

Compressive Strength of Concrete Made from Aggregates of Different Sources

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Abstract

The use of substandard materials, particularly low quality concrete has been identified in literature as the leading cause of building collapse in Nigeria. The roadside artisans/bricklayers usually produce concrete for building construction without taking the aggregate source into consideration. This paper presents a comprehensive data on the compressive strength of concrete made from aggregates obtained from different sources in Ibadan, Nigeria. Experiments have been performed on 12 mixtures made up of fine aggregate from four sources and coarse aggregate from three different sources. The study utilize cement of the same strength (42.5R), coarse aggregate of the same size (10mm), the same water/cement ratio (0.6), and concrete mix (1:2:4) in order to determine the influence of aggregate source on concrete strength. Result revealed that only five mixtures had above the minimum cube compressive strength of 25N/mm² recommended for the construction of the reinforced load-bearing building structural members. Three mixtures had above the cube compressive strength of 20N/mm² recommended for use in plain concrete construction while the rest four mixtures had their cube strength between 19.3N/mm² and 17.9N/mm². Fine aggregate with higher compressive strength showed the lesser amount of deleterious materials. It was concluded that the compressive strength depend on aggregate source.

Keywords

Aggregates, building collapse, cement, concrete, compressive strength, deleterious materials, Ibadan.

1. Introduction and Concept

Concrete is a composite material which consists of cement, fine aggregate (sand), coarse aggregate (gravel or granite) and water in a certain prescribed proportion. The most dominant construction material is concrete and the most collapse structures are concrete structures. A number of researches (Ayininuola and Olalusi, 2004; Ede, 2010 and 2011) have identified the use of substandard materials, particularly concrete as the leading cause of building collapse in Nigeria. Concrete failure still occurs despite adequate design and mix ratio. This advocates the existence of a breach in requirement for production of quality concrete. Previous works confirm the use of inferior concrete aggregates materials as among the causative elements of structural concrete failure in buildings. Gollu et al. (2016) mentioned unsuitable materials, unsound aggregate, reactive aggregate, and contaminated aggregate as part of the sources of concrete failure in buildings. Akinleye and Tijani (2017) stated that the use of low quality aggregates also affect the performance of asphalt concrete in Southwest Nigeria. Concrete will only become a quality material for construction when its constituents are properly sourced. The quality of aggregate can vary significantly due to the geographic location and environmental condition (Ajagbe et al., 2018).

Fowler and Quiroga (2003) reported that aggregates are expected to have important effects on the properties of concrete since they occupy 70-80% of it. Concrete aggregates and paste are the major factors that affect the strength of concrete (Shetty, 2005), the properties of aggregate greatly affect the durability and structural performance of concrete as aggregate with undesirable properties cannot produce strong concrete (Neville, 2011). It is not necessarily true that aggregate whose properties all appear satisfactory will always make good concrete, and this is why the criterion of performance in concrete has to be used. According to Mehta and Monteiro (2001), the aggregates exercise a significant influence on strength, dimensional stability, and durability of concrete. Ajagbe and Tijani (2016) stated that assessment of concrete aggregate is vital to overcome the problem of structure collapse due to concrete failure in a certain environment. De Larrard (1999) and Dewar (1999) agreed that the aggregate source has an impact on concrete strength. Concrete strength is govern by aggregate size, type and source (Hassan, 2014; Aginam et al., 2013; Jimoh and Awe, 2007; Abdullahi, 2012).

Compressive strength is the most significant mechanical property of concrete. It is obtained by measuring concrete specimen after curing for 28 days. Some of the factors that influence the concrete strength include aggregate quality, cement strength, water content and water/cement ratio (Noorzai et al., 2007).

The incessant collapse of building in Nigeria and its associated loss of life, loss of properties and injuries to the survivors of collapsed building incidents have become worrisome to the extent that the Council for the Regulation of Engineering Practice in Nigeria (COREN) has recently advocated for a death penalty for the owners of collapsed buildings. Poor quality of materials has accounted for more than 50% of causes of building collapse in Nigeria (Oke, 2011). Ajagbe et al. (2015) stated that provision of necessary information to local concrete industry and practitioners regarding the application of aggregates from different sources will prevent selection of substandard aggregates for concrete. According to Ayininuola and Olalusi (2004) and Ede (2011), the use of substandard materials for concrete is the leading cause of building collapse in Nigeria. Therefore, an examination of the strength of concrete made from aggregates obtained from different sources in Nigeria is required to overcome the problem of building collapse due to concrete failure.

Investigation of the compressive strength of concrete produced from aggregates obtained from different quarries in Ibadan, Nigeria is the main focus of this paper. The study will use the aggregate of the same size, utilize cement of the same strength, water content and water/cement ratio in order to determine the influence of aggregate source quality on concrete strength. The outcome of the study would enable the provision of data on concrete strength of different coarse-fine aggregate combinations and also help to avoid use of substandard aggregates source materials that might contribute to failures of structures.

2. Methodology

Aggregates were obtained from seven quarries among the sources of concrete aggregates in Ibadan identified by Ajagbe and Tijani (2016). Four of the selected sources are fine aggregate (sand) quarries while the rest three are

coarse aggregate (granite) quarries. The locations of selected quarries are shown in Figure 1.



Figure 1 Google Map Showing Locations of the Studied Quarries. SR – Sasa sand quarry, MR – Moniya sand quarry, AR – Ajibode sand quarry, EB – Egbeda sand quarry, KQ – Kopek granite quarry, RQ – Ratcon granite quarry and EQ – Express granite quarry.

The properties of sands and granites selected for this study are shown in Tables 2 and 3 respectively. The maximum size of coarse aggregate used was 10mm. Dangote Portland Cement grade (42.5R) was used as binders while potable water was used for the mixing. The batching of concrete was done by weight. Twelve (12) mixtures were studied with a total number of 96 cubes prepared by mix ratio of 1:2:4 and 0.6 water/cement ratio using combination

of fine and coarse aggregates as shown in Table 1. Aggregate samples were air dried so as to avoid lumps and obtain a uniform water/cement ratio. Constituent materials were measured and weighed after which cement was mixed with fine aggregate on a water tight platform until the mixture was thoroughly blended. Coarse aggregate was then added and mixed properly until it was uniformly distributed throughout the batch and water was finally added and mixed until the concrete appears to be homogenous and of the desired consistency.

Moulds 100 mm cube were used to mold the concrete cubes. The mould was properly greased by using oil in order to prevent the adhesion of concrete. The concrete was cast using the moulds and in accordance with BS1881: Part 108:1983. After 24 hours in the moulds the specimens were removed and placed in water tank for 7 and 28 days. Compressive strength test was performed on four cubes of each strength level after two hours of removal from the curing tank. This was done in accordance with BS EN 12390-3: 2009.

Table 1 - Research Matrix Mix

Sample codes	KQ	RQ	EQ	Water/cement ratio (constant)	Mix ratio (constant)	Cement brand/grade (constant)	Total no of cubes
SR	KQSR	RQSR	EQSR				12
AR	KQAR	RQAR	EQAR			Dangote	12
MR	KQMR	RQMR	EQMR	0.6	1:2:4	42.5R	12
EB	KQEB	RQEB	EQEB				12
						Total	48

For 7 and 28days curing, the total number of concrete cubes cast was 96 (i.e 48 x 2).

3. Results and Discussion

The properties of sands selected for the study are shown in Table 2. The fineness modulus ranges from 1.9 to 4.0 with EB having the lowest value and SR having the highest value. The bulk density for the four samples complied with ASTM and BS standards. Specific gravity showed that all the samples are normal weight aggregates. Their water absorption capacity does not exceed 2% specified in ASTM C33. Only sample EB exceeded the limit of 5% materials finer than 75µm specified in the code. All samples were free

from clay lump and friable particles as their values were less than 3% maximum specified in ASTM. A good result of sand equivalent was obtained for all samples with SR and EB having the highest and lowest values respectively. Only EB showed an indication of having organic impurities.

Table 2 - Properties of the sands

Sample codes	Fineness Modulus	Loose Bulk Density	Specific Gravity	Water Absorption (%)	Materials Finer than 75µm (%)	Clay Lump & Friable Particles (%)	Sand Equivalent (%)	Presence of Organic Impurities
SR	4.0	1530	2.68	1.8	2.0	0.16	86	Not Present
AR	2.5	1480	2.67	1.2	5.0	0.32	67	Not Present
MR	3.5	1550	2.69	1.7	2.8	0.70	77	Not Present
EB	1.9	1430	2.65	1.3	10.8	0.96	59	Present

Source: Ajagbe and Tijani (2016)

Table 3 shows the physical and mechanical properties of granite obtained from the three quarries selected for the study. Their specific gravity shows that they are normal weight aggregates. The entire sample possess the necessary characteristics for use in concrete works in accordance with BS, IS, ASTM and FMW standards.

Table 3 Properties of the granites

Sample codes	Loose Bulk Density	Specific Gravity	Water Absorption (%)	Flakiness Index (%)	Elongation Index (%)	Aggregate Impact Value (%)	Aggregate Crushing Value (%)	Aggregate Abrasion Value (%)
KQ	1541	2.50	1.01	18.24	25.44	12.46	21.90	21.26
RQ	1622	2.88	0.69	16.03	27.87	10.09	20.30	18.68
EQ	1530	2.81	0.67	16.70	23.96	9.12	19.70	18.32

Source: Ajagbe and Tijani (2016)

The test program consists of casting and testing of 48cubes of concrete for each combination of sands and granites from four and three selected sources respectively. These amounts to a total of 96cubes tested for 7 and 28days

after curing. Tables 4 and 5 show the result of 7 and 28 days compressive strength. The compressive strength increased as the number of days of curing increased (Mindess et al., 2006). The 7 days compressive strength ranges from 10.68N/mm² to 24.4N/mm² while the 28 days compressive strength ranges between 17.9N/mm² and 29.43N/mm². Mindess et al., (2006) stated that the 7-day strength is normally between 60% and 75% of the 28-day strength. As shown in Table 4, the 7 day strength for all mixtures fell between the expected range of 60% and 75% except for the mixtures produced with EB sand which fell below 60%. This low strength development may be attributed to the interference of high amount of materials finer than 75µm and the presence of organic impurities in EB. According to Neville (2011), deleterious substances may hinder the chemical reaction of cement hydration and affect bond development between aggregates and cement paste.

Table 4 7 days compressive strength of concrete made with aggregate of various sources in Ibadan

Units	N/mm ²	N/mm ²	N/mm ²	N/mm ²
Sample codes	KQ	RQ	EQ	Average
SR	22.43	16.92	21.3	20.22
AR	24.4	19.3	16.8	20.17
MR	13.83	13.96	17.75	15.18
EB	12.65	10.95	10.68	11.43
Average	18.33	15.28	16.63	-

In order to determine the best fine and coarse aggregate sources, the average of the compressive strength of concrete at 28 days was used. In respect of the three granite sources used, it was observed that among the sands selected for the study SR gave the highest average compressive strength of 28.38N/mm², MR value was 24.38N/mm² and 23.14N/mm² for AR while EB gave the lowest strength of 18.77N/mm². Moreover, considering the sand sources, KQ gave the highest average compressive strength of 24.96N/mm², EQ value was 23.31N/mm² while RQ value 22.73N/mm² was the lowest.

The 28days compressive strength which is the measure of strength of concrete is of utmost interest in this study. As could be observed in the comparative compressive strength at 28days shown in Table 5. The strength of SR is the highest when mixed with KQ, RQ or EQ while that of EB is the

lowest. This can be linked to the reason that SR has the least amount of deleterious materials such as materials finer than 75µm, clay lumps and friable particles and amount of silt or clay contamination (sand equivalent). For EB, apart from having the highest amount of deleterious materials, it also showed an indication of having organic impurities.

Table 5 28 days compressive strength of concrete made with aggregate of various sources in Ibadan

Units	N/mm ²	N/mm ²	N/mm ²	N/mm ²
Sample codes	KQ	RQ	EQ	Average
SR	29.43	27.2	28.5	28.38
AR	28.9	22.05	18.48	23.14
MR	22.42	22.35	28.37	24.38
EB	19.1	19.3	17.9	18.77
Average	24.96	22.73	23.31	-

According to Neville (2011), deleterious materials exist as surface adherent coatings in aggregate and when present in an undesirable amount they may interfere and seriously affect bond development between aggregate particles and the cement paste and subsequently affecting strength and durability of the concrete.

As shown in Table 5, out of the twelve (12) mixtures studied, only five (5) mixtures representing 41.67% had above the expected strength of 25 N/mm² designed for, while the seven (7) other mixtures representing 58.33% show non-adequacy in strength. The five mixtures (KQSR, RQSR, EQSR, KQAR and EQMR) that had minimum cube strength of 25N/mm² are recommended for the construction of the reinforced load-bearing building structural members such as columns, beams and slabs in mild exposure condition (BS 8110: Part 1, 1997; Mosley et al., 2007). Three (3) mixtures (KQMR, RQAR, and RQMR) had above the cube strength of 20N/mm² while the other four (4) mixtures (EQAR, KQEB, RQEB and EQEB) had their cube strength between 19.3 and 17.9N/mm². Mosley et al. (2007) reported that concrete with minimum cube strength of 20N/mm² is recommended for use in plain concrete construction. However, higher concrete cube strength such as 30, 37 and 45 N/mm² is recommended to be used for reinforced concrete

foundations and other reinforced concrete structural members (BS EN 1992-1-1, 2004).

4. Conclusion

The purpose of this research was to investigate the compressive strength of concrete produced from aggregates of various sources to avoid the use of substandard aggregates materials that might contribute to failures of structures in Ibadan, Nigeria. Experiments were performed on 12 mixtures made up of fine aggregate from four sources and coarse aggregate from three different sources. The study utilized cement of the same strength (42.5R), coarse aggregate of the same size (10mm), the same water/cement ratio (0.6), and concrete mix (1:2:4) in order to determine the influence of aggregate source on concrete strength.

The comprehensive evaluation used in this study revealed that minimum requirement of 25 N/mm² cube strength for reinforced concrete according to BS 8110: Part 1 (1997) was achieved for the 1:2:4 mix ratio by KQSR, RQSR, EQSR, KQAR and EQMR. The cube compressive strength of 20N/mm² recommended for use in plain concrete construction was achieved by KQMR, RQAR, and RQMR while EQAR, KQEB, RQEB and EQEB had their cube strength between 19.3N/mm² and 17.9N/mm².

Fine aggregate with the least amount of materials finer than 75µm, clay lumps and friable particles and amount of silt or clay contamination had the highest compressive strength regardless of the coarse aggregate source, while the one with the highest values of the aforementioned properties showed the lowest compressive strength. It was concluded that the compressive strength depends on aggregate source.

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