

Effect of the Portland-Limestone Cement Grades on the Compressive Strength of Hollow Sandcrete Blocks

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Abstract—The commercial sandcrete block makers in Nigeria use the same cement-sand mix ratio for sandcrete blocks production irrespective of the cement grade. Investigation revealed that the compressive strengths of hollow sandcrete blocks produced with Portland-limestone cement grade 42.5 are higher than the sandcrete blocks produced with cement grade 32.5. The use of stronger sandcrete blocks produced with cement grade 42.5 will ensure the construction of stronger buildings and other sandcrete blocks-based infrastructures and reduce the incessant failure of building and other sandcrete blocks-based infrastructures in Nigeria at no additional cost as both cement grades cost the same amount in Nigeria. It is recommended that the Standards Organisation of Nigeria should create grassroots awareness on the different cement grades in Nigeria and specify that Portland-limestone cement grade 42.5 be used for sandcrete blocks production.

Keywords—Cement grades, Compressive strength, Sandcrete blocks, Portland-limestone cement, Nigerian cement market.

I. INTRODUCTION

IN Nigeria, hollow aggregate concrete blocks manufactured from cementitious binder, aggregate and water, which are generally known as hollow sandcrete blocks are the most widely used material for the construction of building walls, septic tanks, retaining walls, highway drainages, and fences amongst other sandcrete blocks-based civil engineering infrastructures. Presently in Nigeria, hollow sandcrete blocks are produced with Portland-limestone cement, sand and water. In Nigeria, hollow sandcrete blocks are commonly used as a load-bearing unit in two storey buildings or at least they are used as part of structural elements/units that contribute to the strength of buildings and other hollow sandcrete blocks-based civil engineering infrastructures. The incessant collapse of buildings and failure of other sandcrete block-based civil engineering infrastructures in Nigeria has led to loss of lives and properties and has also led to the poor state of sandcrete block-based infrastructures. For example, most Nigerian roads built with hollow sandcrete blocks-based drainages are in poor state because the failure of their sandcrete block-based drainages has led to the failure of their paved areas. The strength, safety and structural integrity of sandcrete block-

based building and other civil engineering infrastructures largely depend on the quality of the hollow sandcrete blocks used for their construction, particularly where the hollow sandcrete blocks act as load-bearing or load-supporting structural units.

One of the most important qualities of hollow sandcrete blocks is their compressive strength. This explains why many papers have been published on the strength of hollow sandcrete blocks and the factors affecting the strength of hollow sandcrete blocks produced in Nigeria. Several researchers [1]-[10] amongst others have conducted research to identify the factors that affect the strength of hollow sandcrete blocks in Nigeria. The factors that these researchers identified as having effects on the strength of hollow sandcrete blocks in Nigeria includes the: quality, grading and density of fine aggregates/sand, curing conditions, quality control, vibration time, amount of water used, cement-sand mix ratios, cavity volume and centre-web to end-web ratio.

Till date, no published work exists on the effect of cement grades generally on the compressive strength of hollow sandcrete blocks and in particular, no published work exists on the effect of Portland-limestone cement grades on the compressive strength of hollow sandcrete blocks. Specifically, no published work exists on the effect of the Portland-limestone cement grades that are available in Nigerian open market on the compressive strength of hollow sandcrete blocks produced in Nigeria. This is due to the fact that past researchers who have published their work on hollow sandcrete blocks in Nigeria like other stakeholders in the Nigerian sandcrete block industry such as the Engineers, Builders, Bricklayers, Masons; sandcrete block makers etc are have little or no knowledge of the existence of different grades of cement in the Nigerian market. This explains why in the work of the ten Nigerian authors referenced earlier, the grade/strength class of the cement they used for their research on the strength of hollow sandcrete blocks in Nigeria was not stated.

Furthermore, most of the stakeholders in the Nigerian sandcrete blocks industry also have little or no knowledge of the type of cement in the Nigerian open market which they buy and use for sandcrete blocks production. This explains why in the work of the ten Nigerian authors referenced earlier and those of [11], [12] amongst others, they all stated that they used OPC which they obtained from the Nigerian open market for the production of the sandcrete blocks used for their research whereas they used Portland-limestone cement which is the only bagged cement in the Nigerian open market. Also, the faint knowledge of the different grades of cement in the

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Nigerian open market explains why the commercial sandcrete block makers in Nigeria use the same cement-sand mix ratio for sandcrete blocks production without any consideration for the cement grade/strength class.

Most Nigerians are unaware of the type of cement and the grades of cement in the Nigerian open market and still believe that the bagged cement in the present Nigerian open market remains the same OPC with no grades/strength classes they used in the past before the adoption and implementation of the current Nigerian Industrial Standards for cement in 2003. Prior to 2003, OPC was the only cement manufactured in Nigeria as OPC was the only cement type allowed to be produced in Nigeria by the old Nigerian Industrial Standards (NIS) for cement: NIS 11: 1974[13] and NIS 439:2000[14]. Also neither [13] nor [14] made any provision for the production of cement with different grades/strength classes.

With the adoption and implementation of the current Nigerian Industrial Standards for cement 444-1:2003[15], which makes provisions for the production of 25 distinct common cements made up of different types and different grades/strength classes of cement, Portland-limestone cement became the only cement type in bagged form in the Nigerian open market. Thus, till date, Portland-limestone cement remains the cement which ordinary Nigerians use for sandcrete block production as OPC in bagged form is no more available in Nigerian open market. OPC with the notation CEM I in the current NIS for cement, NIS 444-1:2003 is produced in Nigeria only on request for the big multinationals handling large construction projects in Nigeria. Portland-limestone cement with the notation CEM II/A-L and CEM II/B-L in [15] is produced by adding limestone to OPC/CEM I. Thus, OPC/CEM I has a higher percentage of clinker (95-100%), the main strength given constituent of cement than Portland-limestone cement CEM II/A-L and CEM II/B-L with 80-94% clinker and 65-79% clinker respectively. As stated by [16], limestone which constitutes 65-94% of Portland-limestone cement is added to OPC to produce Portland-limestone cement because limestone is easier to grind and cheaper than clinker. As stated by Lafarge Cement UK Limited [17] (one of the major cement manufacturers in the world) Portland-limestone cement is different from OPC as it has a slightly shorter setting time than OPC/CEM I and more quantity of it may be needed to produce concrete of the same strength as OPC of the same grade/strength class. Furthermore, with the adoption and implementation of the current Nigerian Industrial Standards for cement [15], Portland-limestone cement grade 32.5 and grade 42.5 are now available in the Nigerian market. Cement grade 32.5 and cement grade 42.5 represent cements with a minimum 28th day's compressive strengths of 32.5MPa, and 42.5MPa respectively. Technically, cement grade 42.5 is a stronger cement as the strength of cement grade 32.5 is usually lower than that of cement grade 42.5.

Hodhod and Abdeen [18] and Mathur et al [19] have studied the effect of cement grades on the compressive strength of concrete in Egypt and India respectively. To the best of the authors' knowledge, the comparison of the effect of

cement grades generally, and specifically, the comparison of the effect of Portland-limestone cement grade 32.5 and Portland-limestone cement grade 42.5 on the compressive strength of hollow sandcrete blocks has not been published. In this paper, the effect of Portland-limestone cement grades 32.5 and 42.5 that are available in the Nigerian open market on the compressive strength of hollow sandcrete blocks is investigated. The investigation was conducted by comparing the strengths of hollow sandcrete blocks produced with five cement-sand mix ratios moulded with Portland-limestone cement grades 32.5 and 42.5 bought at the same price from the manufacturers' depots in the south-western Nigerian city of Ibadan.

II. EXPERIMENTAL

The bagged Portland-limestone cement grades 32.5 and 42.5 used for the production of the hollow sandcrete blocks used for this work were bought directly from their manufacturers' depots in Ibadan which ensured that properly stored good quality cements were used for the research. No experimental work was conducted to confirm the compressive strength of the bagged cement used for this research because the quality assurance tests have been conducted on the bagged cement by the agency in charge of the quality assurance of building materials in Nigeria, the Standards Organisation of Nigeria (SON). The two cement grades are winners/holders of SON's quality conformance awards. The hollow sandcrete blocks used for this research was also produced with water of drinkable quality and with river sand (generally known as sharp sand) that is commonly used for hollow sandcrete blocks production in Nigeria. The particle size distribution of the sand was determined using sieve analysis. The hollow sandcrete blocks were moulded with five cement-sand mix ratios of 1:4, 1:6, 1:8, 1:10 and 1:14. The hollow sandcrete blocks were produced with a mechanical sandcrete block moulder typically used for commercial hollow sandcrete blocks production in Nigeria which mechanically vibrated the blocks and ensured that the blocks were properly compacted. The green/fresh hollow sandcrete blocks were air-cured for 24 hours and thereafter watered in the morning and evening for seven days as recommended by [20]. The top and bottom bedding faces of the blocks were prepared for compressive strength test by capping, which ensured that the top and bottom surfaces of the block test specimens were plane as required by [21]. For each cement grade and for each mix ratio considered, ten 450x225x225mm hollow sandcrete blocks were subjected to compressive strength test in accordance with [21]. The compressive strength test was conducted at a loading rate of $0.05(\text{N}/\text{mm}^2)/\text{s}$ recommended by [21]. The arrangement of the capped sandcrete blocks within the frames and platens of the compressive strength testing machine is shown in Fig. 1.



Fig. 1 Sandcrete blocks compressive strength test setup



Fig. 3 Fracture shape of sandcrete block specimens

III. RESULT

The particle size distribution curve for the sand used for the production of the sandcrete blocks is shown in Fig. 2. The typical fracture shape exhibited by the sandcrete block specimens that were subjected to the compressive strength test is shown in Fig. 3. The average compressive strengths for the hollow sandcrete blocks moulded with Portland-limestone cement grades 32.5 and 42.5 for the five mix ratios considered are presented in Table I. The average compressive strengths were calculated based on the net cross-sectional area of the bedding face.

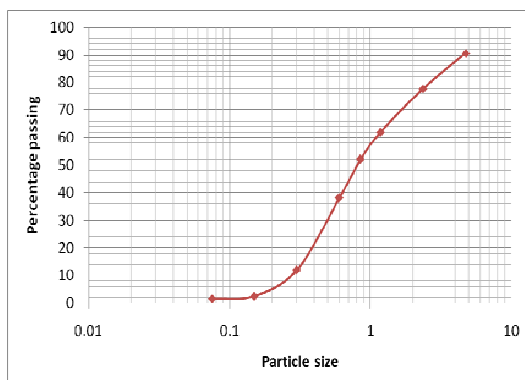


Fig. 2 Sand particle size distribution curve

TABLE I
SANCRETE BLOCKS COMPRESSIVE STRENGTH

Mix ratio	Average Compressive Strength (N/mm ²)		Percentage difference (%)
	Cement grade 32.5	Cement grade 42.5	
1:4	1.8347	1.9284	5.11
1:6	1.3855	1.8673	35.1
1:8	1.1164	1.6059	43.85
1:1	1.002	1.1246	12.26
1:1	0.6578	0.7692	1.94

IV. DISCUSSION

The particle size distribution curve for the sand used for the production of the sandcrete blocks shown in Fig. 2 demonstrates that the sand is well graded. The typical fracture/failure shape exhibited by the fractured sandcrete block specimens shown in Fig. 3 shows that fracture occurred throughout the shells and webs along the entire length and width of the sandcrete block specimens. This demonstrates that the compressive load applied by the testing machine loaded the entire shells and webs of the sandcrete blocks which demonstrates that the compressive strength tests conducted proceeded satisfactorily and consequently demonstrates the validity of the compressive strength tests conducted in this work. As shown in Table I, the compressive strengths of the hollow sandcrete blocks produced with Portland-limestone cement grade 42.5 are generally greater than the compressive strengths of the hollow sandcrete blocks produced with Portland-limestone cement grade 32.5 for all the mix ratios considered. The compressive strengths of the hollow sandcrete blocks moulded with Portland-limestone cement grade 42.5 are 5.11% to 43.85% greater than the compressive strengths of the hollow sandcrete blocks moulded with Portland-limestone cement grade 32.5. The percentage difference between the compressive strengths of the hollow sandcrete blocks moulded with cement with grade 42.5 cement and the compressive strengths of the hollow sandcrete blocks produced with cement grade 32.5 tends to reduce with increase in cement content.

The 1.8347MPa compressive strength obtained from the sandcrete blocks moulded with 1:4 cement grade 32.5 to sand mix ratio is approximately the same as the 1.8673MPa compressive strength obtained from the sandcrete blocks moulded with 1:6 cement grade 42.5 to sand mix ratio. Similarly, the 1.1164MPa compressive strength obtained from the sandcrete blocks moulded with 1:8 cement grade 32.5 to sand mix ratio is approximately the same as the 1.1246MPa compressive strength obtained from the sandcrete blocks moulded with 1:10 cement grade 42.5 to sand mix ratio. Following the same trend, the 1.3855MPa compressive strength of the sandcrete blocks moulded with 1:6 cement grade 32.5 to sand mix ratio is approximately the same as the

1.6059MPa compressive strength of the sandcrete blocks moulded with 1:8 cement grade 42.5 to sand mix ratio. The 1.6059MPa compressive strength of the sandcrete blocks moulded with 1:8 cement grade 42.5 to sand mix ratio is even higher than the 1.3855MPa compressive strength of the sandcrete blocks moulded with 1:6 cement grade 32.5 to sand mix ratio. This results indicate that more quantity of grade 32.5 cement is generally required than the quantity of grade 42.5 cement required to produce sandcrete blocks of approximately the same strength. Since all other factors (such as the aggregate type, size and texture, water-cement ratio, specimen production and curing conditions, test conditions and procedures etc) that affect the compressive strength of hollow sandcrete blocks are exactly the same, the higher compressive strengths of the hollow sandcrete blocks produced with grade 42.5 cement can be attributed to the higher compressive strength of grade 42.5 cement.

V. CONCLUSION

The compressive strengths of the hollow sandcrete blocks produced with cement grade 42.5 cement is generally greater than the compressive strengths of the hollow sandcrete blocks produced with cement grade 32.5 cement irrespective of the mix ratio. The compressive strengths of the hollow sandcrete blocks produced with cement grade 42.5 cement is 5.11% to 43.85% greater than the compressive strengths of the hollow sandcrete blocks produced with cement grade 32.5. To produce sandcrete blocks of the same compressive strength from Portland-limestone cement grades 32.5 and 42.5, more quantity of grade 32.5 cement is generally required. The higher compressive strengths of the hollow sandcrete blocks produced with Portland-limestone cement grade 42.5 can be attributed to the higher compressive strength of cement grade 42.5. Thus, to produce stronger sandcrete blocks in Nigeria which will help reduce the incessant failure of building and other sandcrete blocks-based civil engineering structures, the sandcrete blocks should be moulded with Portland-limestone cement grade 42.5 rather than Portland-limestone cement grade 32.5. It is recommended that the Standards organization of Nigeria should embark on effective public awareness on the presence of cements of different grades in the Nigerian open market and ensure that sandcrete block are moulded with Portland-limestone cement grade 42.5 or higher grade cement.

VI. RECOMMENDATIONS

The Standards Organization of Nigeria (SON) should create adequate awareness for all Nigerians, particularly sandcrete block makers, professionals and stakeholders in the Nigerian construction industry on the different cement grades/strength classes that are available in the Nigerian open market. SON should specify that Portland-limestone cement grade 42.5 be used for sandcrete blocks production in order to improve the strength of marketed sandcrete blocks in Nigeria. SON should also mandate cement manufactures to indicate on the cement bags that only Portland-limestone cement grade 42.5 or a higher cement grade be used for sandcrete blocks production. Nigerian academics and researchers should always confirm the

type of cement and the grade/strength class of the cement they use for their research on sandcrete blocks and indicate the cement type and grade/strength class in their publications so as to enable other researchers confirm/reproduce their work. Nigerian should be encouraged to use cement on the basis of their grade/strength class rather than their brand names. Since there is no significant difference in the cost/price of grade 42.5 cement and grade 32.5 in Nigeria, it will be economical for Nigerians to use grade 42.5 cement for sandcrete blocks production. This is due to the fact that lower quantity of grade 42.5 cement and consequently lower cost would be required than the quantity of grade 32.5 cement and the cost required to produce sandcrete blocks of the same strength.

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