during the block production process at the local sites, hence causing variations of the output products.

(2) The fine aggregates (i.e. sand) used in the production process has proper particle size distribution thus causing a workable mix, however, they must be clean.

(3) The water sources include tap water and drilled well water. Tap water was safe to use in production and do not require testing. On the other hand, drilled well water was not tested before use.

(4) Volume batching was practiced during the mixing of materials. This caused the mix ratio to be poor and thus causing poor quality concrete blocks.

(5) The water cement ratio (w:c) used by the concrete producers was not consistent. This factor contributes to poor compaction thus creating pores in the blocks, consequently cause a high water absorption.

(6) Two thirds (>60%) of the total blocks tested in laboratory absorbed more than 15% of moisture which is higher than the maximum limit set by the Tanzania Bureau of Standards-TBS (TZS 283: 2002(E)). The highest value achieved was 18.47% and the average minimum was 10 %.

(7) The highest compressive strength of concrete blocks was $2.90N/mm^2$ and the lowest value being $0.42N/mm^2$. These values are below the Tanzania Standards that specifies a minimum of $3N/mm^2$ for non-load bearing blocks and a minimum of $7N/mm^2$ for load bearing blocks. The reasons attributing to the

failure is poor production process that do not comply to the standard procedures for the production of concrete blocks.

ACKNOWLEDGEMENT

The author wishes to thank all those who supported this research in all areas and stages. Thanks and appreciation goes to the site owners who were willing and, voluntary permitted the use of information and materials from their local production centres. Many thanks goes to the NHBRA (National Housing Building Research Agency) management and technical/ laboratory staff who supported and facilitated the testing of the blocks.

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BIOGRAPHY

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