Effects of Water-Cement Ratios on the Compressive Strength and Workability of Concrete and Lateritic Concrete Mixes.

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ABSTRACT

The variations of the compressive strengths of concrete and lateritic concrete mixes with water-cement ratios of range 0.55 and 0.80, within 7 to 28 days after casting, were experimentally investigated in this research work. The experiment was carried out at the same ambient temperature and the compressive strengths of both concrete and lateritic concrete mixes were found to increase with age but decrease as the water-cement ratio increases. However, water-cement ratio above 0.65 was observed to have a very significant reduction effect on the compressive strength of the lateritic concrete mixes. This is in contrast to the performance of the concrete mixes which shows consistent decrease of compressive strength in water-cement ratio. Also, the degrees of workability of both concrete mixes were investigated using slump test.

From the findings of this research, lateritic concrete is not workable compared to the normal concrete. Though laterites are usually used for brick making, they are not recommended for making concrete in construction industry.

(Keywords: water-cement ration, lateritic concrete mixes, compressive strengths, workability)

INTRODUCTION

Concrete is one of the most used materials in building and civil engineering construction works. It is a composite material that could be used alone or reinforced with other materials like steel (or possibly with local material like oil palm fibers) depending on the design of the structure. Concrete could be defined as an artificial material resulting from a carefully-controlled mixture of cement, water and aggregate (fine and coarse e.g., sand and gravel) which takes the shape of its container or formwork when hardened and forms a solid mass when cured at a suitable temperature and humidity.

Concrete is brittle and weak in tension but its compressive strength is about ten to thirteen times greater than the tensile (Lafe, 1986). However, Mosley and Bungey (2000) found the compressive strength to be about eight times greater than the tensile. The tensile strength of concrete is commonly neglected in the design of most ordinary structural elements. However, in the design of some structures that are required to contained liquids the tensile strength is taken into consideration. Ideal, standard and good concrete (whether plain, reinforced or pre-stressed) should be strong enough to carry superimposed loads during its anticipated life. Impermeability, durability, shrinkage, cracking, surface wear and cavitations are other properties of good concretes. Different types of concrete include high-alumina concrete, fibrous concrete, lateritic concrete, etc. (Alan, 1970).

Lateritic concrete could be defined as any concrete mixes which uses laterite as a substitute for sharp sand in a specific mix design ratio to give an appropriate strength, appearance and workability using the correct water-cement ratio. Laterite as an aggregate is cheaper and most common and, therefore, could be considered for possible usage as a replacement for sharp sand in concrete mixes.

Aggregate consists of uncrushed or crushed gravel, crushed stone or rock, laterite for lateritic concrete, sand or artificially produced inorganic materials. Aggregates (fine and coarse) constitute between two-third and one-quarter of the total volume of concrete and the careful selection and proportioning of aggregate greatly affect all the important properties of both plastic and hardened concretes. The use of aggregates also improves several of the properties of the hardened concrete such as volume stability and durability of concrete (Nevils, 1983).

The compression strength of concrete is usually determined by performing compression test on standard sizes of concrete blocks or cylinders. The strength of concrete is affected partly by the relative proportion of cement and of the fine and coarse aggregates but the water-cement ratio is another important factor. There is an optimum amount of water that will produce a concrete of maximum strength from a particular mix of fine and coarse aggregate and cement (Lafe, 1986).

The ease of working with the concrete (i.e. workability) also depends on the quality of water used. The use of less than the optimum amount of water may make setting difficult and reduce workability. On the other hand, greater shrinkage and a reduction in strength will occur when more water than the optimum amount is used. The best water-cement ratio, therefore, depends on the particular concrete mix.

Several research work had been conducted on concrete and lateritic soil in the past by evaluating their properties with a view to predicting and controlling their performance in practical applications.

Among the research works conducted on concrete is the one by Umoru *et al.*, (2003) where they investigated and compared the corrosion characteristics of NST-37-2 and NST-60-Mn rebars in concrete exposed to selected acidic, saline and alkaline media. Measurement of the corrosion rate of the steel reinforcements were carried out using gravimetric techniques and the results show that the breakdown of passivity around steel reinforcements, that eventually led to their corrosion, is dependent on the nature and concentration of aggressive ions in the media. It also showed that the corrosion rate of NST-37-2 exceeds that of NST-60-Mn by as much s doubling or higher at lower duration of exposure of 100 hours and almost the same at the highest duration of exposure of 600 hours in all the media investigated.

Also, Salau and Sadiq (2001) investigated the possibility of oil palm fiber strips, obtained locally from oil palm trunks, as a substitute for steel reinforcement in concrete. Tests were performed on flexural resistance and deflection characteristics of concrete beams reinforced oil palm fiber strips. It was found that the use of oil palm fiber strips as reinforcement in concrete improves the flexural strength, post cracking ability and serviceability performance of plain concrete. Also, the ultimate flexural strength of oil palm fiber strip-reinforced concrete with low volume contents compared favorably with lightly mild steel-reinforced beam section.

Among the research carried out on lateritic soil are those done by Ola (1979) and Mataiwal (1982) on lateritic soils in Jos, Nigeria. Also, Matawal and Adepegba (1989) studied Bauchi lateritic soil, also in Nigeria, by including other tests for permeability consistency limit and shear strength characteristics. Results obtained from the tests confirmed the variability in behavioral patterns and properties due to variations in the uniform combinations of clay, sand and gravel.

In his work on genetic influence of compaction CBR characteristics of three lateritic soils in Ile-Ife, Nigeria, Meshiba (1987) investigated among other things the moisture content/density relationship of the soils. After the PSD analysis, the lateritic soils (mica schist, amphibolite and granite gneiss) were subjected to modified AASHO compaction tests. It was discovered that while the poorly graded mica schist soils have relatively low values of maximum dry density, the well-graded amphibolite and granite soils have high values. It was then concluded that particles sizes re-arrangement in the two well-graded soils during compaction are such that higher density could be imparted on them.

However, the present work aims at experimentally comparing the compressive strength and workability of concrete and lateritic concrete mixes under varied water-cement ratios.

METHODOLOGY

Work Materials and Specimens Preparation

The research materials used in this investigation are cement, sand, gravel, laterite and water. Sand size distributions were determined by sieve analysis test which is a process of dividing a sample of aggregate (fine and coarse). A sample of air-dried aggregate was graded by shaking or vibrating a nest of stacked sizes with the largest sieve at the top for the material retained to be coarse compared to the sieve but finer than the sieve above. To evaluate the compressive strength and workability, cube and slump tests were then carried out.

EXPERIMENTAL TEST PROCEDURES

Cube Test: A 6 kg weight of fine aggregate was weighed on a 15cm × 15cm × 15cm pan physical balance and then poured into a wheel barrow. Three kilogram of cement was added and it was thoroughly mixed with the sand. Also, a 12 kg weight of gravel was measured and added to mix. Water-cement ratios of 0.55, 0.60, 0.65, 0.70 and 0.80 (having respective water quantities of 650cl, 1800cl, 1950cl, 2100cl, and 2400cl) were then used with the aggregates. With the addition of water into the mix, the whole mix was then mixed thoroughly into a fine paste. Meanwhile, the concrete moulds/cubes were oiled (lubricated) to prevent the concrete from sticking to them and for easy de-moulding.

The concrete was then poured into the cube and placed on the compacting machine, which when switched on vibrated the cubes, making the concrete to lose the trapped air in the mix. This was allowed for 2 minutes before the switching off. The excess concrete was cleared from the surface with the aid of the travel and the cubes were marked for easy identification to prevent mix-up. These processes were repeated for casting lateritic concrete but the sand was replaced with laterite.

After the casting of the cubes, they were allowed to set and harden for 24 hours before de-moulding. The cubes were then covered with polythene sheets to prevent excess evaporation.

After de-moulding the cubes were placed in a curing tank for specified numbers of days (i.e., 7, 14, 28 days, respectively). At each specified period of days, the cubes were crushed to determine the compressive strength of the concretes. The bearing surfaces of the crushing machine were wiped clean and the test cubes well placed for the load to be applied to the opposite side of the cube as casted. Also, the axes of the cubes were carefully aligned in the centre of the plates.

Slump Test: A means of evaluating workability of concrete is the slump test. Slump is the distance through which a cone full of concrete drops when the cone is lifted. The apparatus used for the slump test are tamping rod, a cone, measuring rule, scoop, straight edge and a clean platform. Cement, sand, gravel, and laterite of 3 kg were used. 12 kg weight of gravel was measured and added to mix. Water-cement ratios of 0.55, 0.60, 0.65, 0.70, and 8.0 were then used with the aggregates. The specific gravity of sand, gravel and cement are 2.5, 3.5, and 3.142, respectively.

The mix proportion used is 1:2:4 and batching was by weight. The mould for the slump test is a frustrum or cone whose inside was moistened; it was placed on a smooth surface with the smaller opening at the top, and filled with concrete in three layers. Each layer was tapped twenty five times with a standard 16 mm diameter steel rod, rounded at the end as the tamping rod. The mould was firmly held against its base during the test, this was facilitated by handles or foot-rest brazed to the mould.

Immediately after filling, the cone was slowly lifted and the unsupported concrete then slumped. The decrease in the height of the concrete was then measured. Concrete which incidentally dropped immediately around the base of the cone was cleaned off.

RESULTS AND DISCUSSION

<u>Effect of Water-Cement Ratios on the Compressive Strength of Concrete and Lateritic Mixes</u>

Table 1 shows the variation of the variations of weight, density and crushing/compressive strength of concrete mixes with water-cement ratios. It was observed that the weight, density and compressive strength of the concrete cubes decrease with increase in water-cement ratio. However, the compressive strength was observed to increase with age; after casting the concrete mixes, the compressive strength increases as the number of curing day increases. This shows that the water-cement ratio is the main determinant of the weight, density and crushing strength of the concrete cubes.

The plot of compressive strength of the concrete mixes versus water-cement ratio is shown in Figure 1 while Figure 2 shows the plot of compressive strength versus age. For the respective water-cement ratio, the compressive strength was observed to be highest at 28 days after casting. Also, during each testing, the compressive strength of the concrete mixes was observed to be highest at 0.55 water-cement ratio.

Table 1: Variations of Weight, Density, and Compressive Strength of Concrete Mixes with Water-Cement Ratio.

S/N	Mix Proportion	Water-Cement Ratio	Date of Casting	Date of Casting	Age (day)	Weight of Cube (g)	Density of Cube (g/cm^3)	Crushing Load (KN)	Compressive Strength (N/mm^2)
1	1:2:4	0.55	04-07-05	11-07-05	7	8100	2.400	245	10.89
2	1:2:4	0.60	04-07-05	11-07-05	7	7850	2.326	238	10.58
3	1:2:4	0.65	04-07-05	11-07-05	7	7799	2.311	237	10.53
4	1:2:4	0.70	04-07-05	11-07-05	7	7499	2.222	218	9.69
5	1:2:4	0.80	04-07-05	11-07-05	7	7401	2.193	207	9.20
6	1:2:4	0.55	05-07-05	19-07-05	14	8300	2.459	360	16.00
7	1:2:4	0.60	05-07-05	19-07-05	14	8000	2.370	323	14.36
8	1:2:4	0.65	05-07-05	19-07-05	14	7897	2.340	305	13.56
9	1:2:4	0.70	05-07-05	19-07-05	14	7600	2.252	290	12.89
10	1:2:4	0.80	05-07-05	19-07-05	14	7450	2.207	281	12.49
11	1:2:4	0.55	06-07-05	03-08-05	28	8397	2.488	450	20.00
12	1:2:4	0.60	06-07-05	03-08-05	28	8100	2.400	390	17.33
13	1:2:4	0.65	06-07-05	03-08-05	28	8000	2.370	385	17.11
14	1:2:4	0.70	06-07-05	03-08-05	28	7698	2.281	367	16.31
15	1:2:4	0.80	06-07-05	03-08-05	28	7600	2.252	360	16.00

Note: Cross-sectional area of concrete = 15cm × 15cm = 225cm^2 = 22500 mm^2
Volume of concrete cube = 15cm × 15cm × 15cm = 3375cm^3

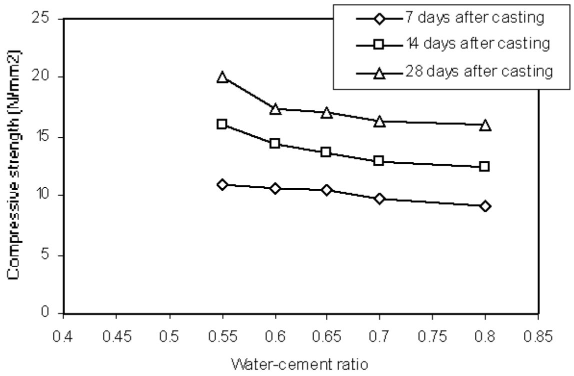

Figure 1: Plot of Compressive Strength of Concrete Mixes vs. Water-Cement Ratio.

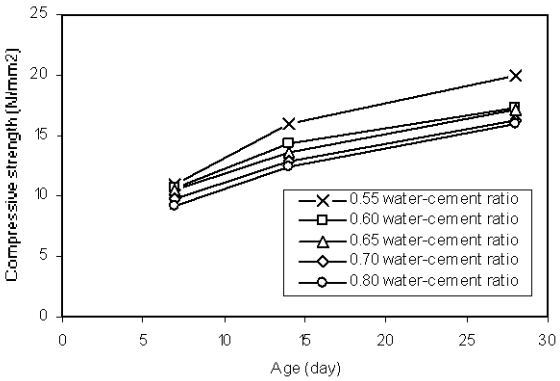

Figure 2: Plot of Compressive Strength of Concrete Mixes vs. Age.

In a similar way, the variations of weight, density and compressive strength of lateritic concrete mixes with water-cement ratios are shown in Table 2. The compressive strength of lateritic concrete mixes was also observed to decrease with increase in water-cement ratio and increase with age; the highest value was exhibited at 28 days after casting.

Figure 3 shows the plot of compressive strength versus water-cement ratio while Figure 4 shows the plot of compressive strength of lateritic concrete versus age.

It was found that water-cement ratio above 0.65 causes a very significant reduction in the compressive strength of the lateritic concrete mixes. This is in contrast to the performance of the concrete mixes which shows consistent decrease of compressive strength with increase in water-cement ratio. The bar chart representations of the variations of compressive strength of concrete mixes and lateritic concrete mixes versus water-cement ratio, for different ageing periods, are respectively shown in Figures 5 and 6.

Table 2: Variations of Weight, Density, and Compressive Strength of Lateritic Concrete Mixes with Water-Cement Ratio.

S/N	Mix Proportion	Water-Cement Ratio	Date of Casting	Date of Casting	Age (day)	Weight of Cube (g)	Density of Cube (g/cm^3)	Crushing Load (KN)	Compressive Strength (N/mm^2)
1	1:2:4	0.55	04-07-05	11-07-05	7	28010	8.299	823	36.58
2	1:2:4	0.60	04-07-05	11-07-05	7	27000	8.000	808	35.91
3	1:2:4	0.65	04-07-05	11-07-05	7	26660	7.899	780	34.67
4	1:2:4	0.70	04-07-05	11-07-05	7	25312	7.500	115	5.11
5	1:2:4	0.80	04-07-05	11-07-05	7	25190	7.464	100	4.44
6	1:2:4	0.55	05-07-05	19-07-05	14	28687	8.500	838	37.24
7	1:2:4	0.60	05-07-05	19-07-05	14	28010	8.299	823	36.58
8	1:2:4	0.65	05-07-05	19-07-05	14	28005	8.298	817	36.31
9	1:2:4	0.70	05-07-05	19-07-05	14	27340	8.101	119	5.29
10	1:2:4	0.80	05-07-05	19-07-05	14	26665	7.901	108	4.80
11	1:2:4	0.55	06-07-05	03-08-05	28	29025	8.600	858	38.13
12	1:2:4	0.60	06-07-05	03-08-05	28	28350	8.400	843	37.47
13	1:2:4	0.65	06-07-05	03-08-05	28	28015	8.301	833	37.02
14	1:2:4	0.70	06-07-05	03-08-05	28	28010	8.299	138	6.13
15	1:2:4	0.80	06-07-05	03-08-05	28	27675	8.200	127	5.64

Note: Cross-sectional area of concrete = 15cm × 15cm = 225cm^2 = 22500 mm^2
Volume of lateritic concrete cube = 15cm × 15cm × 15cm = 3375cm^3

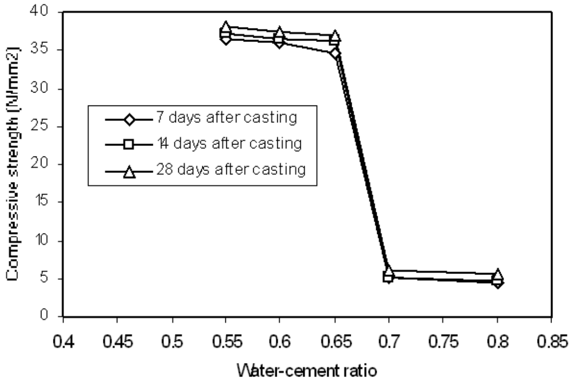

Figure 3: Plot of Compressive Strength of Lateritic Concrete Mixes vs. Water-Cement Ratio.

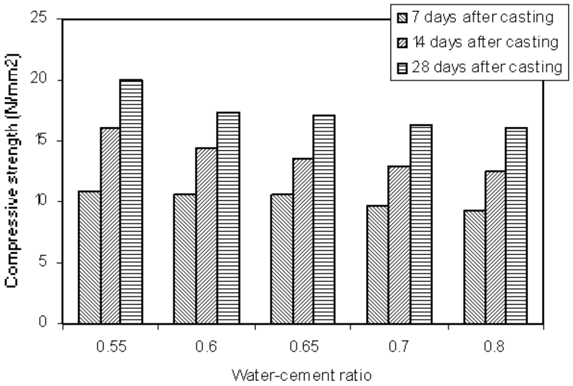

Figure 5: Plot of Compressive Strength of Concrete Mixes vs. Water-Cement Ratio.

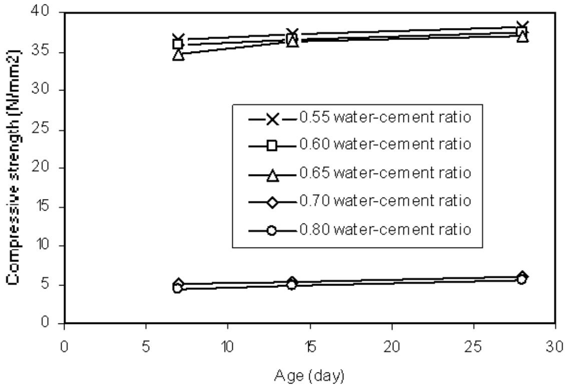

Figure 4: Plot of Compressive Strength of Lateritic Concrete Mixes vs. Age.

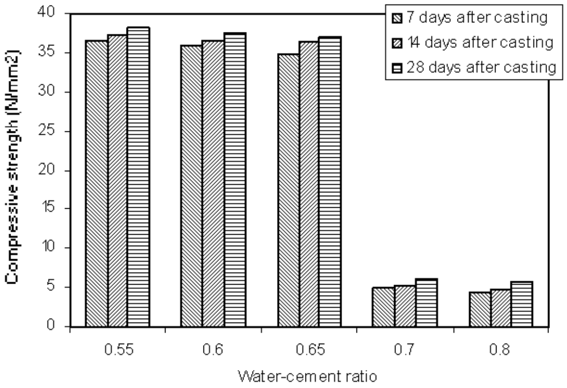

Figure 6: Plot of Compressive Strength of Lateritic Concrete Mixes vs. Water-Cement Ratio.

EFFECT OF WATER-CEMENT RATIOS ON THE WORKABILITY OF CONCRETE AND LATERITIC MIXES

Table 3 shows the results of the slump test on concrete and lateritic concrete.

Table 3: Results of Slump Test on Concrete and Lateritic Concrete Mixes.

Water-Cement Ratio	Concrete Mixes		Lateritic Concrete Mixes	
	Slump (cm)	Type of Slump	Slump (cm)	Type of Slump
0.55	0.9	True	0.0	True
0.60	1.5	True	0.1	True
0.65	2.0	True	0.1	True
0.70	2.5	True	0.1	True
0.80	18.0	Collapse	0.2	True

The slump test measures the fluidity of concrete. Under conditions of uniform operation, changes in slump indicate change in materials, mix proportions or the water contents. In the slump test carried out, the slumps of 0.55 to 0.70 are classified true in concrete mixes, i.e., the water contents are not enough to cause shear. For 0.80 water-cement ratio, the water content is such that the fluidity of the mixture is large enough to cause collapse of the concrete cone. However, in lateritic concrete the slumps of 0.55 to 0.80 are all classified true, i.e., the water contents are not enough to cause shear.

CONCLUSION

From the analysis of the tests carried out, it was revealed that increase in water-cement ratio causes reduction effect on the compressive strength of both concrete and lateritic concrete mixes. However, the compressive strength of both concrete and lateritic concrete mixes increases with age.

Water-cement ratio above 0.65 was found to cause a very significant reduction in the compressive strength of the lateritic concrete mixes. This is in contrast to the performance of the concrete mixes which show consistent decrease of compressive strength with increase in water-cement ratio.

For 0.80 water-cement ratio, the water content is such that the fluidity of the mixture is large enough to cause collapse of the concrete cone but not in the lateritic concrete cone.

RECOMMENDATION

The use of lateritic materials for concrete should be discouraged because the workability is poor and there is a lot of void that have adverse effect on the strength.

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SUGGESTED CITATION

Alawode, O. and O.I. Idowu. 2011. “Effects of Water-Cement Ratios on the Compressive Strength and Workability of Concrete and Lateritic Concrete Mixes”. *Pacific Journal of Science and Technology*. 12(2):99-105.

Pacific Journal of Science and Technology