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Development of Enhanced Strength Concrete Using 10 Mm (3/8") All-In Gravel and Quarry Dust as Aggregates

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Abstract

This paper reports the results of an experimental study on various concrete mixes using quarry dust, 10mm (3/8") gravel and admixture for the development of enhanced strength in concrete. Concrete mixes of 1:1:2 and 1:2:1 was subjected to standard laboratory tests to determine their physical characteristics of aggregates as well as the concrete mixes in their wet and hardened states. A total of 144 cubes were cast at water-cement ratios of 0.35, 0.40, 0.45 and 0.55. A water reducing admixture Aura Mix 4225 was introduced in each mix in contents of 0.75, 0.85, 0.95 and 1.2 of cement. The compressive strength tests were conducted on the specimens after 3 days, 7 days, 14 days and 28 days wet curing. The 1:1:2 mix yielded a maximum compressive strength of 44.44 N/mm^2 at 0.35 water-cement ratio and Aura Mix content 1.2; 49.3 N/mm^2 at water-cement ratio of 0.4 and Aura Mix content 0.95 and 40.0 N/mm^2 at water-cement ratio of 0.5 and Aura Mix content 0.95. These were far higher compared to that of the normal concrete produced without admixture, for which an average compressive strength of 25.33N/mm^2 at 28 days for 0.45 water-cement ratio is documented. The compressive strength values obtained with admixture falls within medium strength concrete grade 50 concrete and hence good for most structural works with medium compression requirements.

Keywords: Compressive strength; Workability; Admixture; Water cement ratio

Introduction

On the basis of recent statistics, Nigeria needs to provide at least one million housing units per annum to meet the country's housing deficit. Consequently, the present administration has made the provision of adequate housing for the citizenry a cardinal point in the transformation agenda and the vision 20:2020 programme. This has led to establishment of the Federal Ministry of Land and Housing in 2010, with a clear mandate for the provision of adequate and affordable housing for her citizens.

The most commonly used aggregates for concrete work are granite (chipping) and fine sand derived from crushed stone and river quarrying respectively. The global consumption of these naturally occurring materials for infrastructural growth has resulted in supply scarcity and hence the need for alternative local materials. Chippings and fine sand have in this research, been fully replaced by 10mm (3/8") all-in-one aggregate and quarry dust which are local materials predominant within the Niger Delta Region of Nigeria. Quarry dust, a by-product of stone crushing unit lie waste in abundance within the quarry zones of the country and constitute environmental load.

The conversion of these materials for useful application in medium strength concrete work will add value to the economy and help create job opportunities for teaming Nigerian youths. Attempts to investigate the independent use of gravel and quarry dust as aggregates are documented in several recent studies. Ephraim and Ode [1] established from their research that 10mm gravel is rather deficient in fine particles and that concrete produced with these materials at optimum W/C ratio of 0.65 represent a grade 15 concrete. From the conclusions of Pedro Nel Quiroga [2], Neville and Brooks [3], Joel and Agbede [4], Ukpata and Akeke [5], Ilangovana et al. [6] among others, the compressive strength of various concrete mixes with 10mm gravel and quarry dust fall between 15-34.50N/mm^2 while the workability varied from 20mm-110mm.

The current trend in construction engineering and design is witnessing a gradual change from normal strength concrete to medium strength concrete. Given the low strengths recorded in previous studies, the authors recognized the need to investigate various concrete mixes with a view to improving the strength and durability of the 10mm gravel and quarry dust concrete system.

Statement of the problem

This research work is aimed at obtaining concrete of medium compressive strength produced with 10mm gravel and quarry dust as total replacement for conventional chippings and fine sand; investigate their mechanical and physical properties; and developing standards and specifications for the use of these materials in the design of concrete mixes for engineering construction which will help both local and global practitioners to achieve durability and functionality within the design period.

The result of this study will help to determine a suitable limit for specification of these materials in structural applications, guarantee safety in structural concrete work, improve economy in waste management cost and create jobs within the catchment areas.

Materials and Methods

The method and procedure employed in this research work involved the various laboratory tests on fresh and hardened concrete. A preliminary test and analysis were carried out on the materials. These included particle size distribution, fineness modulus, specific gravity, bulk modulus to ascertain physical characteristics and the grading limit of the local materials. A total of 144 British Standard 150mm x 150mm x 150mm cubes were produced from concrete 1:1:2 and 1:2:1 using unwashed 10mm gravel and quarry dust as aggregates by weight at water-cement ratios of 0.35, 0.40, 0.45, 0.50 and 0.55. A water reducing admixture Aura Mix 4225 was introduced in each mix in contents of 0.75, 0.85, 0.95 and 1.2 of cement.

27 cubes were produced from each combination of mix, water cement ratio and admixture content, and subjected to compression test after 3, 7, 14 and 28 days wet curing. Slump test was also performed on all the fresh concrete produced to obtain the workability. The results were analyzed to arrive at reasonable conclusions from which recommendations were made as compared to similar works of other researchers. The test set ups are depicted in Figure 1.

Figure 1: Progress photographs of laboratory tests.

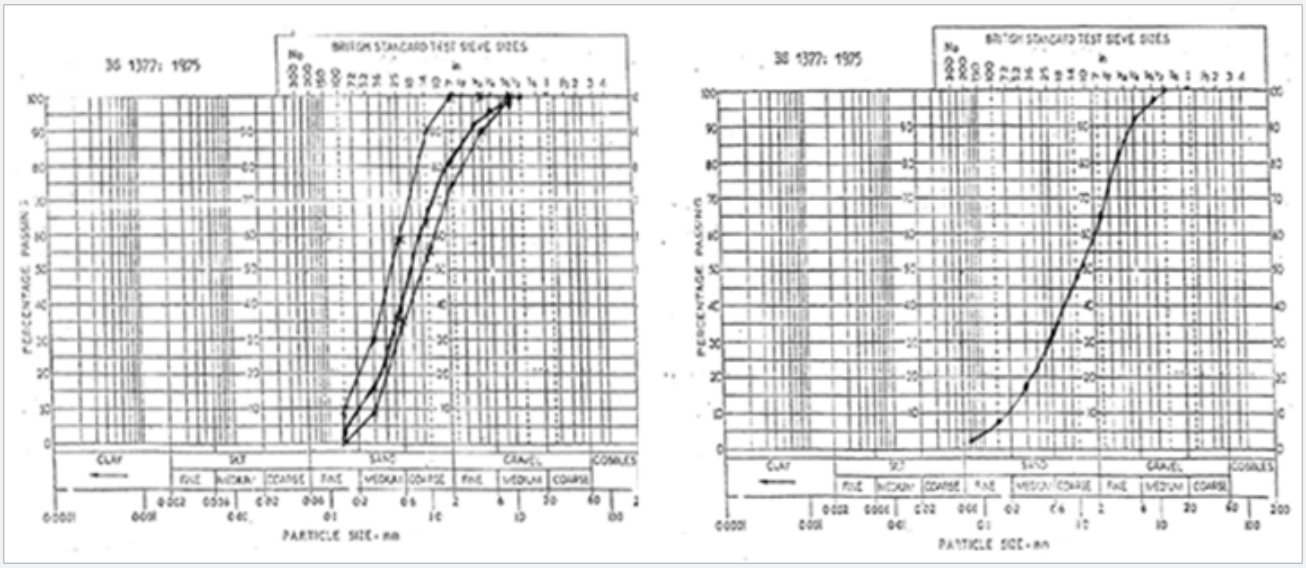

Figure 2: Particle size distribution plots for 10mm all in Gravel and Quarry dust.

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Results and Discussion

The results obtained from the various tests are presented and discussed under the relevant subheading.

The particle size distribution

The results of the particle size distribution are plotted in Figure 2 for the 10mm gravel aggregates and quarry dust. The particle distribution (PSD) analysis carried out showed the grading limits and fractions of particles. The results are in conformity with the specifications of BS1881, BS882, BS5328 and IS383-1970. The distribution extended from fine sand to medium gravel. A 97.64% passing was seen from 10mm (3/8") gravel on a sieve size of 9.5mm. The grading limit gave 73% sand (20% coarse, 70% medium and 10% fine) and 27% gravel. Also observed was that of quarry dust in which 100% passing for a sieve size of 9.5mm and a few particles retained on the 4.5mm sieve accompanied a distribution from fine sand to fine gravel.

The fineness modulus was 2.03 and 3.05 for gravel and quarry dust respectively. These values fall within the limit (2.5-3.2) specified by Ode [4], BS882 and Nawy [7,8] and are good for workable concrete. An Fm of 3.1 is for higher case of coarse aggregates.

Compressive strength

Table 1: Compressive Strength Values for 1:1:2 and 1:2:1 Mixes.

W/C	Admixture (1:1:2 mix)			W/C	Admixture (1:2:1 mix)		
	0.75	0.85	0.95		0.75	0.8	1
0.35	40	42.44	43.44	0.45	27.55	28.44	29.31
0.4	38.7	40	49.3	0.5	21.77	24.44	25.77
0.45	40	39.6	40	0.55	21.77	23.11	24.88

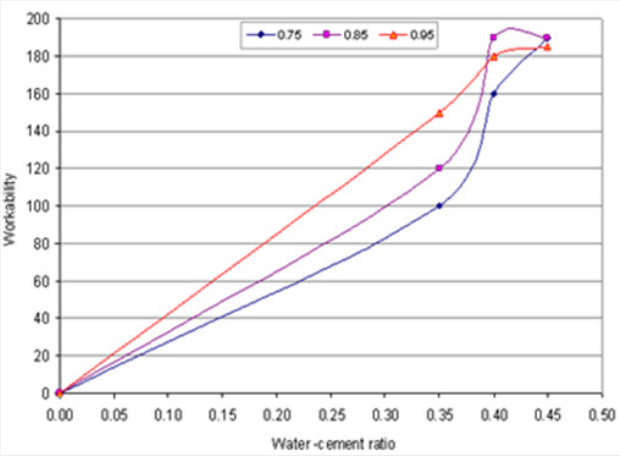

Figure 3: Effect of W/C Ratio on Workability.

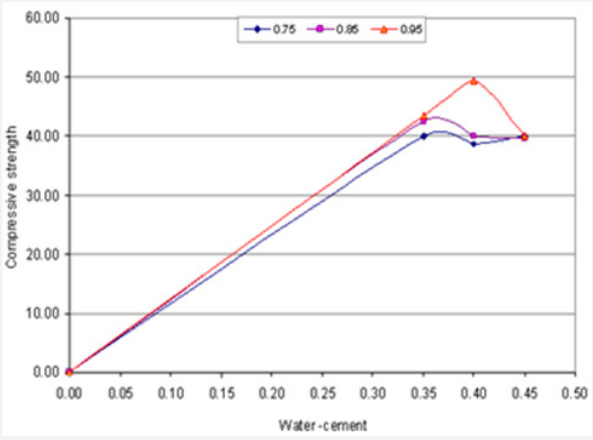

Figure 4: Compressive Strength against Water Cement Ratio (with Admixture).

The average compressive strength values of the hardened concrete are presented in Table 1 and plotted in Figures 3, 4 for the two mixes investigated.

The results show that complete hydration of cement took place at the optimum water-cement ratio of 0.40 and admixture of 0.95 content for the 1:1:2 mix. The corresponding values for the 1:2:1 mix were 0.45 water cement ratio and 1.0 admixture content. From Figures 3 & 4 above, the 0.4 water-cement ratio gives the highest compressive strength of 49.3N/mm^2 with workability 180mm and this gives the optimum specification for 1:1:2 mix. This is compared to mix 1:2:1 with a higher water requirement due to increase in complete surface absorption by quarry dust.

Conclusion

On the basis of the analysis of experimental results obtained in this study, it can be concluded that:

a. 10mm gravel and quarry dust properties conform to the BS 882 specifications and can be used as replacement for conventional materials.

b. The workability test results were 160mm, 180mm and 185 mm at admixture contents of 1.2, 0.95 and 0.95 percent for water-cement ratios of 0.35, 0.40 and 0.45 for 1:1:2. The corresponding values of 35 mm, 39 mm and 45 mm at admixture content of 1.0 for water-cement ratio of 0.45, 0.50 and 0.55 were obtained for 1:2:1 mix.

c. The 1:1:2 mix yielded compressive strength within the range of 39.6-49.3N/mm^2 at 28 days while the 1:2:1 gave average compressive strength of 29.39N/mm^2 at 28 days curing age for a water-cement ratio of 0.45 and admixture of 1.0.

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d. The water absorption for durability was observed to fall within the limit specified in BS 1881.

Recommendation

For durable concrete to be workable and posses medium strength using these materials, a water-cement ratio of 0.40 at admixture of 0.95 and water-cement ratio of 0.45 at admixture of 1.0 should be adopted for 1:1:2 and 1:2:1 mixes respectively.

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