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Research Article

IMPACT OF PRODUCTION CHARACTERISTICS ON CONCRETE STRENGTH IN TROPICAL ENVIRONMENTS

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Abstract:

Quality of concrete is an integrated function of the nature of the constituent materials, mix ratio, production method, curing age, water-cement ratio and the climate. Various standards and code of practices that regulate quality of concrete with the concerned production characteristics are in most cases not complied with in the area of the study; hence quality of concrete work becomes a suspect. To assess the effect of these production conditions, field survey and experimental designs were adopted. Data collected were analyzed using arithmetic mean and correlation to determine the mean strength values of different mix ratios and degree of ranking relationships among the strength values of each curing age in all the mix ratios respectively. It is therefore discovered that some major production conditions like mix ratio, aggregate type and curing age has significant effects on the quality of concrete. Strength of concrete produced with granite is higher than those produced with sedimentary aggregate; besides the strength increases as the curing age in all the experiments. Against the nominal mix ratios which are the standards, strength values of the prescriptive mix ratios commonly used in the area fall short of the standard values. Strength values of the pilot experiments conducted with nominal mix ratios show closeness to the standard strength but, with little lapse due to short fall in other production characteristics. It is also found that irrespective of the total quantity of the content of all the constituent aggregates in a mix, the proportional relationship between the fine and the coarse aggregates is germane. The study therefore recommends for a holistic research approach to designed mix of concrete production in order to develop templates in the form of nomogram, for easy and reliable production of desired concrete works. Other production conditions like aggregate type, water-cement ratio and curing age should as well be utilized optimally for improved quality of concrete works in the study area.

Keywords: Concrete Work, Production Characteristics, Mix Ratio, Aggregates, Curing Age, Compressive Strength, and Quality

Introduction

Production characteristics of concrete consist mainly of batching, mixing, transportation, placing, compaction, curing and finishing mainly (Ononiwu, 2019). Others are determination of type of cement, water-cement ratio, type and size of aggregates, as well as the level of quality control adopted in the concrete production.

Most of the concrete productions in the study area are susceptible to some kind of failures; and every effort made through public enlightenment, symposia, media, seminar/workshops, and inaugural lectures to improve quality of production yielded little result (Okereke, 2003). There are advances in concrete technology however which are capable of using appropriate mix proportion of the constituent ingredients, and proper workmanship to pave way to the best use of the locally available materials. Based on this development Neville, and Brooks (2010) classified concrete mix as either nominal or designed mix. Others are prescribed or performance mix of concrete work. Although the properties of the constituent materials (cement, aggregates, water, etc.) are critical also, the users of concrete work are usually interested in the concrete itself having the desired properties.

Concrete is by far the most widely used man-made composite construction materials; and studies indicate that it will continue to be in the years to come, (Burea of Indian Standard, 1997). This multi-dimensional use of concrete is due to fact that it is possible to modify the properties of the concrete to desired quality through proportional combination of the constituent ingredients to meet the demands of a particular situation or locality.

In the light of this, the study aims at determining the relationship between the major production characteristics and the strength properties of the concrete works in the study area. To this end, the implications of the tropical climate, on concrete was examined; some production characteristics of the concrete works were assessed; stipulated standards guiding the production of concrete examined; and samples from wet concrete mixes in the area investigated of their strength properties.

Research Methodology

The methods of research adopted in the study include field survey and experimental designs. The field survey involves apriori knowledge commonly adopted in the area and the stipulated code of practice on concrete production characteristics. This knowledge comprises cement type, aggregate type, water-cement ratio, curing age, production method, and concrete mix proportion. Nevertheless, experimental design is limited to ex post facto test since prescriptive mix is commonly used in the area of the study.

Two categories of the mix ratio were adopted as 1:4:5 and 1:5:5 ratios. In each case, two kinds of experiment emerged with different types of coarse aggregates as locally sourced sedimentary aggregate and granite aggregate respectively. For each of these experiments, the strength properties of the concrete were tested at the respective curing ages of 7-day, 14-day, and 28day. Manual method of production however was adopted as a common way of practice the area for all the experiments in the study.

Results from the experiments were analyzed with parametric tool (arithmetic mean) and nonparametric tool (correlation). The mean was used to achieve the average result of three different samples taken from each batch of concrete mix respectively. Correlation however was used to measure degree of relationship existing between the properties of concrete works of different types of aggregates; as well as properties of concrete with the various prescribed mix and nominal mix ratios respectively; all across the respective curing ages. They are expressed in the forms:

$X = \Sigma X_n / n$ = = = = $Equ. 1$

Where; X is the Arithmetic Mean ΣX_n - sum of the samples results, n - number of the samples.

$r = 1 - \frac{6\Sigma d^2}{n(n^2-1)}$ = = = = $Equ. 2$ where; d is the difference between the two populations, n = number of the samples.

Test for significant relationship therefore is tested with student 't' test since the sample number is less than 30. It is in this form:

$t = r\sqrt{\frac{(n-2)}{1-r^2}}$ = = = $Equ. 3$

where; r is the correlation, n = number of the samples.

Thus, if r is less than Student $t_{1-\alpha;n-2}$, the null hypothesis (H_O) at 0.10 significant level is accepted; otherwise it is rejected and the alternative hypothesis (H_a) which assumes correlation-ship between the two populations is accepted.

PRESENTATION, ANALYSES AND DISCUSSION OF RESULTS Presentation of Results

The results of the various experiments are presented as follows.

Table 1.0 test results of the both the Prescriptive mix and Nominal Mix

S/n	Locally Sourced Sedimentary Aggregates			Granite Aggregates		
	Mix Ratio	**Curing Age**	**Strength (n/mm^2)**	**Mix Ratio**	**Curing Age**	**Strength (n/mm^2)**
1	1:2:4	7	14.4	1:2:4	7	17.5
		14	17.8		14	19.9
		28	19.2		28	21.3
2	1:3:6	7	13.8	1:3:6	7	14.2
		14	15.7		14	16.7
		28	17.5		28	18.2

3	1:4:5	7	13.0	1:4:5	7	13.5
		14	14.9		14	15.6
		28	16.5		28	17.8
4	1:5:5	7	12.2	1:5:5	7	13.0
		14	13.9		14	14.7
		28	15.7		28	16.5

Source: Author's Laboratory Experiments, (2020)

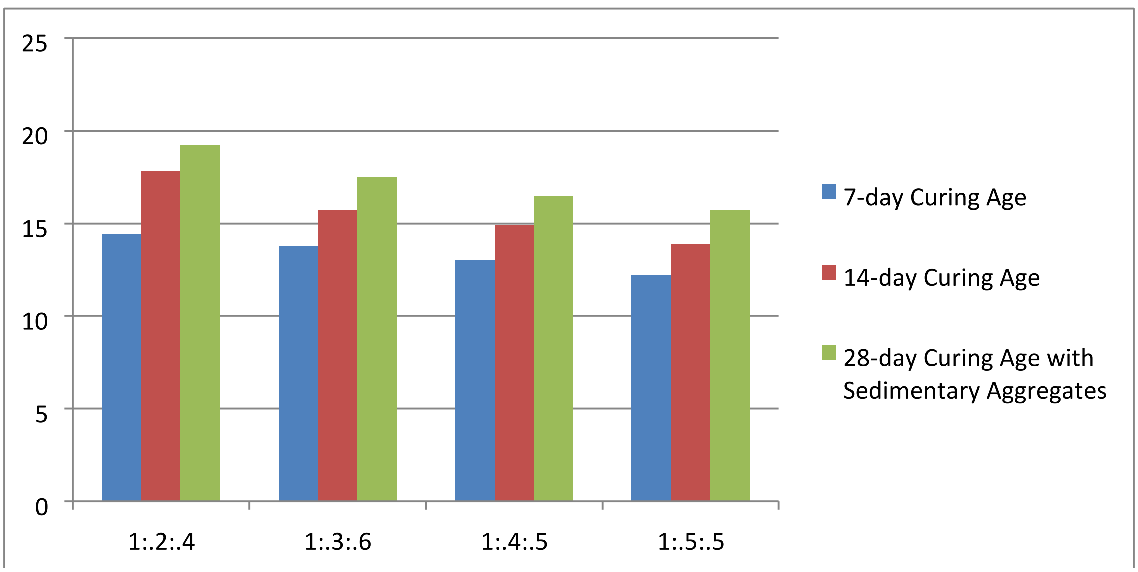

Fig 1. The Strength Values of the Respective Concrete Mixes with Sedimentary Aggregates through 7-day to 28-day Curing Ages **Source:** Author's Laboratory Experiments, (2020)

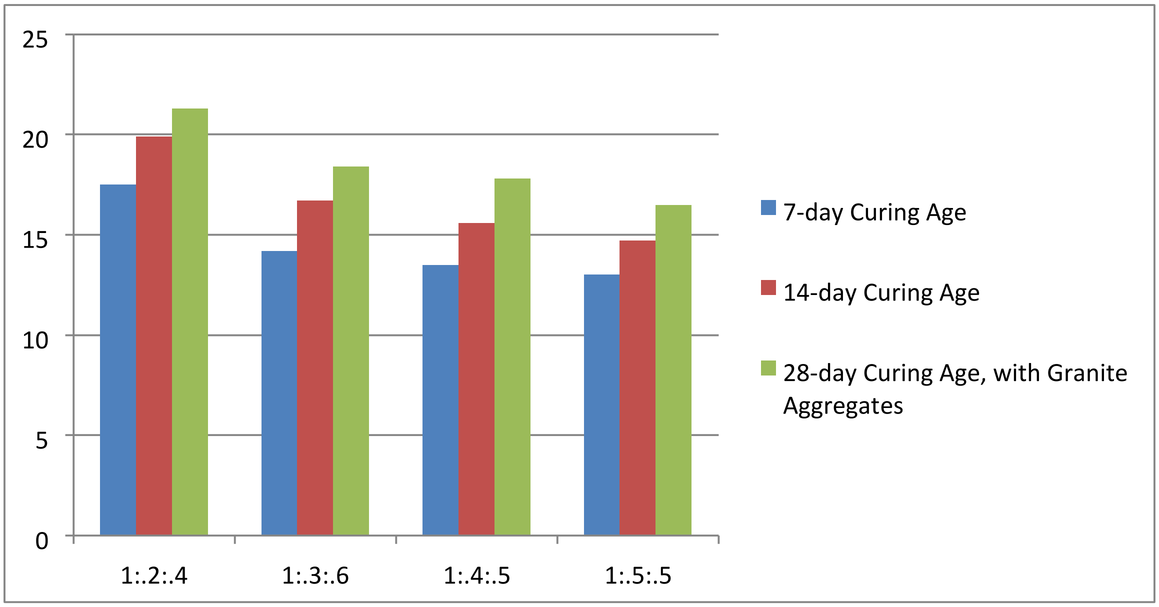

Fig 2. The Strength Values of the Respective Concrete Mixes with Granite Aggregates through 7-day to 28-day Curing Ages

Source: Author's Laboratory Experiments, (2020)

The results as contained in Fig.1 and Fig. 2 for the respective aggregates show the strength values of the respective concrete mixes increase as the curing ages increase through 7-day to 28-day curing ages. According to Ikechukwu and Ezeokonkwo (2016), the strength values of a hygroscopic composite material increases as the curing age of the material irrespective of the production method. In the two categories of the mix, nominal (1:.2:.4 and 1:.3:.6) mixes have higher strength values than the prescriptive (1:.4:.5 and 1:.5:.5) mixes in all the conditions of their productions.

The volumetric comparison of the batching of 1:.3:.6 mix and 1:.4:.5 mix are the same but, the proportion of the fine aggregate to coarse aggregate is lesser in 1:.3:.6 mix compared to 1:.4:.5 mix; hence the strength values of 1:.3:.6 mix are noticeably higher than the ones of 1:.4:.5 mix. In support of this observation, Ikechukwu and Asikogu (2017) noted that the more finely graded the sand, the more the water demand for effective workability, and lesser the resulting strength. If the water content is constant however, the strength still remains compromised.

In an effort to examine the implication of the different types of aggregates in the study, results show that concrete works with granite aggregates are higher in strength than those produced with the locally sourced sedimentary aggregates.

The results of the experiments as shown in table 1 are compared on the basis of production with aggregate types. Irrespective of whether the concrete mix is nominal or prescriptive, 1:.2:.4 mix with sedimentary aggregate has 14.40n/mm^2, 17.80n/mm^2 and 19.80n/mm^2 for 7day, 14-day, 28-day curing ages respectively, while 1:.2:.4 mix with granite has 17.50n/mm^2, 19.90n/mm^2, and 21.30n/mm^2 for 7-day, 14-day, and 28-day curing ages respectively. Besides, 1:.3:.6 mix with sedimentary aggregate has 13.80n/mm^2, 15.70n/mm^2 and 17.50n/mm^2 for 7day, 14-day, 28-day curing ages respectively, while 1:.3:.6 mix with granite has 14.20n/mm^2, 16.70n/mm^2, and 18.40n/mm^2 for 7-day, 14-day, and 28-day curing ages respectively.

Consequently, 1:.4:.5 mix with sedimentary aggregate has 13.00n/mm^2, 14.90n/mm^2 and 16.50n/mm^2 for 7-day, 14-day, 28-day curing ages respectively, while 1:.4:.5 mix with granite has 13.50n/mm^2, 15.60n/mm^2, and 17.80n/mm^2 for 7-day, 14-day, and 28-day curing ages respectively. Besides, 1:.5:.5 mix with sedimentary aggregate has 12.20n/mm^2, 13.90n/mm^2 and 15.70n/mm^2 for 7-day, 14-day, 28-day curing ages respectively, while 1:.5:.5 mix with granite has 13.00n/mm^2, 14.70n/mm^2, and 16.50n/mm^2 for 7-day, 14-day, and 28-day curing ages respectively.

Geologically, igneous stone which includes granite are extremely dense, hard and resistant to knock, abrasion and to attack by ordinary chemicals while sedimentary stones are characterized by bedding planes which makes them potentially weaker than aggregates made from other stones. Hence, no doubt concrete produced with granite is of higher strength than the one produced with sedimentary aggregate in the study.

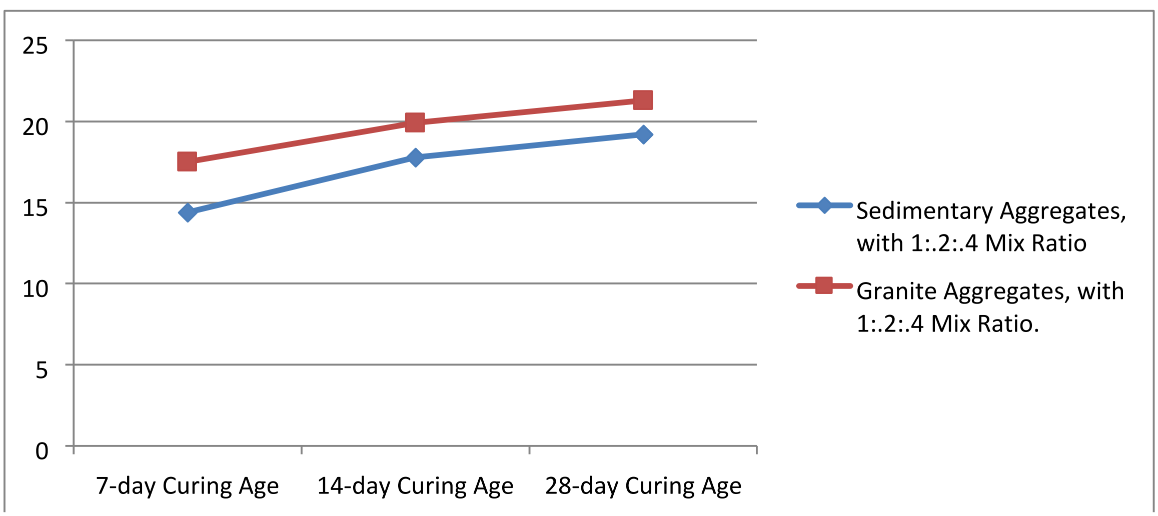

Fig 3. The Strength Relationship of 1:.2:.4 Mix Concrete with Sedimentary Aggregates and Granite Aggregates through 7-day to 28-day Curing Ages

Source: Author's Laboratory Experiments, (2020)

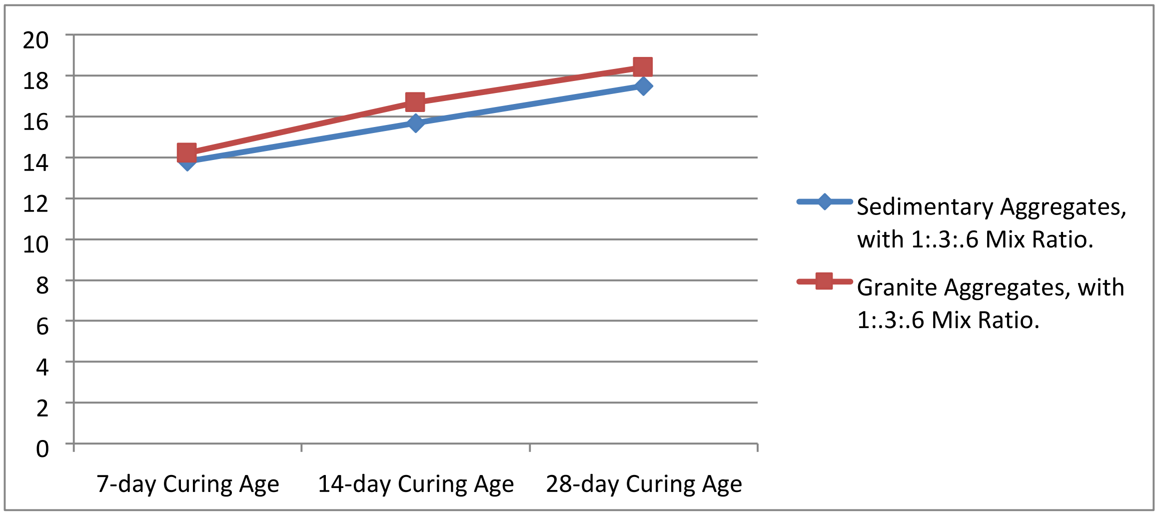

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Fig 4. The Strength relationship of 1:.3:.6 Mix Concrete with Sedimentary Aggregates and Granite Aggregates through 7-day to 28-day Curing Ages

Source: Author's Laboratory Experiments, (2020)

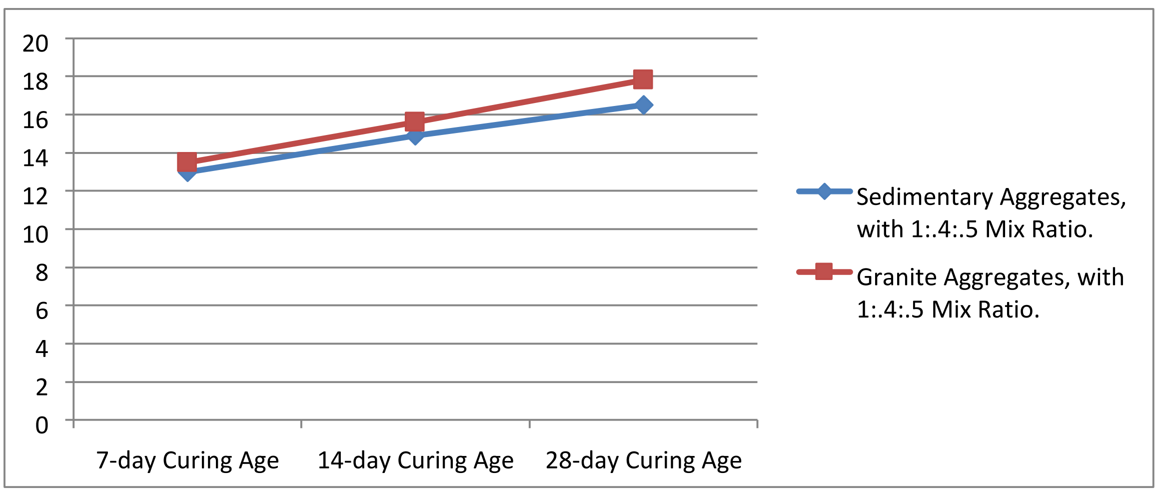

Fig 5. The Strength relationship of 1:.4:.5 Mix Concrete with Sedimentary Aggregates and Granite Aggregates through 7-day to 28-day Curing Ages

Source: Author's Laboratory Experiments, (2020)

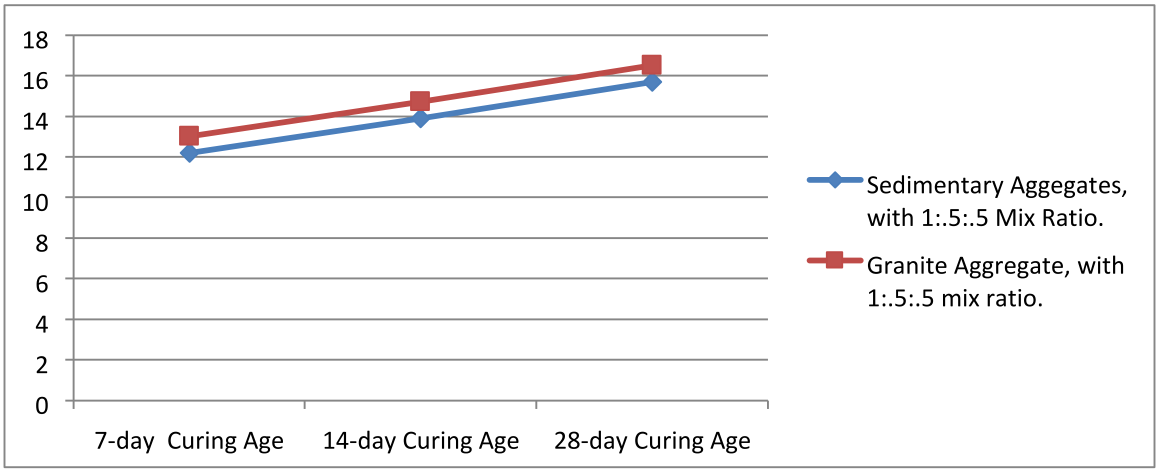

Fig 6. The Strength relationship of 1:.5:.5 Mix Concrete with Sedimentary Aggregates and Granite Aggregates through 7-day to 28-day Curing Ages

Source: Author's Laboratory Experiments, (2020)

All test results across the various curing ages (7, 14 and 28-day) for both the prescriptive and nominal concrete mixes in respect of the respective productions with locally sourced sedimentary, and granite aggregates rank the same. Hence, the degree of relationship among the various conditions involved in all the experiments is I; which is perfect relationships explaining that mix ratio, aggregate type and curing age have very strong effects on the strength properties of the concrete.

Analytically, Fig. 3 - 6 show that the increase in the strength of concrete of all the mix ratios involved in the experiments is proportional to increase in the curing age for both concrete produced with sedimentary aggregate and the one produced with granite in the study.

SUMMARY OF FINDINGS

It is discovered in the study that most of the concrete works in the area of study are not in compliant with the standard nominal mix ratio for both reinforced and mass concrete works. Prescriptive mix ratios used however fall short of the standard strength stipulated for the various purposes of work. Although the constituent ingredients are not ascertained of their prerequisite qualities before use, and manual production method adopted as common practice, the strength values (21.3n/mm2 and 18.4n/mm2 for 1:.2:.4 and 1:.3:.6 mix ratios respectively) of the experiments conducted with the trial nominal mix ratios are very close on average to standard strengths of 28n/mm^2 and 18n/mm^2 for 1:.2:.4 and 1:.3:.6 ratios respectively, at the 28-day curing age.

The total proportion of all the aggregates to the cement ingredient in the concrete influences significantly the strength of the concrete but, with regard to the percentage contents of the individual aggregates (fine and coarse aggregates) in the concrete mix, irrespective of total volume of all the aggregate ingredients; hence the need for concrete mix design.

Nevertheless, quality of concrete works produced with granite is far better than the ones produced with sedimentary aggregates in the experiment. Just like in the previous studies, compressive strength increases also in the experiment as the curing age of the concrete work increases in the study.

RECOMMENDATIONS

In line with the findings in the study, the following recommendations are made:

. The local authorities and stakeholders in the construction industry should encourage research works on concrete mix design using the various available ingredients in respect of various curing ages to emerge with optimum compositions of the concrete ingredients for various desired qualities in different areas of work.

i. Appropriate templates for optimum composition of mix ingredients in form of
'Nomogram' should be developed for quicker, desirable and sustainable qualities in concrete work production in the area of the study.

CONCLUSION

Sustainability of code of practice which involves functional effectiveness, cost effectiveness, appropriateness and compliant with the future demands requires that every practice/product should be reviewed from time to time for adaptation or innovation**.** To this effect, the findings in the study serve as window with a view to improving quality of concrete work that surpasses the effectiveness of the nominal mixes for different purposes of work; by leveraging on optimal compositions of the various ingredients of concrete mixes. There is no doubt this ideology will help to improve building production delivery by improved utilization of available constituent materials, certainty in quality of concrete production, reduced percentage of waste of time and money in the production management, and in the end significant reduction in the rate of failures of the building structures.

Local authorities and stakeholders in the industry through this advocacy will be able to form basis for appropriate regulation of concrete production of all purposes; towards ensuring compliance to standards for uniformity, effective practice and optimum quality of concrete works.

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