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Effect of Nigerian Portland-Limestone Cement Grades on Concrete Compressive Strength

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***Abstract*—**In this paper, the effect of grades 32.4 and 42.5 Portland-limestone cements generally used for concrete production in Nigeria on concrete compressive strength is investigated. Investigation revealed that the compressive strength of concrete produced with Portland-limestone cement grade 42.5 is generally higher than that produced with cement grade 32.5. The percentage difference between the compressive strengths of the concrete cubes produced with Portland-limestone cement grades 42.5 and 32.5 is inversely proportional to the richness of the concrete with the highest and the least percentage difference associated with the 1:2:4 and 1:1:2 mix ratios respectively. It is recommended that cement grade 42.5 be preferred for construction in Nigeria as this will lead to the construction of stronger concrete structures, which will reduce the incidence of failure of building and other concrete structures at no additional cost since the cost of both cement grades are the same.

***Keywords*—**Cement grades, Concrete, Compressive strength, Portland-limestone cement, Ordinary Portland cement.

I. Introduction

AS stated by [1], concrete is the most widely used construction material. The situation in Nigeria is not an exception as most of the infrastructures in Nigeria such as building, bridges, concrete roads, highways drainages; runway, sea ports and harbours etc are constructed with concrete. Sadly, the failure of building and other concrete structures is very common in Nigeria. The safety, strength and structural integrity of concrete structures depend largely on the quality of concrete used for their construction. In terms of the strength of reinforced concrete structures, one of the most important quality parameters is the compressive strength of the concrete, the other being the tensile strength of the reinforcement bars. The compressive strength of concrete largely depends on the quality and quantity of cement as cement is the strength giver in concrete that binds the fine aggregate (usually sand) and coarse (gravel, crushed granites etc) together to form a rigid/solid mass that is capable of sustaining loads. The most important quality of cement that affects the strength of concrete is the compressive strength of cement. Thus it can be stated that the strength of concrete structures largely depends on the compressive strength of cement used for the construction of the concrete structures. Cement grades and cement strength classes which are synonymous, and which are often used interchangeably give an indication of the compressive strength of cement [2]. Thus it can also be stated that the strength of concrete structures largely depends on the grade or the strength class of cement since the strength of concrete which largely determines the safety, strength and structural integrity of concrete structures depends on the grade or the strength class of cement.

Cement grade or cement strength class corresponds to the minimum 28th day compressive strength of cement [2]. Generally, there are three cement grades: grade 33, grade 43, and grade 53 which are also referred to as cement strength classes 32.5MPa, 42.5MPa and 52.5MPa respectively [2]. Grade 33, grade 43, and grade 53 represent cements with a minimum of 32.5MPa, 42.5MPa and 52.5MPa compressive strengths respectively. In terms of the quality assurance of cement, any cement with a compressive strength of 32.5MPa would be adjudged as meeting the strength requirement of cement grade 32.5. Consequently, any cement manufacturer whose target is the production of cement grade 42.5 can easily downgrade the cement to grade 32.5 cement if the compressive strength of such cement is not up to 42.5MPa. Thus, cement grade 32.5 or cement with the strength class of 32.5MPa is the lowest strength cement when compared with cement grade 42.5 and cement grade 42.5.

Prior to the adoption and implementation of the present Nigerian Industrial Standards for cement NIS 444-1:2003 [3], which makes provisions for different grades and different types of cement, Ordinary Portland Cement (OPC) was the only cement known to Nigerians as it was the only cement available in Nigerian market and the only cement approved for production by the old Nigerian Industrial Standards (NIS) for cement NIS 11: 1974 [4]. Both NIS 11: 1974 [4] and NIS 439:2000 [5] did not make any provision for the production of cement of different grades. NIS 11: 1974 [4] specified that OPC be made of clinker and gypsum (calcium sulphate) alone with no additional major or minor constituent. NIS 439:2000 [5] specified that OPC be made of clinker and gypsum both of which constitute 95% to 100% of the cement. NIS 439:2000 [5] only made a provision for the addition of 0%-5% minor additional constituent of calcarious material (e.g. limestone).

OPC which is now simply referred to as Portland cement and designated as CEM I in the present Nigerian Industrial Standards for cement NIS 444-1:2003 [3] is exactly the same OPC/CEM I specified in [5] (i.e. cement with 95% to 100% clinker and gypsum, and 0%-5% minor additional constituent). During the corresponding authors' participation in the quality conformity assessments of cement produced in Nigeria, it was reliably established that OPC/CEM 1 is not produced in bagged form for Nigerian open market as OPC/CEM I is only

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produced in bulk form on request for the "special customers" such as Julius Berger and other big multinational construction firms that handle only very big building and construction projects. The fact that OPC/CEM I is not produced for Nigerian open market is also established by the fact that no bagged OPC/CEM I is available in Nigerian open market till date. Thus, it can be concluded that none of the cement in bagged form, which is the form that is used by majority of Nigerians for building and other concrete structures construction is OPC as they are all Portland-limestone cement designated as CEM II in NIS 444-1:2003 [3].

Portland-limestone cement/CEM II belongs to the type of common cement called Portland-composite cement, which is a generic term for Portland cement/OPC plus a single secondary major constituent [6]. Unlike OPC which is mainly produced from clinker and gypsum alone, Portland-limestone cement/CEM II is produced by adding 6-35% of limestone to OPC. Consequently, Portland-limestone cement/CEM II has a lower clinker content of 65-94% clinker compared with OPC with 95-100% clinker. Clinker is the main strength given constituent of cement. Limestone is added to OPC/CEM I to produce Portland-limestone cement/CEM II because it is easier to grind than clinker and is cheaper than clinker [7]. Portland-limestone cement/CEM II with 80-94% clinker and 6-20% limestone is designated as CEM II/A-L while Portland-limestone cement/CEM II with 65-79% clinker and 21-35% limestone is designated as CEM II/B-L.

Cement manufacturers in Nigeria produce grades 32.5 and 42.5 of both CEM II/A-L and CEM II/B-L with ordinary early strength and with a high early strength. However, the most common cements available in the Nigerian open market that are well known and which are being used for the construction of concrete structures by majority of Nigerians are the ordinary early strength CEM II/B-L 32.5N and ordinary early strength CEM II/A-L 42.5N. The main difference between the ordinary early strength cement (commonly known as normal setting cement) and the high early strength (commonly known as rapid setting cement) is in their rate of strength acquisition as there is no significant difference between their 28 days standard strength. Generally, Portland-limestone cement/CEM II has a slightly shorter setting time than OPC/CEM I [8]. More importantly, as stated by Lafarge Cement UK Limited [8] (one of the major cement manufacturers in the world), to produce a concrete of the same strength from OPC/CEM and Portland-limestone cement/CEM II of the same grade, more of Portland-limestone cement/CEM II may be needed. For example, to produce a concrete of the same strength from OPC/CEM I 32.5N and Portland-limestone cement/CEM II/A-L 32.5N, more of CEM II/A-L 32.5N may be needed.

Till date, many Nigerians including practising Engineers, Academics, Researchers, Contractors, Bricklayers, Masons and others professionals in Nigerian construction industry are neither aware of the fact that OPC no longer exist in bagged form in the Nigerian market nor are they aware of the different cement grades in Nigeria and their effects on the compressive strength of concrete. This explains why in the work of [9]-[18], amongst others, all of which conducted their research with bagged Portland-limestone cement (CEM II/A-L) bought in the Nigerian open market referred to the cement they used for their research as OPC instead of Portland-limestone cement (CEM II/A-L). Also the lack of awareness of the different cement grades in Nigerian market by these ten researchers amongst others also explained why the researchers never indicated the grade/strength class of the cement they used for their research. Generally, most Nigerians still believe that the bagged Portland-limestone cement in the Nigerian open market is the same as the OPC with the same strength they have been using in the past (before the implementation of [3] in 2003) and they tend to buy cement based on the old brand names and not on the basis of the cement grade/strength class. Grade 33 cement or cement of strength class 32.5MPa hereinafter referred to cement grade 32.5 which is the lowest strength cement is still widely used in Nigeria as it represents well over 50% of the bagged cement available in Nigerian open market, particularly in south-western part of Nigeria.

Studies have been conducted on the grade of cement and concrete strength by [19] and [20] in India and Egypt respectively. However [19]'s work was conducted on OPC and fly ash-based Portland Pozzolana cement of grade 42.5 and grade 52.5, while [20]'s work was conducted on OPC of grades 52.5, 42.5 and 32.5; Portland-slag cement of grade 32.5 (CEM II-B-S 32.5N) and Portland-limestone cement of grade 32.5(CEM II-B-L -32.5N). To the best of the authors' knowledge, neither the comparison of the effect of Portland-limestone cement of grade 32.5 and grade 42.5 on the compressive strength of concrete in general nor the comparison of the effect of Portland-limestone cement of grade 32.5 and grade 42.5 in the Nigerian market on the compressive strength of concrete in particular has not been published. There is the need to compare the effect of Portland-limestone cement grades 32.5 and 42.5 on the compressive strength of concrete because unlike the comparison of the effect of OPC grades 32.5 and 42.5 on concrete compressive strength which has been published, detailed comparison of the effect of Portland-limestone cement grades 32.5 and 42.5 on the compressive strength of concrete has not been published. The need to compare the effect of Portland-limestone cement grades 32.5 and 42.5 on the compressive strength of concrete cannot be overemphasized considering the fact that as stated by Lafarge Cement UK Limited [8], Portland-limestone cement is different from OPC in terms of the setting time and in terms of the quantities of Portland-limestone cement and OPC required to produce concrete of the same compressive strength.

In this paper, the effect of Portland-limestone cement grades 32.5 and 42.5 that are readily available in Nigerian open market on the compressive strength of concrete is investigated. The investigation of the effect of Portland-limestone cement of grade 32.5 and grade 42.5 was conducted by comparing the strengths of concrete cubes produced from three mix ratios moulded with Portland-limestone cement of grade 32.5 and grade 42.5 bought at the same amount from the Ibadan depots of two major cement manufacturers in Nigeria. The comparison of the effect of the different grades of OPC

was not conducted as the authors had no access to OPC since OPC is not available in Nigerian open market.

II. Experimental

No experimental work to confirm the compressive strength of the Portland-limestone cement employed for this research was conducted by the authors because the Standards Organisation of Nigeria (SON), the agency in charge of standardisation in Nigeria has adjudged the cement to be of the right quality as the manufactures of the Portland-limestone cement have NIS quality certificates and the cements used are SON quality award winners. The concrete used for this research was produced with cement grade 32.5 and cement grade 42.5 bought directly from their manufacturers' depots in Ibadan which guaranteed that good quality cements (not rebagged or adulterated cement and properly stored) were used for the research. The concrete used for this research was also produced with river sand (generally known as sharp sand) and 20mm crushed granites that are commonly used for concrete production in Nigeria. The particle size distribution of the sand was determined by sieve analysis. The concrete was produced with water of drinkable quality. Concrete cubes were cast/moulded with three mix ratios of 1:2:4; 1:1.5:3; 1:1:2. These ratios represent the ratios of cement to sand to crushed granite by weight. 0.5 water-cement ratio was employed for the research. The concrete cubes were made and cured in accordance with BS EN 12390-2:2009 [21]. The concrete cube moulds were filled in three layers with each layer manually compacted with 25 blows of tamping rod. The top surface of the cubes was smoothened and leveled with a hand trowel. The concrete cubes were demoulded after twenty four hours and cured for twenty eight days. For each cement grade and for each mix ratio considered, ten 150x150x150mm concrete cubes were subjected to compressive strength test in accordance with BS EN 12390-3:2009 [22].

III. Result

The particle size distribution curve for the sand used for this work is presented in Fig. 1. The average compressive strengths for the concrete cubes made with grade 32.5 cement and grade 42.5 cement for all the mix ratios considered are presented in Table I.

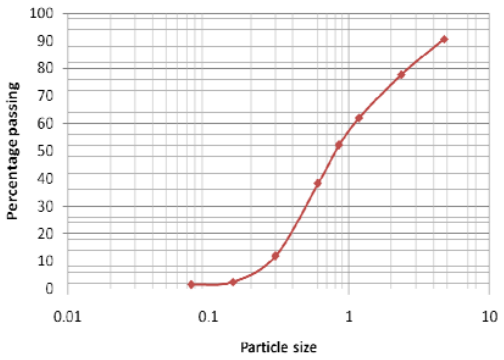

Fig. 1 Sand particle size distribution curve

TABLE I
Concrete Cubes Compressive Strengths

Mix ratio	Strength N/mm^2		Percentage difference
	Cement grade 42.5	Cement grade 32.5	
1:2:4	29.8	24.5	17.78
1: 1½: 3	30.1	27.0	10.30
1:1:2	30.6	29.6	3.27

IV. Discussion

From Table I, it is evident that the compressive strengths of the concrete cubes produced with cement grade 42.5 are generally greater than the compressive strengths of the concrete cubes produced with grade 32.5 cement irrespective of the mix ratio. The compressive strengths of the concrete cubes produced with cement grade 42.5 are up to 17.78% greater than the compressive strengths of the concrete cubes produced with cement grade 32.5 depending on the richness (quantity of cement) of the concrete. The percentage difference between the compressive strengths of the concrete cubes produced with cement grade 42.5 and cement grade 32.5 is inversely proportional to the richness of the concrete with the highest and the least percentage difference associated with 1:2:4 and 1:1:2 mix ratios respectively. The higher compressive strengths of the concrete cubes produced with grade 42.5 cement are due to the higher compressive strength of grade 42.5 cement since all other factors that affect the compressive strength of concrete such as the aggregate type, size and texture, water-cement ratio, specimen production and curing conditions, test conditions and procedures etc are exactly the same.

V. Conclusion

There is no ordinary Portland cement in bagged form in the Nigerian market as many Nigerians believe as the bagged cement in Nigerian market are Portland-limestone cement designated as CEM II/A-L and CEM II/B-L in the current Nigerian Industrial Standards for cement NIS 444-1:2003. The presence of different grades of cement in Nigerian market is not well known to practicing Engineer, Contractors, Academics, Researchers, Bricklayers, Masons and others professionals in Nigerian construction industry as these professionals are only aware of the different cement brand names and not the different cement grades. The compressive strengths of the concrete cubes produced with grade 42.5 cement is generally greater than the compressive strengths of the concrete cubes produced with cement grade 32.5 cement irrespective of the mix ratio. The percentage difference between the compressive strengths of the concrete cubes produced with cement grade 42.5 and cement grade 32.5 is inversely proportional to the richness of the concrete with the highest and the least percentage difference associated with 1:2:4 and 1:1:2 mix ratios respectively.

VI. Recommendations

There is the need for the Standards Organisation of Nigeria (the agency in charge of standardization) to create awareness

for all Nigerians generally and professionals and stakeholders in Nigerian construction industry in particular on the different cement grades/strength classes that are available in Nigerian market. The Standards Organisation of Nigeria should also make it known to Nigerians that cement grade 42.5 are generally stronger than grade 32.5MPa cement. Since the cost/price of cement grade 42.5 and cement grade 32.5 is approximately the same in Nigeria, Nigerians should prefer the use of grade 42.5 cement for both structural and non-structural applications. This is due to the fact that concrete made with grade 43 cement are stronger than concrete made with grade 32 cement. Thus, the use of grade 42.5 cement will lead to the construction of stronger buildings and other concrete-based civil engineering structures in Nigeria. Also, the use of grade 42.5 cement is more economical as a lower quantity of grade 42.5 cement would be required than the quantity of grade 32.5 cement required to achieve the same strength for both structural and non-structural applications. The use of cement grade 42.5 rather than grade 32.5 will ensure that buildings and other concrete structures in Nigeria are stronger and reduce the frequency of the incessant collapse of building and other concrete structures in Nigeria.

REFERENCES

[1] T. R Naik, "Practice periodical on structural design and construction, ASCE, pages 98-103, 2008.
[2] Raw Polymers Ltd – Cement division, http://www.ordinaryportlandcement.com/portlandcement-grades/, accessed on the 19/01/2014.
[3] NIS 444-1:2003. Composition, specification and conformity criteria for common cements. Standards Organisation of Nigeria.
[4] NIS 11: 1974: Specification for ordinary Portland cement, Standards Organisation of Nigeria.
[5] NIS 439:2000. Standard for cement. Standards Organisation of Nigeria.
[6] BS EN 197-1:2011. Cement Part 1: Composition, specifications and conformity criteria for common cements, British Standards Institute.
[7] P. Hawkins, P. D. Tennis and R. J. Detwiler, "The Use of Limestone in Portland Cement: A State-of-the-Art Review", Portland Cement Association, Skokie, Illinois, USA, 2003.
[8] Lafarge Cement UK Limited, Portland limestone cement, 2002. http://www.lafarge.co.uk/CementDatasheet/Portland%20Limestone%20Cement.pdf, accessed on 24/04/2012.
[9] C. Emiero, O. J. Oyedepo, "An Investigation on the Strength and Workability of Concrete Using Palm Kernel Shell and Palm Kernel Fibre as a Coarse Aggregate", International Journal of Scientific & Engineering Research vol 3, Issue 4, pages 1-5, 2000.
[10] K. A. Mujedu, I. O. Lamidi, D. O. Ayelabola, "An Investigation on the Suitability of the Broken Tiles as Coarse Aggregates in Concrete Production", The International Journal Of Engineering And Science, vol 3, Issue 4, pages 35-41, 2014
[11] J. O. Ukpata, M. E. Ephraim, G. A. Akeke, "Compressive strength of concrete using lateritic sand and quarry dust as fine aggregate", ARPN Journal of Engineering and Applied Sciences, vol 7, Issue 1, pages 81-92, 2012.
[12] M. Abdullahi, "Effect of aggregate type on Compressive strength of concrete", International Journal of Civil and structural engineering, vol 2, Issue 3, pages 791-800, 2012.
[13] L. M. Olanitori, "Cost Implication of Mitigating the Effect of Clay/Silt Content of Sand on Concrete Compressive Strength", Journal of Civil Engineering and Urbanism, vol 2, Issue 4, pages 143- 148, 2011.
[14] S. P. Ejeh, O.A.U. Uche, "Effect of Crude Oil Spill on Compressive Strength of Concrete Materials", Journal of Applied Sciences Research, vol 5, issue 10, pages 1756-1761, 2009
[15] J. I. Aguwa, "Effect of Hand Mixing on the Compressive Strength of Concrete, Leonardo Electronic Journal of Practices and Technologies, Volume17, pages 59-68, 2010.
[16] G. L. Oyekan, O. M. Kamiyo, "Effect of Nigerian rice husk ash on some engineering properties of concrete and sandcrete blocks. Proceeding of the 32nd Conference on Our world in concrete and structures, 28 - 29 August 2007, Singapore.
[17] D. O. Onwuka, L. Anyaogu, C. Chijioke, W .E. "Igwegbe, Optimization of Compressive Strength of River Sand-Termite Soil Concrete Using Simplex Design", International Journal of Scientific and Research Publications, vol 3, Issue 5, pages 1-8, 2013.
[18] D. Dahiru, N. Shehu, "An evaluation of the concrete production in typical construction sites in Nigeria", Proceedings of the 4th West Africa Built Environment Research (WABER) Conference, 24-26 July 2012, Abuja, Nigeria, Pages 463-472.
[19] R, Mathur, A. K. Misra, P. Goel, "Strength of Concrete vs Grades of Cement", Central Road Research Institute, New Delhi. http://www.nbmcw.com/articles/concrete/25796-strength-of-concrete-vs-grades-of-cement.html. Assessed on 17th April, 2014.
[20] H. A. Hodhod, M. A. M Abdeen, "Experimental Comparative and Numerical Predictive Studies on Strength Evaluation of Cement Types: Effect of Specimen Shape and Type of Sand", Scientific research, Engineering, Volume 2, pages 559-572, 2010.
[21] BS EN 12390-2:2009. Testing hardened concrete. Part 2: Making and curing specimens for strength tests. British Standards Institute.
[22] BS EN 12390-3:2009. Testing hardened concrete. Part 3: Compressive strength of test specimens. British Standards Institute.