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CONCRETE MIX DESIGN USING AVAILABLE COARSE AGGREGATE IN YOLA, ADAMAWA STATE

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ABSTRACT

This study examines the physical properties and the compressive strength characteristics of two samples of available coarse aggregate in Yola metropolis which were identified as Basalt and Granite. Design mixes were produced using the coarse aggregates at water-cement ratio of 0.45, 0.50 and 0.55, concrete mix proportion in ratio1:1:3 and 1:2:3 was achieved and the workability checked. Concrete cubes were cast with target strength of 30N/mm^2 at 28 days hydration. Result obtained shows that compressive strength increase in age of curing and decreased with increase in fine aggregate content and water cement ratio. It was found that concrete cubes made with sample I aggregate (Basalt) have lower compressive strength than those made with sample II aggregates (Granite) at a given water cement ratio, fine aggregate content and curing age. All the cast cubes attained 55-63% of their 28 days strength at 7 days. It was established that at 28 days hydration, sample I cubes attained the strength of 29.7 N/mm^2 while sample II cubes attained the strength of 31.30N/mm^2 at water cement ratio of 0.45. Based on the above findings, the study recommends concrete mix proportion in ratio 1:1:3 and 1:2:3 at water cement ratio of 0.45 for Yola's coarse aggregates to achieve the needed workability and target strength of 30N/mm^2.

INTRODUCTION

Concrete is the most widely used man-made construction material in the world and is second only to water as the most utilized substance on the planet (Gambhir, 2005). It is obtained by mixing cementatious material, water and aggregates (and sometimes admixtures in required proportions).

The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, the proportions of mix, the method of compaction and curing. The popularity of concrete is due to the fact that the common ingredients, it is possible to tailor the properties of the concrete to meet the demands of any particular situation. Proportioning of concrete by the application of concrete mix design principle, unlike the rule of the thumb adoption of the nominal mixes considers the necessary characteristics of the concrete materials method of preparation and the exposure conditions to which the concrete will be subjected.

Accordingly, Neville (1996) defines concrete mix design as the process of selecting suitable ingredients of concrete and determining their relative quantities with the objective of producing an economically as possible concrete of certain minimum properties. The minimum properties required to be possessed by a concrete is durability (Irving, 1999). The durability of concrete may be defined as the period for which the concrete will continue to serve the purpose for which it was designed under stated service condition(s) Garba and Zubairu(2002).

Similarly, Jackson and Dhir (1996) argued that a concrete element or structure that is durable in the hinterland may not be durable along the seashore. Also, a durable concrete in a clean rural environment may not be durable in a heavily polluted industrial city atmosphere.

Concrete that is properly designed prepared, placed and compacted will be durable under normal service conditions and could lack durability if exposed to aggressive influences which could be internal or external. A concrete that is not durable is not economical in the long run (Garba, et al; 2002).

But by strict adherence to the principles of concrete mix design which involves careful proportioning of mix and tests, durable concrete of any desired quality can be achieved using the available materials from even an apparently "poor mix" at economical cost.

OBJECTIVES OF THE STUDY

The objectives of the study is

1. To investigate the physical characteristics of the coarse aggregates found in Yola metropolis.
2. To carry out design mixes using the aggregates.
3. Produce concrete cubes using the aggregates.
4. To investigate the properties of concrete made with the coarse aggregates.

MATERIALS AND METHOD

Materials

The materials used for the production of the specimen for this study are cement, aggregate and water.

Cement

The ordinary Portland cement (OPC) manufactured in Ashaka Cement Company was used as the binding medium.

Aggregate

The aggregate used for the study include: the fine and coarse aggregates which were obtained from local supplies and the quarry station located along Numan road. The aggregates complied with the grading requirements of BS 882 part 2 (1973)

(i) Fine aggregate: The fine aggregate was sharp and thoroughly clean to remove element that might be harmful to the cement. The fine aggregate was made to pass through 5mm sieve conforming to the specification of BS 882 part 2 (1973).

(ii) Coarse aggregate: Two samples of coarse aggregate were obtained from the quarry station. Sample I aggregates were identified as basalt which is an intrusive igneous rock formed under low temperature while sample II aggregates were identified as granite which is an extrusive igneous rock formed under high temperature.

(iii) Water: Suitable clean drinking water was used throughout the test.

EXPERIMENTAL PROCEDURE

Two samples of coarse aggregates were obtained from the quarry station located along Numan road in Adamawa State.

The physical properties of the coarse aggregates were first examined. These properties are namely: the shape, texture, the specific gravity, bulk density and the particle size distribution.

The second category of test examines the slump and compacting factor as well as the compressive strength of the mixes and cubes respectively.

Design mixes were produced, with each mix carried out at a water-cement (w/c) ratio of 0.45, 0.50 and 0.55. A total of 54 cubes were cast and tested with each sample of coarse aggregates having 27 cubes. Hand mixing of aggregate was employed. The workability of each mix was assessed using slump and compacting factor tests at varying water – cement ratio and aggregate-cement content in accordance with the provision of BS 1881 (1970) standard test methods.

After the workability has been assessed, the specimens were cast in three layers with the compaction of each layer depending on the water-cement ratio and mix proportions. The top surfaces of the specimens were then trowelled smooth and the moulds covered with polythene sheets for 24 hours. The cubes were demoulded and subsequently cured in water at room temperature. The cubes were then tested after 7, 14 and 28 days of curing to determine the compressive strength characteristics. The British method of mix design was adopted for this research work.

PRESENTATION AND DISCUSSION OF RESULTS

Sieve Analysis

The results of the sieve analysis for the fine and coarse aggregate samples 1 and 2 are tabulated in tables 1, 2, and 3 respectively.

Table 1: sieve analysis of fine Aggregate.

Sieve size (mm)	Weight of Material Retained (g)	Weight of Material Passing (g)	Percentage Of material Retained (%)	Percentage of Material Passing (%)
5.00	0.00	999.90	0.00	100
4.75	0.80	999.00	0.10	99.90
2.36	3.50	995.50	0.40	99.50
1.70	7.90	987.60	0.80	98.70
1.18	32.30	995.40	3.20	95.50
600	206.20	749.20	20.62	74.90
300	604.40	144.80	60.40	14.50
100	136.30	8.50	13.60	0.90
Pan	8.50	-	0.90	-

Total mass of material = 1000g

Table 2: Sieve Analysis of Coarse Aggregate sample 1

Sieve size (mm)	Weight of Material Retained (g)	Weight of Material Passing (g)	Percentage Of material Retained (%)	Percentage of Material Passing (%)
37.50	0.00	998.60	0.00	100
19.00	12.00	986.60	1.20	98.80
13.20	84.90	901.70	8.50	90.30
9.50	268.40	633.30	26.90	63.40
6.70	625.30	7.99	62.60	0.80
Pan	7.99	-	0.80	-

Total weight = 998.60g

Table 3: Sieve analysis of Aggregate Sample II

Sieve size (mm)	Weight of Material Retained (g)	Weight of Material Passing (g)	Percentage Of material Retained (%)	Percentage of Material Passing (%)
37.50	0.00	998.60	0.00	100
19.00	12.00	984.81	1.27	98.73
13.20	94.25	890.56	9.45	89.28
9.50	265.50	625.06	26.62	62.66
6.70	623.20	1.86	62.48	1.86
Pan	1.86	-	1.86	-

Total Mass of Material = 997. 5g

SPECIFIC GRAVITY

Table 4, 5 and 6 shows the results obtained for sand course aggregate sample I and II respectively.

Table 4: specific gravity of Fine Aggregate

	TEST 1	TEST 2
W1 = Glass plate+ gas jar, (g)	616.0	616.5
W2=Glass plate+ gas jar + sample (g)	816.0	816.5
W3=glass plate+gas jar+sampleWater (g)	1436.0	1437.0
W4=Weight of water W3_W2 (g)	620	620.5
W5=glass plate + gas jar + water (g)	1312.3	1312.8
Specific gravity = $\frac{W2 - W1}{W5 - W1 - W4}$	2.62	2.64

Average specific gravity = $\frac{2.62+2.64}{2}$ = 2.63

Table 5: specific Gravity of Coarse Aggregates (Sample I)

	TEST 1	TEST 2
W1 = Glass plate+ gas jar, (g)	616.0	616.5
W2=Glass plate+ gas jar + sample (g)	915.5	915.0
W3=glass plate+gas jar+sampleWater (g)	1498.5	1499.0
W4=Weight of water (g)	583.5	583.5
W5=glass plate + gas jar + water (g)	1312.8	1312.2
Specific gravity = $\frac{W2 - W1}{W5 - W1 - W4}$	2.64	2.66

Average Specific Gravity = $\frac{2.64 + 2.66}{2}$= 2.65

Table 6: Specific gravity of Coarse Aggregates (Sample II)

	TEST 1	TEST 2
W1 = Glass plate+ gas jar, (g)	616.0	616.5
W2=Glass plate+ gas jar + sample (g)	916.0	916.5
W3=glass plate+gas jar+sampleWater (g)	1505.0	1510
W4=Weight of water (g)	589.5	593.5
W5=glass plate + gas jar + water (g)	1318.7	1322.4
Specific gravity = $\frac{W2 - W1}{W5 - W1 - W4}$	2.65	2.67

Average specific gravity = $\frac{2.65+2.67}{2}$=2.66

Table: 7 Summary of Physical properties of Aggregates

	Coarse Aggregate Sample I	Coarse Aggregate Sample II	Sand
Bulk density kg/m3	1686.4	1829.6	1545.8
Specific gravity	2.65	2.66	2.63
Water absorption	0.72	0.70	0.50
Shape	Irregular	Irregular	Crystalline
Texture	Rough	Rough	Fine

MIX DESIGN STIPULATION

i Characteristics compressive Cube strength at 28 days 21N/mm²
ii Maximum size of Aggregate (Combined) 20mm-5mm
iii Types of Aggregates Sample I, crushed irregular Basalt Sample II, crushed irregular Granite
iv Degree of workability (Slump 60-75mm) / (0.90-0.95 CF)
v Degree of quality control Good
vi. Type of Exposure Mild

Characteristics of materials

i Cement
(a) Type of cement used : ordinary Portland cement (OPC)
(b) Specific gravity of cement: 3.15
(c) Bulk density cement: 1500kg/m3
ii Aggregate:

		Coarse Aggregates (Sample I) (Basalt)	Coarse Aggregates (Sample II) (Granite)	fine Aggregate
(a)	Specific gravity	2.65	2.66	2.63
(b)	Bulk density	1686.4kg/m3	1829.6kg/m3	1545.8kg/m3

Table 8.Mix Design manipulation Table

	CALCULATION/ REFERENCES	OUTPUT
1	TARGET MEAN STRENGTH. The target mean strength is given by Ft = Fck + 1.65 Where Ft = target mean strength. Fck = specified mean strength. S = margin permissible. Thus Ft = 21 + (1.65*5) = 30 N/mm²	Target mean strength = 30N/mm2
2	Free water – cement ratio required for the target mean strength of 30N/mm2 is 0.50, which is lower than the maximum value of 0.55 prescribed for mild exposure (Shah, 2005)	Water – Cement ratio = 0.50
3	Slump of 60 – 75 mm and compacting factor of 0.90 – 0.95 were assumed for this mix and later confirmed from trial mix as adequate for the design	Slump = 60 – 75 mm CF = 0.90 – 0.95
4	Water and sand content for 20mm nominal maximum size aggregates, water content per cubic meter of concrete by absolute = 35% (Shah, 2005)	Water content = 35%
5	CEMENT Water – cement ratio = 0.50 Since 186kg of water is needed, then the quantity of water in litres = 186 litres : cement = 186/0.50 = 372 kg/m3	Cement = 372kg/m3
6	TOTAL AGGREGATE CONTENT - Wet density of concrete = 2400kg/m³. V = 2400 * (1 - C/1000Sc - W/1000) V = 2400* (1 - 372/(1000*3.15) – 186/1000) V = 1670kg/m3 Where V= total volume of aggregates Sc = specific gravity C = cement W = water content.	Total aggregates = 1670 kg/ m³.
7	Based on the water – cement ratio, slump and specified strength, the proportion of fine aggregates = 35% Fine aggregates = (35*1670)/100 = 585kg/m³	Fine aggregates content = 585kg/m³
8	Coarse aggregate content = V- F = 1670 – 585 = 1085kg/m³	Coarse aggregate = 1085kg/m³
9	Mix proportions Water:: cement: fine:coarse 186:372:585:1085 Actual quantities required for mix per bag cement 186/372: 372/372 : 585/372 : 1085/ 372 0.5: 1 : 1.57 : 2.92 By mass 1: 2 :3	Mix proportion = 1:2:3
10	For a 50 kg of cement, the quantities of material are a) Cement – 50kg. b) Sand – 79 kg. c) Coarse aggregate – 146kg.	50kg:79kg :146kg

Table 9 TRIAL MIXES

STAGE	CALCULATION/REFERENCE	OUTPUT
1	Using 30% of sand with water – cement ratio = 0.5 Sand content = 30 * 1670 / 100 = 501kg/m^3 Mix proportion Water : Cement : Fine : Coarse 186 : 372 : 501 : 1169 Actual quantities by mass 0.5 : 1 : 1.34 :3.14 MIX 1 = 1 : 1 : 3	Sand content = 501kg/m^3 MIX 1 = 1 : 1 : 3
2	Water – Cement ratio kept constant = 0.50 but the proportions of sand, cement and water were varied by 3% Sand content = 33 * 1670 / 100 = 543kg/m^3 Coarse aggregate content = 1670 – 543 = 1127kg/m^3 Mix proportions Water : cement : Fine : Coarse 191.7 : 383.4 : 543 : 1127 Actual quantities by mass 0.5 : 1 : 1.41 : 2.94 Mix 2 = 1 : 1: 3	Sand Content = 543kg/m^3 Coarse aggregate content = 1127kg/m^3 Mix 2 = 1: 1: 3
3	Water – Content increased by 10% and Sand content increased to 34% Water – cement = 0.55 Volume of water = 191.7 Cement content = 191.7/0.55 = 348.5kg/m^3 Sand content = 34* 1670 / 100 = 569kg/m^3 Coarse aggregate content = V – F = 1690 – 569 =1101 kg/m^3 Mix proportions Water : Cement : Fine : Coarse 191.7 : 348.5 : 569 : 1101 Actual quantities by mass 0.55: 1: 1.63: 3.15 Mix 3= 1: 2 : 3	Cement content = 348.5kg/m^3 Sand content = 569kg/m^3 Coarse aggregate = 1101kg/m^3 Mix 3 = 1: 2 : 3
4.	Water content decrease by 10% Sand percentage reduced to 32% W/C Ratio = 0.45 Volume of water = 197.7 Cement content = 197.7 / 0.45 = 426kg/m^3 Sand content =32 * 1670 / 100 = 516.94kg/m^3 Coarse Aggregate Content = V – F = 1670 – 516.94 = 1098.5kg/m^3 Mix proportions Water : Cement : Fine : Coarse 197.7 :426 : 516.94 : 1098.5 Actual quantities by mass 0.45 : 1 : 1.21 : 2.57 Mix 4 = 1 : 1 : 3	Cement content = 426kg/m^3 Sand content = 516.94kg/m^3 Coarse aggregate content = 1098.5kg/m^3 Mix 4 = 1:1:3

Table 10: SUMMARY OF TRIAL MIXES.

Quantities of Materials Per cubic meter of concrete						Concrete Characteristics	
Mix No	W/C Ratio	Cement (kg)	Water (kg)	Sand (kg)	Coarse Aggregates (kg)	Compacting factor	
						Sample I	sample II
1	0.50	372	186	501	1169	0.80	0.78
2	0.50	383.4	191.7	503	1127	0.89	0.93
3	0.55	348.5	191.7	569	1101	0.90	0.92
4	0.45	426	191.7	516.94	1098.5	0.91	0.92

TABLE 11: Compressive strength of concrete cubes made with sample I (coarse Aggregate) at seven days curing.

	MIX. 2			MIX. 3			MIX. 4		
	0.5			0.55			0.45		
TRIALS	1	2	3	1	2	3	1	2	3
WEIGHT(g)	8202	8206	8210	7910	7915	7920	8100	8150	8175
DENSITY(g/cm³)	2.43	2.43	2.43	2.34	2.35	2.35	2.40	2.41	2.42
DIAL READING(KN)	414	437	452	403	416	430	452	450	488
COMPRESSIVE STRENGTH(N/mm²)	18.4	19.4	20.1	17.9	18.5	19.1	20.1	20.0	21.7
AVERAGE COMPRESSIVE STRENGTH (N/mm²)	19.3			18.5			20.6		

TABLE 12 Compressive strength of concrete cubes made with sample 1 (Coarse aggregates) at fourteen days curing

	MIX. 2			MIX. 3			MIX. 4		
	0.5			0.55			0.45		
TRIALS	1	2	3	1	2	3	1	2	3
WEIGHT(g)	8120	8135	8120	8005	8010	8010	8122	8154	8134
DENSITY(g/cm³)	2.41	2.42	2.41	2.37	2.37	2.37	2.41	2.42	2.41
DIAL READING(KN)	523	580	561	452	527	527	556	564	561
COMPRESSIVE STRENGTH(N/mm²)	23.5	25.76	24.95	20.1	23.4	23.4	24.70	25.05	24.95
AVERAGE COMPRESSIVE STRENGTH (N/mm²)	24.72			22.30			24.90		

TABLE 13 Compressive strength of concrete cubes made with sample 1 (Coarse aggregates) at Twenty - eight days curing.

	MIX. 2			MIX. 3			MIX. 4		
	0.5			0.55			0.45		
TRIALS	1	2	3	1	2	3	1	2	3
WEIGHT(g)	8340	8300	8280	8110	8210	8150	8475	8225	8335
DENSITY(g/cm³)	2.46	2.45	2.45	2.40	2.43	2.41	2.51	2.44	2.45
DIAL READING(KN)	646	637	641	603	619	608	673	668	666
COMPRESSIVE STRENGTH(N/mm²)	28.7	28.3	28.5	26.8	27.5	27.0	29.9	29.7	29.6
AVERAGE COMPRESSIVE STRENGTH (N/mm²)	28.5			27.1			29.7		

TABLE 14 Compressive strength of concrete cubes made with sample II (Coarse aggregates) at Seven days curing.

	MIX. 2			MIX. 3			MIX. 4		
	0.5			0.55			0.45		
TRIALS	1	2	3	1	2	3	1	2	3
WEIGHT(g)	8312	8335	8135	8025	8025	8182	7090	8000	8030
DENSITY(g/cm³)	2.46	2.47	2.41	2.38	2.46	2.43	2.37	2.37	2.38
DIAL READING(KN)	497	482	468	485	490	490	538	535	530
COMPRESSIVE STRENGTH(N/mm²)	22.1	21.4	20.8	21.5	21.8	21.8	23.5	23.7	23.6
AVERAGE COMPRESSIVE STRENGTH (N/mm²)	21.5			21.7			23.6		

TABLE 15 Compressive strength of concrete cubes made with sample II (Coarse aggregates) at Fourteen days curing

	MIX 2			MIX 3			MIX 4		
	0.5			0.55			0.45		
TRIALS	1	2	3	1	2	3	1	2	3
WEIGHT(g)	8020	8120	8180	7905	7896	8002	8042	8060	8075
DENSITY(g/cm³)	2.38	2.41	2.42	2.34	2.34	2.37	2.38	2.39	2.39
DIAL READING(KN)	585	586	588	560	550	565	613	624	627
COMPRESSIVE STRENGTH(N/mm²)	26.0	26.0	26.2	24.8	24 4	25.1	27.3	27.7	27.9
AVERAGE COMPRESSIVE STRENGTH (N/mm²)	26.1			24.8			27.6		

TABLE 16: Compressive strength of concrete cubes made with sample II (coarse Aggregate) at twenty eight days curing.

	MIX. 2			MIX. 3			MIX. 4		
	0.5			0.55			0.45		
TRIALS	1	2	3	1	2	3	1	2	3
WEIGHT(g)	8440	8670	8640	8350	8300	8400	8550	8550	85551
DENSITY(g/cm³)	2.50	2.57	2.56	2.47	2.47	2.48	2.53	2.53	2.533
DIAL READING(KN)	675	698	682	675	670	680	695	681	731
COMPRESSIVE STRENGTH(N/mm²)	30.0	31.0	30.3	30.0	29.7	30.2	30.9	30.5	32..5
AVERAGE COMPRESSIVE STRENGTH (N/mm²)	30.4			29.9			30.3		

DISCUSSION OF RESULTS

The results of the calculated quantities of material per cubic meter of concrete are as shown in Table 10. Mix. 1 as calculated consists of batch quantities required per m³ of concrete, but in actual trial, the mix did not achieve the desired workability; this could be attributed to the fact that the mix was under-sanded as only 30% fine aggregate content in relation to the total volume of aggregates was used in the mix. Mix. 2 was achieved at constant water- cement ratio of 0.50 as in mix No. 1, but the proportions of sand, cement and aggregates were varied to 543kg, 383.4kg and 1127kg respectively. By visual observation, it was seen that a more cohesive mix was achieved for both the two samples of aggregates with an acceptable workability in terms of the target slump and compacting factor. It was observed that for mix. 3 in which the water – cement ratio was increased by 10% (i.e 0.55), a more cohesive mix was achieved with an increase in workability in terms of compacting factor of 0.90 and slump of 65mm for sample 1 and compacting factor of 0.90 and slump of 72mm for sample II aggregates as targeted in the design stipulations. This could be attributed to the increase in water – cement ratio, which in turn increase workability. Furthermore, mix. 4 was calculated by decreasing the water – cement ratio of mix. 1 by 10% (i.e 0.45) and also increasing the percentage of sand content to 516.94kg, it was observed that the mix was cohesive and possesses the desired workability in terms of compacting factor = 0. 91 and 0.92 for sample I and sample II aggregate respectively which is greater than the targeted 0.90 and falls within the range of the slump interval of 60 – 75mm for both the two sample of aggregates.

Variation of the 28-day cube strength with the water – cement ratio for mixes of different workability is shown in table 13 and 16 for sample I and sample II aggregates respectively. For a given water – cement ratio, the cubes made with sample I aggregates have lower compressive strengths than those made with sample II aggregates. Furthermore, it was noted that compressive strength decreased as the fine aggregates content increases and increased as the fine aggregate content decreases. From tables 11 - 16, it was established that compressive strength for all mixes decreases with increasing water –cement ratio. This is as would be expected (Neville, 1981).Furthermore, it was observed that at 28 days of curing for cubes made with sample I (basalt) as tabulated in Table 13, mix. 4 with water – cement ratio of 0.45 achieved the target strength of 30N/mm², this could be attributed to the fact that the mix has low water –cement ratio and the low the water – cement ratio, the fewer capillary pores and thus the higher the strength of concrete cubes. Conversely, mix.2 and mix.3 have strengths lower than the target strength by 1.5N/mm^2 and 2.9N/mm^2 respectively but falls within the required strength range. The reduction in strength is as a result of the high water – cement ratio in the mixes.

Similarly, at 28 days of curing, concrete cubes made with sample II (Granite) as tabulated in table 16 all achieved the target strength of 30N/mm^2; this could be as a result of the density of sample II aggregate. The data for the compressive strengths of the trial mixes for sample I and sample II as shown in the tables 11-13 and 14-16 respectively, generally showed that, age of curing and the variations in the size of the aggregates could partly be responsible for the increasing compressive strength of the concrete cubes. It was also observed that within the first seven days of curing, compressive strength generally varied between 55 to 63% of the final strength obtained after twenty – eight days.

CONCLUSION

From the study the following conclusion are drawn:

Mixes containing 30% fine aggregates content did not achieved the desired workability in terms of slump and compacting factor.

High fine aggregate content and water-cement ratio increases workability but decreases compressive strength of the cubes made with Yola aggregates.

The compressive strength of cubes made with sample II aggregate have higher strength than those made with sample I aggregate at a given water-cement ratio and curing age.

All concrete cubes cast using the coarse aggregates attained 55 – 63% of their 28 – day strength at 7 days hydration.

Properly designed concrete mix composition in ratio 1:1:3 or 1:2:3 can be used instead of 1:2:4 concrete using Yola's coarse aggregates.

Water – cement ratio of 0.45 is adequate to achieve the target strength of 30N/mm^2 with the two samples of coarse aggregates in Yola metropolis.

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