THE EFFECTS OF COARSE AGGREGATES ON THE STRENGTH OF CONCRETE USING ORDINARY PORTLAND CEMENT.

By:

OKPANACHI SAMUEL ADAMU

PGD/AGRIC ENG/2000/2001/152

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A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF POST-GRADUATE DIPLOMA IN AGRICULTURAL ENGINEERING (SOIL AND WATER ENGINEERING) FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

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CERTIFICATION

This is to certify that, this project was carried out by Okpanachi, Samuel A. in the Department of Agricultural Engineering, Federal University of Technology, Minna.

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Mr. B.A. Alabadan	**Date**
(Supervisor)	
....	....
Dr. D. Adgidzi	**Date**
(Head of Department)	
....	....
External Examiner	**Date**

DEDICATION

I dedicate this work to God, and my family - Mrs. Ruth Samuel, Ahiaba Samuel, Helen Samuel, Ojonoka P. Samuel, Ebiojo V. Samuel, Eikojonwa J. Samuel and Blessing A. Samuel and my late mother Rebecca Ademu Garbiel Okpanachi.

CHAPTER ONE

1.0 Introduction

Concrete plays a vital role in Agricultural development as are eminent in farm structures like: dams, irrigation drains, wells, roads, culverts etc. It is because of these tremendous importance that concrete plays that has brought our mind to think of the effect of the aggregates on the strength and to also see the step to step manufacturing techniques bearing in mind the standard use of the various elements that compose concrete.

In building farm structures. Concrete is needed in the foundation, the over site (German floor), the lintels, slabs and column. This study looks at the type of aggregates and the concrete mix that could be used for all the various purposes.

In irrigation, which is a very important aspect of Agriculture, it is needed to transport water long distance to improve the soil moisture for the life of plants. These are done through either open or closed channel drain using concrete construction. The concrete must meet all requirements, which include the use of coarse aggregates as an element.

It is therefore important to know the effect these aggregates have on the strength so that we may be able have an effective structure. This is a systematic study of the technology of concrete, its various elements, and the strength so attained after some period of time.

1.1 STATEMENT OF PROBLEM

(i) The study looks at the effect of coarse aggregates on the strength of concrete.

(ii) This study intends to find out the effect of the duration of curing on the strength of concrete.

1.2 AIMS OF THE STUDY

The major aims of this study is to determine the effect of coarse aggregate on the strength of concrete using Ordinary Portland Cement and specifically aimed at finding out:

(a) The composition of the various elements and the coarse aggregate to determine their effects on the strength of concrete.

(b) The effect of duration of curing of the concrete on the strength.

1.3 SIGNIFICANCE OF THE STUDY

Concrete is a vital element in the strength, durability, deflection, and longevity of a structure, we intend that agriculturists should know the techniques and principles of producing concrete bearing in mind the various elements involved and the batching techniques. That also the appropriate material for concrete production are employed at appropriate time in other not to jeopardize the final strength of the concrete which is at its final at the age of the 28th day

CHAPTER TWO

2.0 Literature Review

2.1 Concrete

Concrete is a very variable material having a wide range of strength and stress-strain curve. A typical curve for concrete in compression is in the form of the graph.

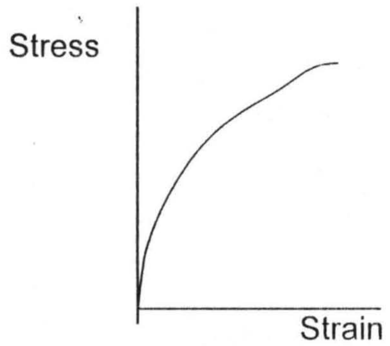
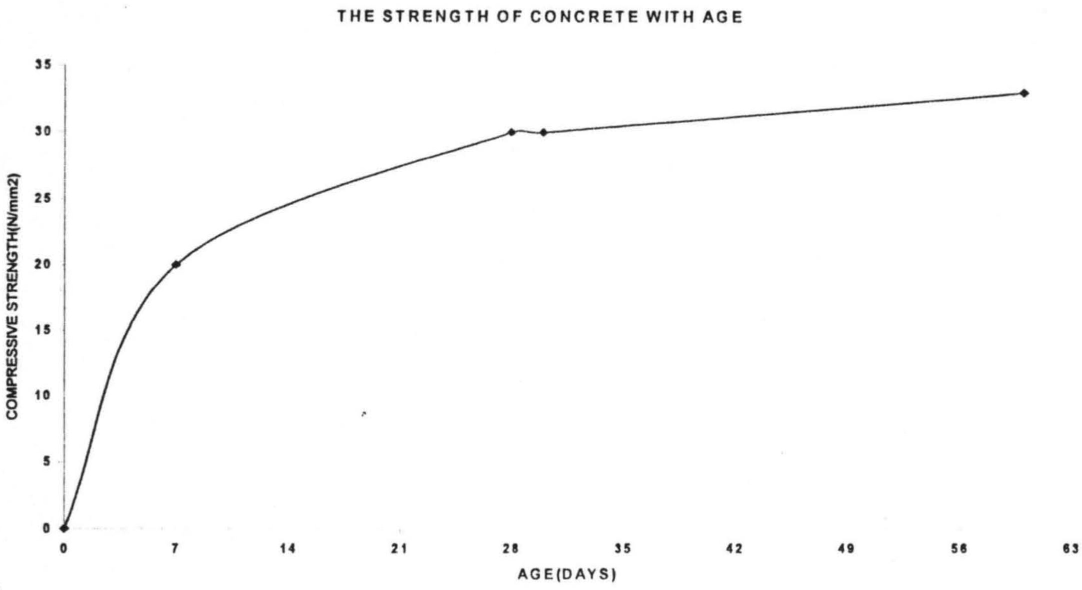


Fig. 1. **STRESS – STRAIN CURVE FOR CONCRETE IN COMPRESSION**

A load is applied on a cast cured concrete cube, at first the ratio between stress and strain are approximately linear and the concrete behaves almost as an elastic with virtually some expectation of recovery if lead is recovered. But as this loading continues beyond this elastic point, there is permanent deformation where recovery is no more possible. Irrespective of the grade of the concrete, it is a recorded fact that concrete generally increases in strength with age during curing to a maximum strength in 28 days as illustrated below.



\ typical variation in strength of an adequately cured ordinary Portland cement oncrete as suggested by Bs 8110 and CP 110, Part 1, 1972 is as Shown in tables 1 and 2 below:

'able 1 Variation in strength of adequately cured concrete

Duration	Strength N/MM^2
7 days	20
1 month	30
2 months	33
3 months	35
6 months	36
1 year	37

Table 2 Grade of concrete

;rade	Characteristic Strength N/MM^2	Lowest Grade for Compliance with Appropriate Use
	7.0	Plain concrete
0	10.0	
5	15.0	Reinforced concrete with light weight aggregate
?0	20.0	Reinforced concrete with dense aggregate
?5	25.0	
30	30.0	Concrete with Post-Technical tendons
10	40.0	Concrete with the tensioned tendons
;0	50.0	

Sources: Table 47 CP 110 Part 1 1972

Bs 8110 condemns the use of concrete beyond the curing strength of that of 28 days.

The selection of a type of concrete is mostly governed by the strength required which depend on the intensity of loading and the form and size of structural members. The strength is assessed by crushing, the cubes or a cylinder of concrete made from the designed mix. The type of cement used in concrete production cannot be over-looked. Exposure condition and durability are factors to look out for in the choice of cement. For example, a structure subjected to corrosive action of chemical will trigger the mind to use a denser and higher grade concrete and a blast furnace or sulphate resisting cement being used. So also low-heat cement is used to reduce the heat of hydration.

Rapid hardening is employed when an early strength is required. In this experiment we are concerned with ordinary Portland cement in the production of normal concrete.

Minimum cement content is required in the production of normal concrete to ensure durability under specified condition of exposure and the maximum free water/cement ratio to be used are recorded in the
Table 3 below.

2.3 CP110 Part 1(1972). Minimum Cement Required in Portland Cement Concrete to ensure durability under specified condition or exposure.

Exposure	Reinforced Concrete				Prestressed Concrete				Plain Concrete			
	Nominal Maximum Size of Aggregate				Nominal Maximum Size of Aggregate (mm)				Nominal Maximum Size of Aggregate (mm)			
	40	20	14	10	40	20	14	10	40	20	14	10
Mild: e.g. completely protected against weather, or aggressive conditions, except for a brief period of exposure to normal weather conditions during construction.	Kg/m^3 220	Kg/m^3 250	Kg/m^3 270	Kg/m^3 290	Kg/m^3 300	Kg/m^3 300	Kg/m^3 300	Kg/m^3 300	Kg/m^3 200	Kg/m^3 220	Kg/m^3 250	Kg/m^3 270
Moderate: e.g. sheltered from severe rain and against freezing whilst saturated with water. Buried concrete and concrete continuously under water.	260	290	320	340	300	300	320	340	220	250	280	300
Severe: e.g. exposure to sea water, moorland water, living rain, alternate wetting and drying and to freezing whilst wet. Subject to heavy condensation or corrosive times.	320	360	390	410	320	360	390	410	270	310	330	360
Subject to salt used for de-icing (see 6.3.7)	260	290	320	340	300	320	340	240	280	210	210	330
When the maximum free water/cement ratio can be strictly controlled (see 6.3.3) these values may be reduced to:												

2.4 REQUIREMENT FOR FRESH CONCRETE

Workability: CP 110 Part 1, 1972 Clause 6:4:2 states that – The workability of the fresh concrete should be such that the concrete is suitable for the condition of handling and placing so that after compaction it surrounds all reinforcements, tendons and ducts and completely fills the formwork.

Workability should be assessed by means of slump test, compaction factor test or VB consisto-meter test as appropriate. The above code was strictly adhered to as slump test was conducted for each experience.

2.5 PRODUCTION OF CONCRETE

Provision should be made to protect cement before use to prevent accidental mixing of different types – (CP 110, 1972 – 6.7.2).

2.5.1 **Aggregates:** separate fine and coarse aggregates should be used except for grades 7, 10 and 15 where all in aggregate may be used. Separate storage facilities with adequate provision of drainage should be provided for each different size of aggregate used.

For grades of concrete other than 7, 10 and 15, the grading of each size of aggregate from each pit, quarry or other source of supply should be determined (sieve analysis). - (CP 110, Part 1, 1972, 6:7:3).

2.6 Batching And Mixing

This recommend that; the quantity of cement, the quantity of fine aggregate and the quantity of the various sizes of coarse aggregate should be measures by weight to be aided by table next page except that aggregate may be measured by volume in the following instances:-

(1) Concrete of grade 7, 10 and 15 using dense aggregate.

(2) Concrete of grade 7 and 10 using lightweight aggregate.

(3) The light - weight coarse aggregate component only in concrete of grade 15 and higher - (CP 110, Part 1, 1972 – 6:7:4).

2.6 CP110 Part 1(1972). Prescribed Mixes for Ordinary Structural Concrete

Concrete Grade	Nominal size of aggregate (mm)	40		20		14		10	
	Workability	Medium	High	Medium	High	Medium	High	Medium	High
	Limits to slump that May be expected (mm)	50 – 100	100 – 150	25 – 75	75 – 125	10 – 50	50 – 100	10 – 25	25 – 50
7	Cement (kg) Total aggregate (kg) Fine aggregate (%)	180 1950 30 – 45	200 1850 30 – 45	210 1900 35 –50	230 1800 35 – 50	--	--	--	--
10	Cement (kg) Total aggregate (kg) Fine aggregate (%)	210 190 30 – 45	200 1850 30 – 45	240 1850 35 – 50	260 1800 35 – 50	--	--	--	--
15	Cement (kg) Total aggregate (kg) Fine aggregate (kg)	250 1850 30 – 45	270 1800 35 – 45	280 1800 35 – 50	310 1750 35 – 50	--	--	--	--
20	Cement (kg) Total aggregate (kg) Sand* Zone 1 (%) Zone 2 (%) Zone 3 (%)	300 1850 35 30 30	320 1750 40 35 30	320 1800 40 35 30	350 1750 45 40 35	340 1700 45 40 35	380 1700 50 45 35	360 1750 50 45 40	410 1650 55 50 45
30	Cement (kg) Total aggregate (kg) Sand* Zone 1 (%) Zone 2 (%) Zone 3 (%)	370 1750 35 30 30	290 1750 40 35 30	400 1700 40 35 30	430 1650 45 40 35	430 1700 45 40 35	470 1600 50 45 40	460 1650 50 45 40	510 1650 55 50 45

A separate weighing device should be provided for weighing the cement. Alternatively, the cement may be measured by using a whole number of bags in each batch. The amount of water should be measured by volume or by weight.

2.7 *Compliance With Specified Requirements*

Clause 6.8.1 of CP 110, Part 1, 1972 specifies that:-

Provided that the Engineer is satisfied that that materials used are in accordance with his specification and with the constituent materials of the concrete and that correct methods of manufacture and practices of handling raw materials and manufactured concrete have been used, the compliance of:-

2.5.4 (1) A designed mix for ordinary structured concrete should be judged by the strength of the compression with the specified characteristic strength, together with the cement content in compression with the specified minimum cement content.

2.5.4 (2) A prescribed mix for ordinary structural concrete should unless otherwise specified, be judged on the basis of the specified mix proportions and required workability. The Engineer must satisfy himself that the concrete is likely to have strength.

A separate weighing device should be provided for weighing the cement. Alternatively, the cement may be measured by using a whole number of bags in each batch. The amount of water should be measured by volume or by weight.

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(1) A designed mix for ordinary structural concrete should be judged by the strength of the compression with the specified characteristic strength, together with the cement content in comparison with the specified minimum cement content.

(2) A prescribed mix for ordinary structural concrete should unless otherwise be specified, be judged on the basis of the specified mix proportions and required workability. The Engineer must satisfy himself that the concrete is likely to have strength.

2.8 Strength

Clause 6:8:2:1 specifies about strength that – the characteristic strength of concrete is that 28 – day – cured strength below which not more than 5% of the test results may be expected to fall.

Compliance with the specified characteristic strength should be judged by tests made on cubes at an age of 28 days unless there is evidence, satisfactory to the Engineer, that a particular regime is capable of predicting the strength at 28 days of concrete test at an earlier age when compliance may be based on the results of such tests alone.

2.9 Water/Cement Ratio

The total water/cement ratio of batch of concrete should not exceed the specified maximum value by more than 5% of that value. If maximum water/cement ratio has been specified the ability to comply with that requirement at a suitable level of workability will have been determined by means of trial mixes, provided that the constituent materials and mix proportion are not substantially different from those used in the trial mixes. A maximum water/cement ratio may be judged from workability test as contained on CP 110, Clause 6:8:5.

CHAPTER THREE

3.0 Materials And Methods

3.1. Location:

The experiments were conducted at Abuja at the Dantata and Sawoe Construction Company Abuja. All their available materials from the quarry, the soil and concrete laboratory were used. The company is involved in the construction of "outstanding engineering infrastructure at Gudu District Phase II of Abuja City using grade 25 for all the experiment specifically the samples that were taken were the materials for concreting of bridges.

3.2 . Materials:

The materials that were involved in the experiments were water, ordinary Portland cement (Ashaka cement), washed river sand, crushed stone dust and coarse aggregates from quarry along airport road which complied with BS 1047, BS 882 BS 3797 and 4619.

3.3. Methodology:

The experiments to determine the strength were divided into three basic parts- (a) Sieve analysis (b) Production of concrete (c) Testing for strength.

(a) Sieve Analysis:

Aggregates of nominal sizes 0-10mm, 16mm, 19mm, 32mm diameters were employed for the experiments.

The materials so got from the quarry and river for the concrete after using mechanic batch were fetched, hundred grammes of the material passed through a column of BS sieves and the individual pass weight were recorded. The analysis were corresponded with each other to see to their conformity with the road note 4 of "Design of concrete mixes"- (Transport and Road Research Laboratory U.K)

(b) Production of Concrete

After the configuration envelope was examined and found to be adequate, the material were batch from the result obtained from the mix design, bearing in mind the minimum cement ratio, to total aggregate weight, minimum cement/water ratio to ascertain the slump level, the relevant aggregate percentages.

Three sets of concrete were cast for each nominal diameter of the coarse aggregates in steel mould of 15cm x 15cm x 15cm. These were left to set after been well vibrated. The steel mould was struck off to reveal the concrete cubes which were submerged into pool of water for curing for seven days.

All the necessary precautions were taken in the production of the concrete, as such we did not allow curing up to the 28^{th} day bearing in mind clause 6:8:2 of CP 110.

(c) Crushing for strength:

The three cubes for each of the nominal diameters used were crushed in – turn starting from the fine aggregate, to the 16mm, 19mm and the 32mm nominal diameter sizes.

The calculations to determine the cube strength are attached in the appendices.

Table 6 Sieve Analysis – 16mm

INDIVIDUAL GRADING (% PASSING)											
S/ NO	SIZE (MM)	TYPE	0.15	0.3	0.60	1.18	2.36	4.76	9.52	12.7	19.00
1	0 – 5	UKES	2.3	8.8	35.5	63.4	83.7	94.8	100	100	100
2	0 – 5	ST. DUST	17.7	44.2	58.8	68.3	79.2	96.3	100	100	100
3	5 – 10	CR. ST	-	-	-	-	0.9	4.6	4.6	100	100
4	10 – 16	CR . ST	-	-	-	-	-	1.3	1.3	37.2	100
5	16 – 22	CR. ST	-	-	-	-	-	-	-	-	

Table 7 Sieve Analysis for 19mm

For this experiment just like the former one, a coarse aggregate of 19mm was used. A fresh sieve analysis is conducted to see grading envelope as recorded below:

Table 7 Sieve Analysis for 19mm aggregates

			INDIVIDUAL GRADING (% PASSING)							
S/ No	**Size mm**	**Type**	**0.15**	**0.30**	**0.60**	**1.18**	**2.26**	**4.76**	**9.52**	**19.00**
1	0 – 5	UKRS	2.9	19.8	36.6	54.0	72.4	90.1	98.0 0	100
2	0 – 5	STD	14.1	32.9	51.9	68.6	84.6	99.2	100	100
3	5 – 12	CR. ST	-	-	3.1	3.8	4.9	16.0	77.9	100
4	12 – 19	CR. ST	-	-	-		0.7	1.3	6.1	99.4

Table 8 Sieve Analysis for 32mm

This experiment takes the form of the preceding ones only that the largest nominal size of coarse aggregate in use is 32mm diameter.

Table 8 Sieve Analysis for 32mm aggregates

			INDIVIDUAL GRADING (% PASSING)								
S/NO	SIZE	TYPE	0.15	0.3	0.6	1.18	2.36	4.75	9.50	19	38.1
1	0 –5	UKE RS	1.6	11.1	32.0	57.0	80.7	94.0	100	100	100
2	0 – 5	ST. DUST	14.1	27.7	42.7	59.0	78.1	98.4	100	100	100
3	4 – 10	CR. ST	-	-	-	10.1	15.7	47.0	99.6	100	100
4	10 – 16	CR. ST	-	-	-	-	-	6.2	36.7	65.5	100
5	16 – 32	CR. ST	-	-	-	-	-	0.5	1.00	24.5	100

COMBINED GRADING

The Road note 4 "Design of concrete mixes"– (Transport and Road Research laboratory UK) is aimed at corresponding the total percentage design pass to that of established lower and upper limits to determine their suitability for use in concrete work. This influences the tables of the combined grading (Tables 9,10 and 11).

Table 9 –combined grading envelope for 16mm diameter nominal size

S/ NO	Size	% Allot	0.15	0.30	0.06	1.18	2.36	4.76	9.52	12.70	19.00	SG
1	0 –5	25	0.58	2.2	8.9	15.9	19.8	24.0	25.0	25.0	25.0	2.56
2	0 –5	12	2.0	5.2	7.1	8.2	9.5	11.6	12.0	12.0	12.0	2.67
3	5 – 10	31	-	-	-	-	0.3	1.4	19	31.0	31.0	2.67
4	10 –16	32						0.4	2.1	12	12	2.7
5	16 – 22	-										
Total		**100**	**2.58**	**7.5**	**16.0**	**24.1**	**29.6**	**37.4**	**58.1**	**80**	**100**	

Referring to appendix ii and drawing from table 50, CP110, the percentage allotment for this group must not be exceeded by more than 5%. The allotment is used to multiply out all the percentage passes to obtain the above result.

Table 10 combined grading envelope for 19mm diameter nominal size.

S/ No	Size mm	% All	0.15	0.30	0.60	1.18	2.36	4.76	9.52	19.00
1	0 – 5	30	0.87	5.94	10.98	16.2	21.72	27.03	29.4	30
2	0 – 5	10	1.4	3.29	51.9	68.6	84.6	9.92	10	10
3	5 – 12	35	-	-	1.00	1.33	1.7	5.6	27.3	35
4	12 – 19	30	-	-	-		0.21	0.39	1.83	29.82
Total			**2.27**	**9.23**	**17.2**	**24.4**	**32.1**	**43**	**68.53**	**105**

Appendix iii and table 50 0f CP 110 in reference brings about the above grading. The percentage allotment is also multiplied by all the percentage retained.

Table 11 combined grading envelope for 32mm diameter nominal size.

S/ NO	**SIZE**	**TOTAL% allotment**	**0.15**	**0.3**	**0.6**	**1.18**	**2.36**	**4.75**	**9.5**	**19**	**100**
1	0 –5	18	0.3	2	5.76	10.26	14.53	16.92	18	18	18
2	0 –5	17	2.4	4.7	7.3	10.0	13.3	16.7	17	17	17
3	4 – 10	15	-	-	-	1.5	2.4	7.1	14.94	15	15
4	10 – 16	25	-	-	-	-	-	1.55	9.2	16.4	25
5	16 – 32	20	-	-	-	-	-	0.1	0.2	4.8	20
TOTAL			**2.60**	**6.7**	**13.06**	**30.7**	**30.23**	**42.37**	**59.34**	**71.2**	**95**

Using appendix iv and table 50 like the other nominal diameters the above table came into been.

Table 12 Configuration envelope for 16mm nominal diameter.

S/No	0.15	0.30	0.6	1.18	2.36	4.76	9.52	12.70
Max Pass	3	8.1	21	28	35	42	65	100
Total Pass	2.58	7.5	16.0	24.1	29.6	37.4	58.1	80
Max pass	0	3	14	21	28	35	55	100

Table 13. Configuration envelope for 19mm nominal diameter

Individual passing	0.15	030	0.60	1.18	2.36	4.76	9.52	19.00
Maximum	1.5	12	27	34	42	48	75	100
Total Passing	1.27	9.23	17.2	24.4	32.1	43	68.53	100
Lowest Passing	0	2	9	16	23	32	45	100

Table 14 Configuration envelope for 32mm nominal diameter

S/No	0.15	0.30	0.60	1.18	2.36	4.76	9.50	19	100
Maximum Passing	5	15	22	30	37	47	60	75	100
Total Passing	2.60	6.7	13.06	30	30.23	42.37	59.34	71.2	95
Lowest Passing	2	7	12	18	23	32	44	60	100

THE CONFIGURATION

After the percentage allotment on the various nominal size of aggregates in table 9,10,6 and 11. The total configurations are found in tables 12, 13, and 14.

Table 12: for 16mm: the combined configuration envelope to road note 4- RTRL, UK was adequate. The total pass for this size fits into the envelope. For example sieve No 0.15 passed 2.58 % of the material, it was needed to be a minimum pass of 0% and a maximum of 3%. Sieve 1.18 passed a total of 24.1% the minimum pass according to configuration should be 21 with a maximum pass of 28% . Sieve 12.70 should pass 100 maximum and within 70% minimum but there was a total pass of 80%.

We say that the 16mm nominal size in this experiment is adequate and conforms to code.

Table 13.

In this envelope, we observe that sieve 0.15% has maximum allowable pure of 1.5% while the lever limit is 0% but the total pass is 2.27%. This is above the maximum pass for this sieve. But the road rote permit differences in this case up to 5%. Therefore this is ok. Sieve 19.00 passed 100% the lowest and maximum should be 100%. The result for this is equally adequate. The materials is fit for use and has such we proceed to batch and cast the concrete according to design.

Table 14

This are the results of the percentage allotment for 32mm configuration the total pass for sieve 0.15 was 2.60% and 30% for sieve 1.18 and 71.2% for sieve 19.00. This configuration we say is adequate because it is within the confine of the envelope.

The configuration shows that we could go on and batch the various elements using the mix design.

Table 15 Crushing strength result at 7 and 28 days

Description	0 – 5mm	16m	19mm	32mm
Age of concrete	7 days	7 days	7 days	7 days
Size of cube	15x15x15	15 x 15 x 15	15 x 15 x 15	15 x 15 x 15
Density	2.19	2.36	2.3	2.13
Weight (kg)	7.38	7.98	7.68	7.18
Crushed fore (N)	288	440	450	478
Strength N/mm2	12.8	19.56	19.73	21.26
Crushing Strength for 28 days	19.2	29.34 N/mm2	29.54 N/mm	31.89 N/mm2
The use of the concrete where applicable	Mortar, blocks, pipes etc.	Lintel, slabs, colums, concrete walls, piers, piles, tunnel etc	Same as 16mm	Foundation, over size concrete, slab (bridges) etc.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The strengths obtained from the experiment for 7days were 16mm – 19.56 N/mm^2, 19mm – 19.73N/mm^2 and 32mm – 21.26N/mm^2.

Those obtained for 28 days were for 16mm – 29.34N/mm^2, 19mm – 29.54N/mm^2 and 32mm – 32N/mm^2.

There exist a relationship between the aggregate and the strength of concrete and also the strength increases with age.

5.2 RECOMMENDATIONS

a. I recommend the following for use in construction of structures on agricultural and building sites – 0-5mm be used as mortar, blocks, construction of ring pipes, poles etc.

b. 16mm nominal diameter for lintels, slabs, columns, walls, drains, pile etc.

c. 19mm nominal diameter – same as 16mm and also for dam-diaphragms, grouting etc.

d. 32mm could be used for foundation, over site concrete, mass concrete, slabs (bridges) etc.

I would recommend further studies on **THE EFFECT OF CEMENT ON THE STRENGTH OF CONCRETE.**

APPENDIX I

Mixed design for 10mm diameter nominal size

Referring to tables 48 and 50 for plain concreter of grade 25 for the mix design,

For grade 25 - 10mm aggregate and medium workability =

Cement (Kg) for 10 mm =. 360

Total aggregate (Kg) = 1750

Sand:

Zone 1 % = 50% = .5 x 1750 = 875 kg

$\therefore$ 360 : 875

1 : 2 . 4 $\cong$ 1:2

The step by step crushing are calculate thus:

The size of the cubes - 15cm x 15cm x 15cm

AREA = 15cm x 15cm = 225 cm^2 = 22500 mm^2

VOLUME= 15cm x 15cm x 15cm = 3375 cm^3 = 3375000 mm^3

The cubes were weighed and their weights recorded as before

(a) - 7340g

(b) - 7420g

The Density of each of the Cubes are –

(1) $\frac{\text{Mass}}{\text{Volume}} = \frac{7340}{3375} = 2.17$

(2) $\frac{7420}{3375} = 2.198 = 2.20$

The Crushed reading

(1) 285.75 KN = 285750 N

(2) 290.25 KN = 290250 N

$\therefore$ The crushed strength (1) $= \frac{285750}{22500} = 12.7 \text{ N/mm}^2$

(2) $= \frac{290250}{22500} = 12.9 \text{ N/mm}^2$

The average strength $= \frac{12.7 + 12.9}{2} = \underline{12.8 \text{ N/mm}^2}$ for 7 days

APPENDIX II

Mixed design for 16mm and 19mm nominal sizes

Referring to table 50 for concrete grade 25 and up to 20mm maximum size of aggregate for mild workability the following information will help us to determine the configuration envelope.

Cement (cubic meter) = 320kg.

Total aggt = 1800kg

Sand:-

Zone 1 (%) = 40

2 (%) = 35

3 (%) = 30

Total aggt. For 20mm = 1750kg Density = 2.651 gm/cm3

Volume = 1750 / 2.651 = 660m3

The concrete was cast using the composition of the aggregate so arrived at above. After seven days of curing the cubes so cast for this experiment were crushed and the following readings and calculations obtained:-

Size of cube 15 x 15 x 15 (cm^3)

Area = 15 x 15cm^2

Volume = 15 x 15 x 15cm^3

The cubes were weighed on a balance where the following were revealed

(1) 8.010 Kg

(2) 7.980 Kg

(3) 7.960 Kg

Densities of the cubes = $\frac{8010}{3375}$ = 2.4gm/cm3

(2) $\frac{7980}{3379}$ = 2.36 gm/cm3

(3) $\frac{7960}{3375}$ = 2.36 gm/cm3

Average = $\frac{8.010 + 7.980 + 7.960}{3}$ = 7.983kg

Average Density = $\frac{2.4 + 2.36 + 3.36}{3}$ = 2.36gm/cm3

Crushing Reading

(a)	450KN	=	450000N
(b)	440KN	=	440000N
(c)	430KN	=	430000N

Average = 440KN = 440000N

The Characteristic Strength = $\frac{\text{Strength}}{\text{Area}}$ $=\frac{450{,}000}{22500}$ $=20N/MM^2$

$\frac{440{,}000}{22500}$ = $19.56\ N/MM^2$

$\frac{430{,}000}{22500}$ = $19.111\ N/MM^2$

Average Strength $\frac{20 + 19.56 + 19}{3}$ = 19.56 N/MM for seven days

APPENDIX III

Bearing in mind these information about the concrete grade 25 with nominal aggregate size 19mm with moderate workability which are:-

Cement: 320 kg/m^2

Total Aggt 1800

Zone (%) – 40

Zone (%) – 35

Zone (%) – 30

The concrete was cast using the composition of the weights worked out in the design. It was cured for seven days and the crushing test conducted. The following information was handy for use.

Size of cube 15 x 15 x 15 (cm^3)

Area 15 x 15 (cm^2)

Dm^3 = 15 x 1.5 x 15 = 3.375cm^3

Weights of the cubes

(a) 7585kg

(b) 8001kg

(c) 7450kg

Densities

(a) 7585 / 3375 = 2.25gm/cm3

(b) 8001 / 3375 = 2.4gm/cm3

(c) 7450 / 3375 = 2.21gm/cm3

Average Wt. = $\frac{7.585 + 7.450}{3}$ = 7.678

= 7.6787kg

Average Density = $\frac{2.25 + 2.4 + 2.21}{3}$ = 2.3gm/cm3

Crushing Force

(a) 450KN

(b) 500KN

(c) 400KN Average Force = 450KN

Crushing Strength N/mm^2

(a) 19.74 N/mm^2

(b) 21.93 N/mm^2

(c) 17.54 N/mm^2

Average = 19.73 N/mm^2 for seven days

APPENDIX IV

For concrete grade 25 of medium workability and limit of slump of 50 – 100

Cement/m^3	340kg	340kg
Total Aggregates (kg)	1800	
Sand (Aggregates)		
	Zone 1 (%)	35
	Zone 2 (%)	30
	Zone 3 (%)	30

Aggt Total = $\frac{1750}{2.56}$ = 660.4

Weight of Individual Aggregate

Min cement = 220kg

Max full water cement Ratio = 0.70

Water = 154kg

The concrete was then cast in the cube and cured for seven days after which the following information's covering the crushing was obtained.

Size of cubes cm^3 = 15 x 15 x 15 = 3375cm^3

Or 1.5 x 1.5 x 1.5 = 3.375 cm^3

Weight of cubes (a) 7500kg

(b) 6950kg

(c) 7100kg

Average Wt $\frac{21550}{3}$ = 7.183kg

Density (a) $\frac{7500}{3375}$ = 2.2gm/cm3

(b) $\frac{6950}{3375}$ = 2.1gm/cm3

(C) $\frac{7100}{3375}$ = 2.1gm/cm3

Crushing force (a) 480KN

(b) 485KN

(c) 470KN Average = 3478KN

Crushing Strength N/mm^2

(a) $\frac{480 \times 1000}{150 \times 150}$ = 21.33 N/mm^2

(b) $\frac{485 \times 1000}{150 \times 150}$ = 21.56 N/mm^2

(c) $\frac{470 \times 1000}{150 \times 150}$ = 20.89N/mm^2

Average 21.26 Nmm^2 for 7 days

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