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AN EVALUATION OF THE EFFECTS OF LOCAL MIX DESIGN ON THE COMPRESSIVE STRENGTH OF CONCRETE

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Abstract
This is a report on an evaluation of the effect of local mix design of concrete on its compressive strength. In order to accomplish this research work, field survey was first undertaken with a well-structured questionnaire. This questionnaire was administered to the respondents who are directly involved in concrete production. Oral interview was also carried out in order to confirm the information given by the respondents concerning batching, mix ratio, etc. A study of contract document was undertaken with emphasis on specification of contract, bill of quantity and structural design in order to study how mix design is carried out in construction industry. Based on the information obtained from the respondents on how concrete is designed and specified in contract document and how such information is used in the production of concrete on construction sites, an experimental programme was set up in order to assess the extent of deviation from the normal. In the experiment, six different mixes were used. A total number of one hundred and twenty (120) cubes were cast; twenty (20) cubes were cast for each of the design mix specified. The samples were cured and crushed after 1,3,7,14,21 and 28 days of curing so as to determine the compressive strength. The test result shows that, the compressive strength for both mass and reinforced concrete produced in the construction firm are 3.13N/mm² and 6.00N/mm² respectively at 28 days, which are lower than that produced using the standard mixes and that produced using the target mixes. It is concluded that there is a very wider deviation from the normal in the concrete produced on site and it affects the strength of concrete and therefore, durable and qualitative concrete cannot be achieved through such means (their mix design). It is recommended that professionals should be involved in the production and supervision of concrete works so as to take care of quality control and guard against irregularities.

Keywords: Mix design, local, influence, quality, batching, concrete

1. Introduction

Concreting in Nigeria, in terms of its level is at its primitive stage as classified by writers. It is primitive because most of activities in concrete production are carried out using manual labour. The importance of mix design and determination of the quality of concrete cannot be overemphasized. However, some researchers [1 - 6] have observed that batching in most construction firms is done by eye - estimate. That is, the mix design is not followed, and this will no doubt affect the concrete produced. As a result of this, incessant problem of structural failures have been recorded which have claimed huge loss of lives and properties. Result of recent investigation shows that 35% of this problem could be attributed to the use of defective materials [7]; [8]; and [9]. It has been estimated that there were well over 400 thousand different types of construction materials, and out of all these numeral materials, concrete is not only the most popular, but is widely used man-made material[10].

Concreting in Nigeria is faced with many problems. According to [11-13], presence of fine or coarse aggregate over and above the quantity specified in the design seriously affect the quality of concrete produced. It was also noted that water/cement ratio has a great influence on concrete as it was observed that there is inverse relationship [9]. According to [14], most of the construction sites use higher water/cement so as to achieve good workability.

Since what is specified in the design is not the same with what they use on sites in producing concrete, which has made the quality of concrete produced to fall below the minimum standard, therefore, there is need for the provision of factor of safety in the design so as to make up for the lapses and cater for the unforeseen structural failures.

2. Objectives

The main objective of the study is to evaluate the effect of local mix design on the strength of concrete produced on site. The specific objectives are to:

(a) To examine contract documents used in the execution of construction projects, with special emphasis on mix design and/specification in the contract document.
(b) To determine the extent to which construction firms use such specification /mix design as provided in the contract document to produce concrete.
(c) To produce concrete using the specification/design as provided in the contract document and what is actually produced on site.
(d) To assess the extent of deviation.

3. Materials and methods

3.1 Field Survey

In view of the fact that many experts have noted that construction firms in Nigeria do not use the mix design/specification as provided in the contract document ([3]; [4]; [14] and [15]). Field survey was carried out with the use of structured questionnaires, which were distributed to professionals in some selected construction firms in Zaria and Kaduna.

This was carried out in order to know the various design mixes used by the construction firms and to find out which one is the most common one adopted by them , and their impacts on the strength development of concrete. More importantly, effort was made to establish what is actually obtained in the field concerning the design mixes.

In order to accomplish this task, physical observation was undertaken during the production of concrete. Also, oral interview was carried out and questionnaires were designed basically for the professionals in the construction firms especially those that are directly involved in the supervision of project such as site engineer, project manager, project coordinator, etc , to sample their opinions on the design mixes.

3.2 Materials

The materials used in this research include cement, fine aggregate, coarse aggregate and water. Details of materials used are as follows:

3.2.1 Cement

The cement used in the research work was the Ordinary Portland Cement, OPC, produced by Dangote Cement Company Plc and it was a recently supplied batch and found to conform to specifications of [16].

3.2.2 Fine Aggregate

Fine aggregates used in this research work were clean and air - dried river sand obtained from Bomo – Zaria. It was sieved with a 5mm sieve, so as to remove the impurities and larger aggregates. Before, the fine aggregate was used; it was subjected to sieve analysis. This was undertaken in accordance to the specification of [17].

3.2.3 Coarse aggregate

The coarse aggregate used were crushed granite stones obtained from a single quarry site along Zaria-Sokoto road. Sieve analysis was carried out on the coarse aggregate used in the experiment in accordance to [14]. Other properties of coarse aggregate that were investigated include specific gravity on oven dried basis, apparent specific gravity and water absorption. These tests were undertaken in accordance to the following British standards [17]; [18].

3.2.4 Water

Water used for mixing was clean, fresh water, free from injurious oils, chemical and vegetable matter or other impurities and satisfies the specification requirement of [19].

3.3 Sieve Analysis

Sieve analysis was carried out in order to determine the particle size distribution of aggregate. Approximately 32.2kg of the combined aggregate was analysed and result of sieve analysis conducted for the research is presented in Table 1. As it can be observed from the table, 9.28kg equivalent to28.83% was retained on B.S. sieve sizes of 9.5mm while 71.17% represented the percentage of aggregate passing. While for 4.75mm B.S sieve sizes 44.89 and 26.28 represent the percentage passing and those that were retained respectively. Looking at the result of sieve analysis it shows that the distribution of sizes of aggregate is fair except for those retained between 1.18mm BS sieve and 300micron B.S sieve thus, it can be said that the aggregate belongs to zone C.

3.4 Method

The procedure of this study entails four steps which are as follows:

(a) Study of Contract Document: Study of contract documents was undertaken so as to know how concrete is specified and the influence of such specification on the quality of concrete.
(b) Field survey: This was carried out using structured questionnaire as the instrument of the study. The questionnaire was administered to the respondents who are directly involved in

the production of concrete. This was aimed at finding out how concrete mix design is done and situation where mix design is not undertaken, attempt was made to determine the way constituents are batched/proportioned.

(c) Structured interview: This was carried out in order to confirm the information given by the respondents concerning batching, mix ratio, etc.

(d) Experimental programme: Based on the information obtained from the respondents on how concrete is designed and specified in contract document and how such information is used in the production at construction sites, an experimental programme was set-up in order to assess the extent of deviation from the conventional mix design and production of concrete.

Table 1: Sieve Analysis

B.S. Sieve sizes (mm)	Weight Retained (Kg)	Percentage Retained	Percentage Passing
20	0.00	0.00	100
9.5	9.28	28.83	71.17
4.75	8.46	26.28	44.89
2.36	1.58	4.91	39.98
1.18	0.59	18.42	21.56
600µ	0.38	11.82	9.74
300µ	2.30	7.15	2.59
150µ	0.48	1.92	0.67
Pan	0.22	0.67	0.00

3.4.1 Preparation of concrete sample

Result of field survey shows that various methods were used in the design and production of concrete. These can be classified into three sets: 1) Concrete specified in the contract document: In this case conventional method was followed – by specifying the concrete in grades depending where it is to be used. 2) There is also the popular mix – which most sites used as the accepted technique. For example 1:2:4 is used for any reinforced concrete irrespective of where it will be placed/used, 1:3:6 for plain concrete and 1:1.5:2 for pre-stress concrete.3) There is also local mix design or just proportioning of constituents using individual approach, where head pans, wheel barrows, etc were used to batch the constituents. In this case oral interviews were carried to know the most common way of batching/designing concrete mix. Result of the survey reveals that there are various ways. These methods were recorded and the commonest ones were selected. This led to the preparation of three sets of concrete so as to study the effect of local batching on the quality of concrete. Details are presented in Table 2.

Table 2: Three Sets of Concrete Used in the Experiment

Mix Design	Proportion of Constituents	W/C Ratio
Concrete Specified in Contract Document	Grade 25 (1:1.89:3.5) Grade 20 (1:2.1:3.9)	0.55 0.60
Popular Mix known to all	Reinforced Concrete 1:2:4) Plain Concrete (1:3:6)	0.65 0.65
Common local mix Design	Reinforced Concrete (1:6:3) Plain Concrete (1:8:4)	0.75 0.75

A total number of one hundred and twenty (120) cubes were cast for this experiment. Twenty (20) cubes were cast for each of the design mix ratios specified above. The cubes were demoulded after 24 hours of casting, cured in curing tank for 1,3,7,14,21 and 28 day, weighed and subjected to compressive tests. The specimens were prepared in the concrete laboratory, Department of Building, A.B.U, Zaria.

3.4.2 Compressive strength test

Test was conducted in accordance with the provision of [20] in the determination of cubes compressive strength.

4. Results and discussion

4.1 Compressive Strength

The results of the compressive test show that the concrete produced in the site for mass concrete has an average strength of 3.13N/mm^2 at 28 days using design mix (1:8:4) as against 16.6N/mm^2 at 28 days using design mix (1:3:6) while the one produced in the site for reinforced concrete has an average strength of 6.00N/mm^2 at 28 days using design mix (1:6:3) as against 22.53N/mm^2 at 28 days using design mix (1:2:4). The concrete produced using design mix (1:1.89:3.5) has an average strength of 23.13N/mm^2 at 28 days while that produced using (1:2.1:3.9) has an average strength of 21.53N/mm^2 at 28 days.

From the above results, it is observed that strength of concrete of (1:8:4) is far below the standard. The reason is that the site mix ratio is weak compared to (1:3:6) as the specified standard for mass concrete and it has an adverse effect on the strength of concrete. The compressive strength of (1:3:6) is also low, but from observation It may be said that there are factors militating against its strength which are stated below:

1. The material used may contain some impurities which can hinder the bonding of concrete.
2. During the concrete production, tamping and compaction may not be uniform since it was done manually.

As for the result of (1:6:3) as against (1:2:4), the strength is far below the standard while that of

(1:2:4) is adequate. Finally, the results of the target strength for both mass and reinforced concrete are also adequate.

4.2 Density of the Cubes

The summary of the average density of the cubes are also presented in the tables.

Table 3: Average density of (1:3:6) and that of the one (1:8:4) observed in the site.

Mix Ratio	Age (in days)	Average Density (Kg/m^3)
1:8:4	1	2171
	3	2116
	7	2188
	14	2108
	21	2069
	28	2147
1:3:6	1	2057
	3	1993
	7	2089
	14	1446
	21	1952
	28	1990

From Table 3, the average density of 1:8:4 is ranging from 2069-2188kg/m^3 while that of 1:3:6 ranges from 1446-2089kg/m^3.

Another important property that was used in the assessment of concrete strength is density. Looking at Table 5, it could be see that the average density of (1:3:6) is from 1446-2089kg/m^3 and that of (1:8:4) ranging from 2069-2188kg/m^3 are below the ranges of density allowed which is from 2293-2450kg/m^3. As for (1:2:4), (1:1.89:3.5) and (1:2.1:3.9), their average densities are within the normal range while that of (1:6:3) is below the ranges allowed. From this it can be concluded that the density of concrete produced on construction site has a serious impact on the concrete.

Table 4: Summary of average density of cubes of (1:2:4) and the one (1:6:3) observed in the site

Mix Ratio	Age (in days)	Average Density (Kg/m^3)
1:2:4	1	2372
	3	2356
	7	2339
	14	2344
	21	2336
	28	2360
1:6:3	1	2210
	3	2226
	7	2228
	14	2193
	21	2187
	28	2220

From Table 4 the average density of 1:2:4 ranges from 2336-2372kg/m^3 while that of 1:6:3 is from 2187-2228kg/m^3.

Table 5: Summary of the average density of grade 25N/mm^2.

Mix Ratio	Age (in days)	Average Density (Kg/m^3)
1:1.89:3.5	1	2392
	3	2356
	7	2389
	14	2318
	21	2323
	28	2409

From Table 5, the average density ranges from 2318-2409kg/m^3.

Table 6: Summary of average density of grade 20N/mm^2.

Mix Ratio	Age (in days)	Average Density (Kg/m^3)
1:2.1:3.9	1	2300
	3	2305
	7	2248
	14	2365
	21	2401
	28	2307

From Table 6, the average density ranges from 2248-2401kg/m^3.

4.3 Percentage variations between mixes compared to target strength mixes

The percentage variation result of the standard mixes (1:2:4) and (1:3:6), and those of the site's (1:8:4) and (1:6:3) in relation to the target strength specified in contract documents are shown in Tables 7 and 8.

Table 7: shows the percentage result of 1:3:6 and 1:8:4

Mix Ratio	Days (Age)	Percentage Variation
1:8:4	28	85.46%
1:3:6	28	69.35%

Table 8: shows the percentage result of 1:2:4 and 1:6:3.

Mix Ratio	Days (Age)	Percentage Variation
1:6:3	28	74.05%
1:2:4	28	2.59%

Tables 7 and 8 show that there is wide deviation between the concrete produced on site and that of the one produced using the standard mixes.

In Tables 7 and 8, it is observed that 85.46% and 74.05% deviations are recorded in the concrete produced on the site using ratio (1:8:4) and (1:6:3) for both mass and reinforced concrete respectively when compared to that produced using the target strength as specified in contract documents. This means there is wider gap between them and those of the standard. In any mix design, the coarse aggregate is always higher than the fine aggregate but the reverse is the case in the construction firms. This deviation is as a result of too much sand in the mixes which will always tend to give weak concrete that will result in poor quality of concrete produced.

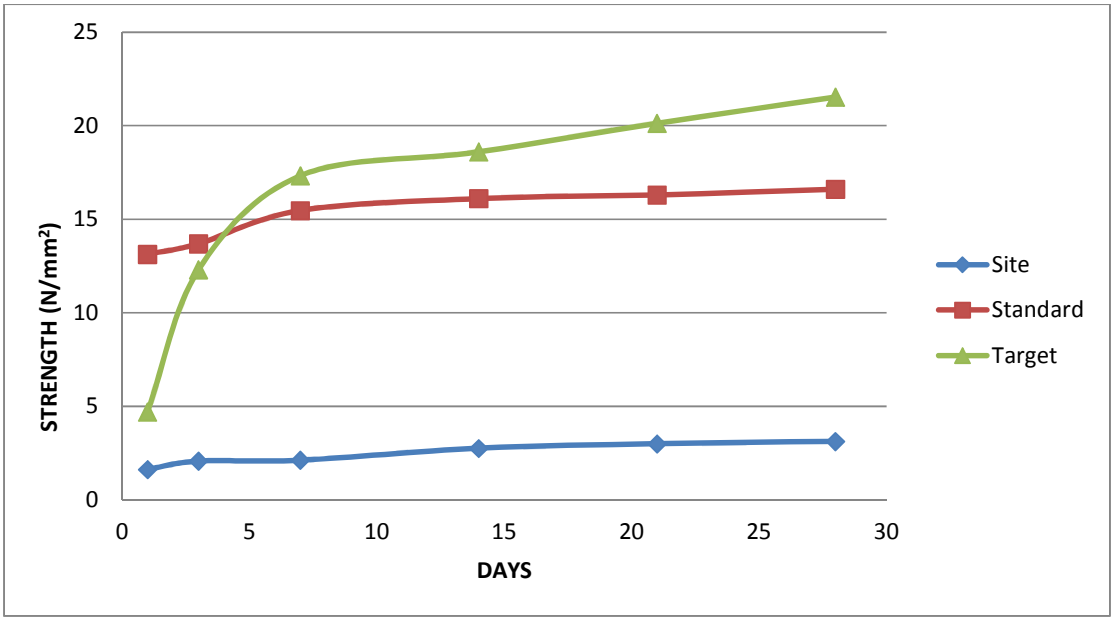

Figure 1: Graph showing the difference between mass concrete of the site and that of the standard and the target.

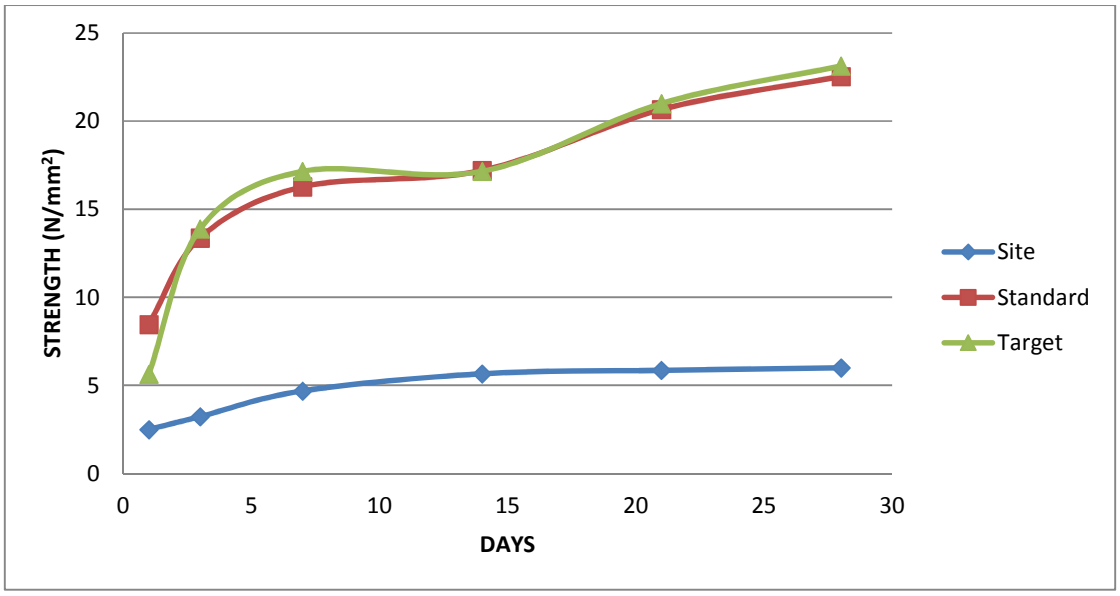

Figure 2: Graph showing the difference between reinforced concrete of the site and that of the standard and the target.

From the graph in Figure 1, the lower curve represents the mass concrete produced using 1:8:4(site mix design) while the middle and top most curve represents mass concrete produced using 1:3:6 (standard mix) and 1:2.1:3.9 (target strength) respectively. It can be observed from the graph that, the strength of concrete produced in the site is too low compared to the standard and the target.

Also, in Figure 2, the lowest curve represents reinforced concrete produced using 1:6:3(site mix design) while the middle and top most curve represents reinforced concrete produced using 1:2:4 (standard mix) and 1:1.89:3.5(target strength).It can also be observed from the graph that, the strength of reinforced concrete produced in the site is too low compared to the standard and the target. In nutshell, the graphs have clearly depicted the differences between the concrete produced on the site and those produced using the standard mixes and the design mix of the target strength. The graphs have also shown what is actually happening and the extent of deviation going on in the construction firms

5. Conclusions and recommendations

5.1 Conclusions

Based on the results obtained from this research, the following conclusions are drawn:

(a) The way and manner in which construction firms carry out their concrete production is contrary to the standard.

(b) The average compressive strength of cubes of the site design mixes (1:8:4) for mass concrete and (1:6:3) for reinforced concrete, which are 3.13 N/mm^2 and 6.00N/mm^2 at 28 days are not up to the standard.
(c) The concrete mixes used in production on most of the construction firms have adverse effects on the strength of concrete.
(d) One of the prominent problems facing the production of qualitative concrete on site is negligence of quality control.

5.2 Recommendations

(a) Professionals should be involved in the production and supervision of concrete works so as to safeguard against quality control.
(b) High institutions especially universities should also help in introducing certificate courses in building construction or concrete technology so as to enable the middle- man power or sub-professionals in improving their skills in the production of concrete.
(c) The designers should always try to include the factors of safety in their design since the sub-professionals are negligent about following the standards.

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