Properties of Different Grades of Concrete Using Mix Design Method

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Abstract: ***The aim of this study is to investigate the characteristics exhibited by three different grades of concrete using mix design approach. From the result of the sieve analysis, it shows that the sands used for the experiment is a well graded sand of zone 1 of BS882 parts 2 (1973). The average specific gravity of 2.63 was obtained, this result falls within the lower limits for natural aggregate which have specific gravities between 2.6 and 2.7 Neville (2000). The average bulk densities of uncompacted and compacted sand were found to be 1422 kg/m³ and 1538kg/m³ respectively. The crushed stones used have specific gravity of 2.63, and a compacted and un compacted bulk densities of 1415kg/m³ and 1326kg/m³ respectively, which clarified it as normal weight aggregates. The values of density recorded in this work ranged between 2441kg/m³ and 2558kg/m³. The values of compressive strength ranged between 28.66N/m² to 39.55N/m² up to 28 days of curing, the strength was also observed to increase with hydration period which inform non-deterioration of concrete. The results for the values of flexural strength range between 3.5N/mm² and 6.0N/mm² at 28days of curing.***

Keywords: Mix design, Grades, Concrete and Aggregates

1. Introduction

According to Nataraja (2014) the process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in two states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The extent of quality control according to www.engineeringcivil.com is often an economic compromise, and depends on the size and type of job. The cost of labour depends on the workability of mix, e.g., a concrete mix of inadequate workability may result in a high cost of labour to obtain a degree of compaction with available equipment.
For the design requirement of any concrete structured project to be achieved, close supervision of the project and adequate concrete mix design should be by the civil Engineer involved. In recent year we have witness allot of concrete structural failure either during construction, after the completion or few year of the project age of completion, without satisfying design age of the project life (Yunusa, 2011).

2. Literature Review

2.1 Types of Mixes

CORBON (2014) classifies mixes into three types of namely:
(i) Nominal Mixes
(ii) Standard/Prescribed Mixes
(iii) Designed Mixes

2.1.1 Nominal Mixes

In the past the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes. These offer simplicity and under normal circumstances, have a margin of strength above that specified. The proportion of cement and aggregate is fixed, only the water cement ratio is varied. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

2.1.2 Standard/Prescribed mixes

The nominal mixes of fixed cement-aggregate ratio (by volume) vary widely in strength and may result in under- or over-rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed standard mixes. Here the structural Engineer prescribes a standard concrete mix ratio that he thinks will produce the required concrete. He may also indicate the type and size of aggregate to be used. The Builder/site engineer prepares the mixes based on the ratio that has been prescribed.

2.1.3 Designed Mixes

In these mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics. However, the designed mix does not serve as a guide since this does not guarantee the correct mix proportions for the prescribed performance.

Proportioning concrete based on the specified design mixes involves; more steps, and the use of tabulated data and charts. The approach results in the production of concrete with the appropriate properties most economically. This is because the characteristics of the materials to be used and the characteristics of the concrete required are incorporated in the design procedure.

2.2 Grade Designation

According to Yunusa (2011) every concrete has its strength in N/mm2 when subject to test after 28 days of curing in any medium. The choice of concrete grade, depends on the purpose and usage as follows:

Table 1: Concrete Grade Designation

Concrete Grade N/mm^2	Ratio Cement, Sand and Aggregates	Usage
10	1:4:8	Blinding concrete
15	1:3:6	Mass concrete
20	1:2.5:5	Light reinforced concrete
25	1:2:4	Reinforced concrete/pre-cast
30	1:1.5:3	Heavy Reinforced concrete/pre-cast
35	1:1.5:2	Pre-stressed/pre=cast concrete
40	1:1:1	Very heavy reinforced concrete/pre-cast/pre-stressed

3. MATERIALS AND METHOD

The Dangote brand of ordinary Portland Cement (OPC) manufactured by Dangote Cement Company Plc Obajana in Kogi State and conforms to BS 12 (1996) and ASTM C 150 (1994)

The fine aggregate used for this research was natural quartzite dredge from river obtained from Gumor, Toro local Government Area of Bauchi State. It has a specific gravity of 2.63 and bulk density of 1480kg/m3 and was free from deleterious matters. The coarse aggregate used was a normal weight aggregate (machine crushed granite) with maximum size of 20mm and was obtained from PW Nigeria Quarry site near Vom, Jos south local government of Plateau state. It has a specific gravity and bulk density of 2.63 and 1370 kg/m3 respectively.
The water used throughout the tests was water fit for drinking and obtained from the public supply system, University of Jos.

The quantity of sand was first measured and poured on the floor, followed by cement which was also measured and spread on the sand. Both materials were thoroughly mixed using a shovel. The coarse aggregate was then measured and spread on the sand and cement mix. Mixing of the concrete was done manually, with w/c ratio of 0.45 kept constant throughout the experiment. They were thoroughly mixed before the required quantity of water was added. The mixing process was continued until a uniform matrix was obtained. Concrete of grade 20, 30 and 40 was produced accounting for low, middle and high strength requirements. The moulds were filled with fresh concrete and then vibrated using the vibrating table. After 24 hours, the concrete specimens were demoulded and cured in water curing tank. All the specimens were cured for hydration period of 7, 14 and 28, days respectively. Flexural strength and compressive strength of the various grades of the concrete were determined.

Cubes of dimension 150mm x 150mm x 150mm were produced for the compression strength test while beams of 100mm x 100mm x 500mm were produced for the flexural test. A total of 27 cubes and 18 beams were produced respectively.

3.1 Workability Tests

Slump test was carried out to determine the workability of each mix. The tests were carried out in all cases in accordance with the requirements of BS 1881: Part 102(1983) for slump test and BS 1881: Part103 (1983) for compacting factor tests. The results are shown in Table 10.

3.2 Compressive Strength Test on Sample Cubes

The compressive testing machine was used to test the entire concrete cubes for crushing strength at 7, 14 and 28 days respectively. The various weights were taken in order to determine the various densities of the sample produced.

The average failure loads were used to obtain the compressive strength.

3.3 Flexural Strength Test on Sample Beams

The tensile strength testing machine was used to test the flexural strength of the concrete beams at 7, 14 and 28 days respectively after taking their weights in order to ascertain their densities. Results were recorded based on the average tensile strength.

4. RESULTS AND FINDINGS

4.1 Hardened Concrete

Results of the characteristics of different grades of concrete using mix design method are discussed in terms of density, compressive strength, flexural strength and workability.

4.2 Density of Specimen

Table 4 shows density of concrete cubes ranging from $2441kg/m^3$ to $2588kg/m^3$.These values fall within the density values for normal weight concrete as stated by Neville (2000). It can be seen that the densities of the specimen increase with the days of curing, which suggest that there is no deterioration of the said concrete. This is in agreement with the findings of Neville and Brooks (1997).

Table 2: Variation of Density of Cubes (kg/m^3) with Hydration Periods (Days)

	Hydration Period (Days)					
	7		14		28	
Conc. Grade	Ave. Wt. (Kg)	Den. (Kg/ m^3)	Ave. Wt.	Den. (Kg/m^3)	Average Wt. (Kg)	Den. (Kg)
20	8.70	2558	8.75	2573	8.80	2588
30	8.30	2441	8.35	2455	8.50	2500
40	8.65	2544	8.60	2529	8.80	2588

4.3 Compressive Strength of Hardened Concrete

Results of the compressive strengths development with hydration periods of 7, 14 and 28 days for the various grades of concrete is presented in Table5. The results show that the compressive strength generally increases with higher grades and also with the hydration periods, which informs non-deterioration of the concrete.

It was also was observed that maximum compressive strengths of 39.55N/mm², 34.88N/mm^2 and 28.66N/mm^2 at 28 days of curing was recorded with grade 40, 30 and 20 concretes respectively. All the grades of concrete meet up to the design target strength. This result obtained conforms to the findings of Yunusa (2011)

Table 3: Variation of Density of Beams (kg/m^3) with Hydration Periods (Days)

	Hydration Period (Days)					
	7		14		28	
Conc. Grade	Ave. Wt. (Kg)	Den. (Kg/m^3)	Ave. Wt.	Den. (Kg/m^3)	Ave. Wt. (Kg)	Den. (Kg)
20	12.55	2510	12.55	2510	12.65	2530
30	11.85	2370	12.20	2440	12.45	2490
40	11.95	2390	12.15	2430	12.20	2410

4.4 Tensile Strength of the Hardened Concrete

Table 7 shows the results of the flexural strength test at 7, 14 and 28days of curing. It could be deduced from the result that the behaviour pattern of flexural strength follows that of compressive strength as discussed above. The results of the flexural strength falls between 10% and 30% 0f the values of compressive strength in N/mm² which is in agreement with the assertion of Neville (2000).

Table 4: Variation of Compressive Strength of Cubes (N/mm^2) with Hydration Periods

	Hydration Period (Days)					
	7		14		28	
Conc. Grade	Ave. Ld. (N)	Comp. Str. (N/mm^2)	Ave. Ld. (N)	Comp. Str. (N/mm^2)	Ave. Ld. (N)	Comp. Str. (N/mm^2)
20	570	25.33	625	27.77	645	28.66
30	572	25.42	648	28.80	745	33.11
40	685	30.44	780	34.67	890	39.55

5. SUMMARY AND CONCLUSION

From the study of the properties of different grades of concrete using mix design method, the following conclusions were drawn;

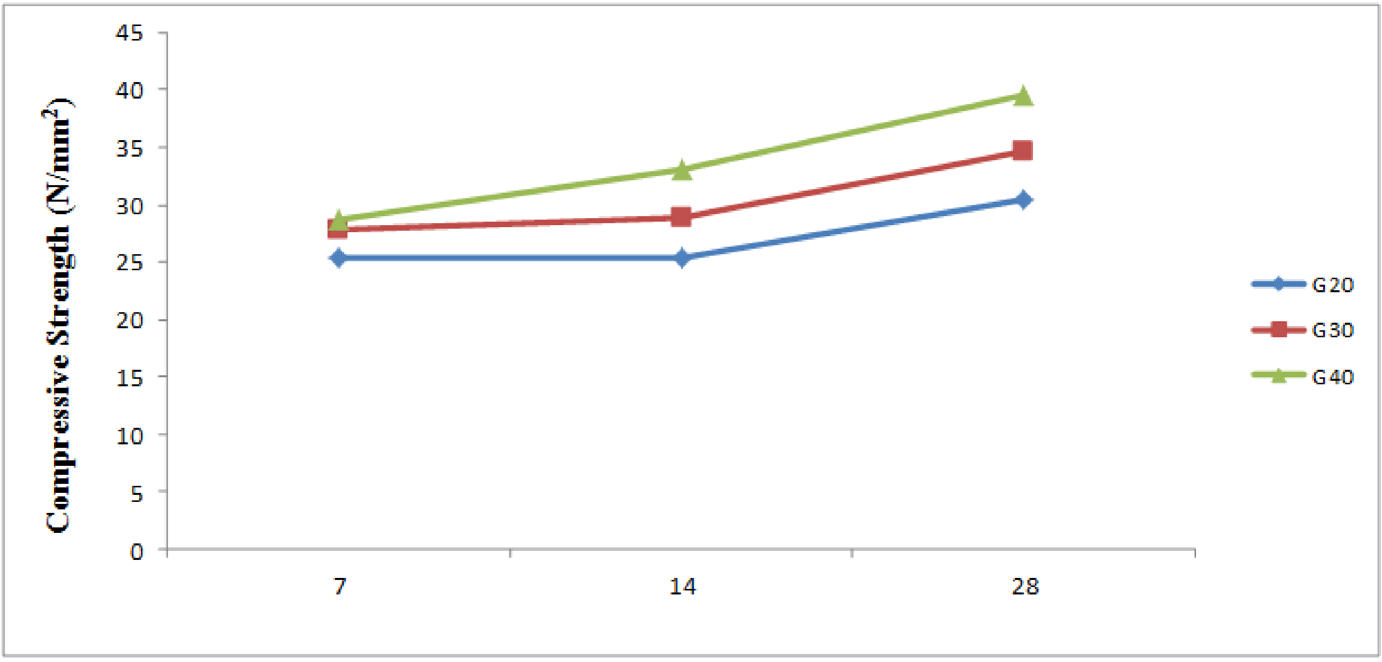
(i) All compressive strength values obtained were greater than the required characteristic strength at 28 days curing, hence the design is considered adequate.
(ii)Concretes of grade 40 recorded the highest workability of up to 170 mm slump followed by grade 30 concrete with moderate workability. This very high values could be useful in very heavy and congested reinforcements as observed by Yunusa (2011).
(iii)The percentage increase in compressive strength of concrete up to 13% exist between grades 20 and 30 concretes, while percentage increase of up to 11% exist between grades 30 and 40 concretes respectively.

6. RECOMMENDATIONS

(i) All concrete works should be designed for and quality controlled by an experienced professional.

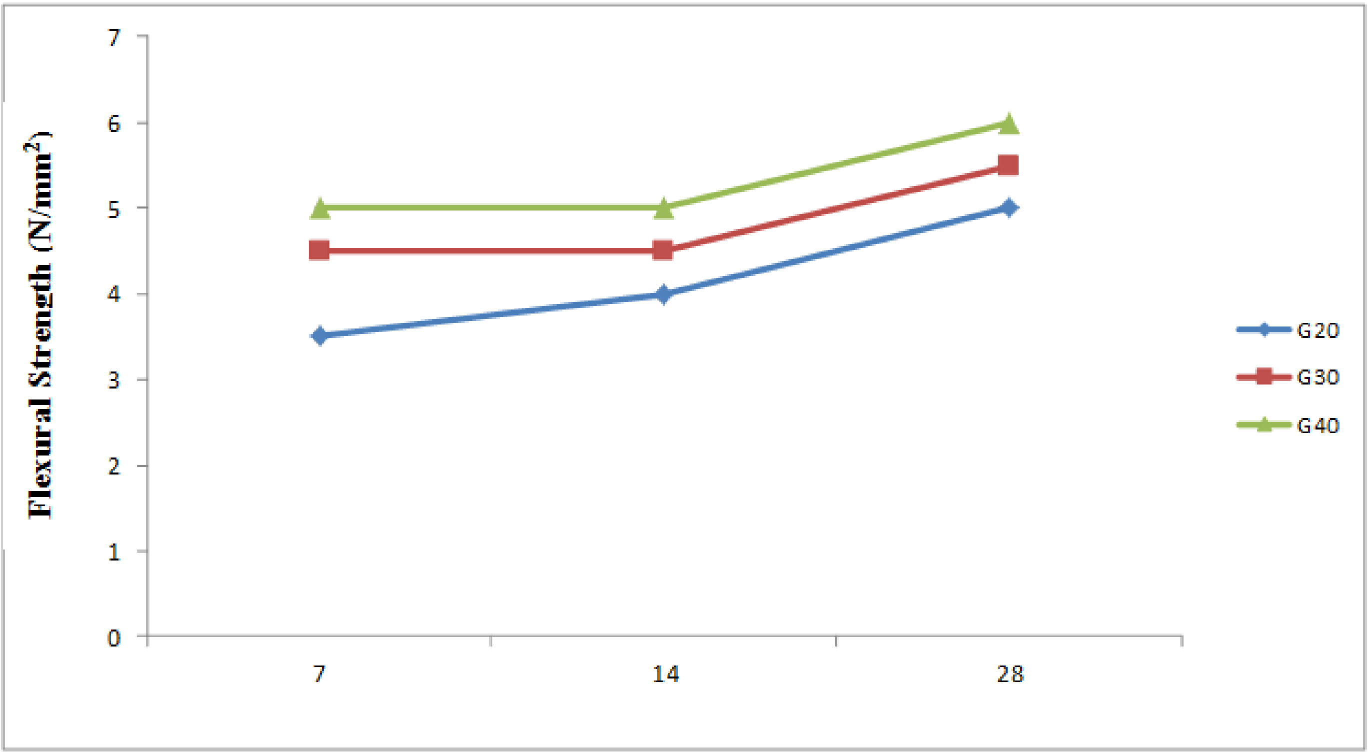
(ii) The local authorities should include designed mix details as part of requirements for approval of projects involving concrete works.

(iii)There should be improved awareness about the importance of designed mix with the professional in the construction industry in order to control failures in concrete.



Hydration Period (days)

Fig 1: Variation of Compressive Strength (N/mm^2) with Hydration Period (days)



Hydration Period (days)

Fig 2: Variation of Flexural Strength (N/mm^2) with Hydration period (Days)

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