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CHARACTERISTIC AND EFFECTS OF A SUPERPLASTICIZER QUANTITY VARIATION IN SOME CONCRETE STRENGTHS OPTIMIZATION

I. Akiije
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING, UNIVERSITY OF LAGOS, AKOKA-YABA, LAGOS STATE NIGERIA
E-mail address: *iakiije@unilag.edu.ng*

ABSTRACT
This study investigates the properties of superplasticized concrete and compared results to that of normal concrete. Four different concrete proportioning of 1:2:3 mix ratio have been considered. A0 is normal concrete having 0.4 water cement ratio (w/c) and is the control while A1, A2 and A3 are superplasticized concretes having 0.3 water cementitious materials ratio (w/cm) with varied percentages of the superplasticizer. Beams, cubes and cylinders, 60 each were cast, de-moulded and cured. They were tested for strengths at different days of curing; 7, 28, 56, 90 and 120 days. Appropriate casting of fresh concrete paved way for 60 beams, 60 cubes and 60 cylinders specimens which were subjected to 7, 28, 56, 90 and 120 moist cured days and were duly subjected to strength tests. Tests on the material constituents used for the concrete production showed that they satisfied standard specification requirements. The workability test results on fresh concretes showed that as the dosage of superplasticizer is increasing the values of both slumps and compaction factors are increasing. Significantly, the flexural, compressive and tensile splitting tests results showed that as workability of the fresh concrete is increasing the related hardened concrete strength is also increasing. An improvement in the appearance (smoothness) was observed in the specimens produced as the superplasticizer dosage increases.

Keywords: *Experimental, Properties, Proportioning, Superplasticizer, Concrete*

1. INTRODUCTION

The water-cement ratio (w/c) for normal concrete varies from 0.4-0.6. Low workability and improper consistency are usually observed at lower range of w/c, which makes the hardened concrete not to be smooth and appealing. Normal concrete constituents are usually water, cement, fine and coarse aggregates. It becomes superplasticized concrete when superplasticizer; a chemical admixture in form of solution or powder is added to the mixture. Superplasticizers of high water reduction with slump retention ability excellent workability, wide adaptability for concrete and excellent durability are now readily available in the market for use. One of such superplasticizer is MasterRheobuild 850.

The influence of a superplasticizer dosage of 0.25%, 0.30% and 0.35 % by cement weight individually on performance of self-compacting concrete containing 10% fly ash of cement content has been studied [1]. The result from the experiments showed that for constant water cement ratio and increase of superplasticizer dosage in self-compacting concrete there was marginal reduction in weight with slight increase in compressive strength than that of normal concrete.

Aggregates can be classified [2] as fine or coarse depending on the particle size distribution whilst fine aggregates is generally natural sand or soil collected from the riverbank and whilst graded from particles of 5 mm in size down to the finest particles but excluding dust. Coarse aggregate could be natural gravel or crushed stone usually larger than 5 mm and that perhaps a maximum size of 80 mm can be used for normal concrete and superplasticized concrete [3 - 5].

In civil and environmental engineering works, attention is normally focused on compressive, flexural and tensile strengths of concrete for durability and

*** Author, tel: +234 – 803 – 300 – 5815**

sustainability. Compressive strength of concrete is the most commonly considered property, although in many practical cases, other characteristics, such as durability, impermeability and volume stability, are also of importance [4]. Flexural strength determination is important for the design and construction of road and airport concrete pavements.
The aim of this study is to optimise concrete strength using a superplasticizer; MasterRheobuild 850 and newly introduced cement; Nigeria Supaset Portland cement. Specifically the main objectives of this study are to examine:

1. The chemical composition and compound composition of the cement
2. Properties of the fresh and hardened concrete incorporating the superplasticizer
3. Optimum use of the superplasticizer that would yield the same strength (Compressive, flexural and tensile strength) for concrete grade C35, C40 and C45

An attempt has been made on this study to know the effect of varying superplasticizer content on the properties of concrete. The effect on consistency and workability was also investigated and result compared with conventional concrete without superplasticizer.

2. MATERIALS AND METHODOLOGY

The properties of the materials used and the details of the methods of testing are as follows. Water, superplasticizer, cement, fine and coarse aggregates are concrete constituents. The proportioning of concrete constituents is by mix of 1:2:3 respectively using water ratio (w/c) of 0.4 for normal concrete and also of water cementitious materials ratio (w/cm) of 0.3 aimed at superplasticized concrete. The percentages of superplasticizer by weight of cement are limited to1%, 1.25% and 1.5% by individual batch of concrete production. The aggregates and cement were subjected to laboratory experiments before the production of fresh concrete. The fresh concrete produced per batch was subjected to slump and compacting factor tests in order to define the fresh concrete produced workability status. Hardened concrete were tested for flexural, compressive and tensile splitting tests after being appropriately moist cured.

2.1 Concrete Constituents

Drinkable water found in the concrete laboratory of the Department of Civil and Environmental Engineering, Faculty of Engineering, University of Lagos was employed to produce each concrete batch. Master Rheobuild 850 superplasticizer is the name of the high-range water reducer chemical admixture used for the purpose of increasing the workability of the concrete mixtures whilst reducing the amount of mixing water.
A relatively new brand of cement produced in the Nigeria which is Superset of grade 42.5N ordinary Portland cement Type I was used for the concrete production in this study. The cement was subjected to laboratory tests to identify its properties and the level of conformity [6]. The chemical and compound composition together with physical properties tests on the cement were carried out. The relative density of cement used was determined in accordance to [7] whilst the bulk density was determined [8] as its weight per unit volume in the laboratory. The fineness of the cement used was measured [9] by determining the percent passing the 0.045 mm sieve. The cement was also subjected to initial and final setting time tests including the determination of consistency value based on the Vicat apparatus methodology [10].
Ogun River sand obtained from Akute, outside Lagos environs, was air dried in the laboratory for the production of the concrete specimens. The sand gradation, coefficient of uniformity and curvature were determined according to [11] methodology. The moisture content, relative density, dry density and absorption of the fine aggregate used were determined according to [12]. The bulk densities of both fine and coarse aggregates used were determined separately according to [13]. Also, coarse aggregate of gradation of nominal size 19 mm was used in the production of the concretes. Sieve analysis, coefficient of uniformity and curvature tests of the coarse aggregates used were performed according to [11]. Also, the moisture content, specific gravity, dry density and absorption of the coarse aggregates used were determined separately according to [18]. Crushing and impact values were determined according to [15]. Abrasion value test was carried out by the Los Angeles abrasion test as described in [16].

2.2 Required Average Strength

An empirical formula for estimating the flexural strength from compressive strength values as contained in [17] is shown in equation 1.

$$R = (0.62\ to\ 0.830)\sqrt{f_c'} \qquad (1)$$

Where R is the flexural strength and f'_c is the compressive strength

Table 1 below shows the determination of required compressive strength [17].

Table 1: Required average compressive strength when data is not available to establish a standard deviation

Specified compressive strength, f'_c,N/mm²	Required average strength, f'_{cr},N/mm²
Less than 21	f'_c + 7.0
21 to 35	f'_c + 8.5
Over 35	f'_c + 10.0

Equation (1) is a useful paradigm to check the relationship between flexural strength and concrete compressive strength values.

2.3 Fresh Concrete Production and Casting of Specimens

Fresh concrete was produced per batch using one bag of cementitious materials individually for each type of concrete mix identification as described in Table 2 and Table 3. Table 2 shows the relationship among the concrete constituents while Table 3 is depicting the mix proportioning in kilograms per metre cube of concrete. Tilting mobile rotating drum mixer was used for the missing of constituents. In the process, the ingredients were thoroughly mixed dry in a damp rotating drum mixer machine before 80% of the required water was added in the case of Type A0 mix or water plus superplasticizer in the case of other Types A1, A2, and A3. After that, the balance of 20% of same was added after the fresh concrete has been poured out of mixer drum on a saturated dry platform and immediately thoroughly mixed by hand.

Specimens making and curing of concrete were carried out in accordance to [18]. Concrete specimens of 60 beams, 60 cubes and 60 cylinders as shown in Table 4 were cast individually for flexural, compressive and tensile splitting strengths respectively. Each flexural beam specimen size was 550 mm by 150 mm by 150 mm while compressive cube specimen size was 150 mm by 150 mm by 150 and that of cylinder tensile splitting specimen was 150 mm diameter and of 300 mm length.

Casting of each specimen was in three layers of fresh concrete of which each layer was rodded using 16 mm diameter rod of 600 mm length. Specimens made from fresh concrete were allowed to stay in their respective moulds for 24 hours before demoulding and they were immediately submerged inside clean water in a container for curing.

The workability tests which are for the determination of slump value and that of the compaction factor were also carried per batch of concrete production about the commencement of the specimens casting. The slump test was carried out on the fresh concrete produced in accordance to [19]. Also, the compacting factor test on the fresh concrete was carried out in accordance to [20].

2.4 Hardened Concrete Tests

24 hours after casting of the fresh concrete, moulds were dismantled to pave way for specimens' removal and for curing of same by water ponding. Hardened concrete tests were carried out on the specimens that had been cured in water for 7, 28, 56, 90 and 120 days. For each testing day, three beams, three cubes and three cylinders specimens were tested respectively and results recorded of which the average was considered for the flexural, compressive and tensile strengths individually. It has been observed [21] that 28-day to 90-day moist cured strengths are being used for roads and streets since very few stress repetitions occur during the first 90 days of pavement life compared with the millions of repetitions that occur after that time.

Each hardened specimen concrete beam was tested for flexural strength test according to [22]. Also, each hardened specimen concrete cube was tested for compressive strength test in accordance to [23]. Furthermore, each hardened concrete cylinder specimen was also tested for tensile splitting strength in accordance to [24]" with " Each beam, cube and cylinder specimens was test for flexural strength, compressive strength and tensile splitting strength in accordance to relevant codes, [21-24]

Each standard cube as well as the cylinder specimen was tested using a 1500 kN capacity hydraulic compression testing machine powered with electricity in accordance to [25]. The hydraulic flexural testing machine was powered manually and in accordance with [22].

Table 2: Relative amount of concrete constituents

Concrete Mix Identification	Nominal Maximum Coarse Aggregate Size	w/c	Cement Content	Fine Aggregate	Coarse Aggregate
Type A0	19 mm	0.4	1	2	3
Type A1	19 mm	0.3	1	2	3
Type A2	19 mm	0.3	1	2	3
Type A3	19 mm	0.3	1	2	3

Table 3: Concrete mix proportions for cement content of 400 kg/m³

Concrete Mix Identification	Water cementitious material ratio (water/ superplasticizer) by weight of cement	Water content kg/m³	Admixture content kg/m³	Cement content kg/m³	Fine Aggregate kg/m³	Coarse Aggregate kg/m³
Type A0	0.4 (0.4/0)	160	0	400	800	1200
Type A1	0.3 (0.28/0.02)	112	8	400	800	1200
Type A2	0.3 (0.275/0.025)	110	10	400	800	1200
Type A3	0.3 (0.27/0.03)	108	12	400	800	1200

Table 4: Concrete specimens casting modules

Concrete Mix Identification	Flexural Beam Specimen (550x 150 x 150)	Compressive Cube Specimen (150 x150 x150)	Tensile Splitting Cylinder Specimen (150 Ø x 300)
Type A0	15	15	15
Type A1	15	15	15
Type A2	15	15	15
Type A3	15	15	15
Total number of specimens	60	60	60

3. RESULTS AND DISCUSSIONS

The results of the concrete constituents, fresh concrete and hardened concrete specimens are discussed as follows:

3.1 Cement Properties

The result of the chemical analysis, compound composition and the physical properties of the cement used are in Table 5, Table 6 and Table 7 respectively. It is obviously seen that the cement is found to be satisfactorily suitable based on chemical composition values than that of compound composition when related to standard specification requirements. Also, as seen in Table 7, the cement values for bulk density and specific gravity are suitable for concrete mix proportioning by weight and absolute method. The cement physical properties and chemical compositions as in Table 5 through Table 7 have shown that the Portland cement grade 42.5 N (normal) used in this study satisfied standard specification requirements satisfactorily.

3.2 Fine and Coarse Aggregates Properties

The fine aggregate used in this study is a well-graded river sand material based upon the gradation test and as seen in Figure 1. The fine aggregate gradation is satisfactory by requirements and could be classified as grading no. 1 specification for fine aggregate by the standard specification requirements [27]. Figure 2 is showing that the coarse aggregate used in this study is a well-graded granite material [27]. It is obvious that Figure 1 and Figure 2 of fine and coarse aggregates gradation curves fit very well within each individual envelope thereby meeting the required standard specifications. The semi-log gradation chart of fine and coarse aggregates as found in Figure 1 and Figure 2 separately showed that the river sand and granite with nominal maximum size of 19 mm used in this study are of well graded types.

Also, the semi-log combined aggregates gradation chart of Figure 3 is showing the combined fine and coarse aggregates gradation shape of the materials used in this study. It is of dense and strong mixture that can ensure maximum density and strength gradation specification requirement for highway bases, concrete and asphalt mixes. Figure 3 showed that the appropriate combination of sand and granite used in this study for concrete proportioning formed a dense strong mixture.

The results of the physical properties of fine and coarse aggregates are shown in Table 8 of which the value obtained for each property depicts materials representation satisfactorily for concrete production. The physical properties of fine and coarse aggregates as shown in Table 8 satisfied standard specification requirements satisfactorily hence they are reliable materials for producing good concrete.

Table 5: The cement chemical composition

Chemical Composition	42.5 R Cement	Specification Requirements Content (%); AASHTO M 85	Remarks
Silicon Dioxide (SiO^2)	21.23	18.7 – 22.0	Conformed
Aluminium Oxide (Al_2O_3)	5.11	4.7 – 6.3	Conformed
Iron oxide (Fe_2O_3)	0.95	1.6 – 4.4	Not Conformed
Calcium Oxide (CaO)	63.74	60.6 -66.3	Conformed
Magnesium Oxide (MgO)	2.10	0.7 – 4.2	Conformed
Sulphur Trioxide (SO_3)	1.02	1.8 – 4.6	Not Conformed
Sodium Oxide (Na_2O)	0.64	0.11 -1.2	Conformed

Table 6: The cement compound composition

Compound Composition	42.5 R Cement	Specification Requirements Content (%); AASHTO M 85	Remarks
Tricalcium Silicate, C3S	70.67	40 - 63	Not Conformed
Dicalcium Silicate, C2S	6.13	9 -31	Not Conformed
Tricalcium Aluminate, C3A	11.45	6 -14	Conformed
Tetracalcium Aluminate, C4AF	2.95	5 - 13	Not Conformed

Table 7: The cement physical properties

Parameters	42.5 R Cement	Specification Requirements; *AASHTO M 85*	Remarks
Specific Gravity γ_G	3.15	3.13-3.15	*Conformed*
Bulk Density, γ_b kg/m³	1160	1000-1300	*Conformed*
Fineness, % retained on 45 µm	2	10 maximum	*Conformed*
Loss of Ignition , LOI	0.006	0.04-0.05	*Not Conformed*
Insoluble Residue, IR	99.96	99.95-99.97	*Conformed*

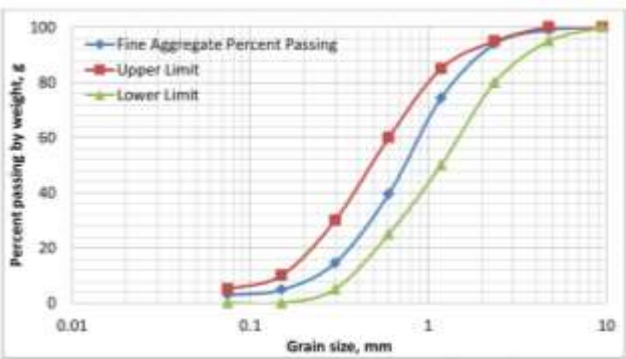

Figure 1: Semi-log fine aggregate gradation chart

3.3 Fresh Concrete Properties

The workability characteristics of the fresh concretes Type A0 through Type A3 produced in this study are presented in Table 9, Figure 4 and Figure 5. Slump values and compaction factors obtained are based upon the different usage of percentages of superplasticizer over the production of concrete mixtures. Table 5 exhibits that there is a 5 mm slump value difference between a particular type of mix to the other and of which a difference of 0.01 is observed similarly for compaction factor from one mix to the other. Figure 4 and Figure 5 individually displays similar polynomial graph but different quadratic equations as displayed. Hence, it is evident that as there is an increase in superplasticizer dosage there is also workability increase. However, the values of coefficient of determination R^2 in regression function of both slump and compaction factor are the same. This is an indication that each one of the graph could predict effectively for slump value or compaction factor within the range of the experiments based upon the available same superplasticizer for similar concrete production as of this study.

Table 8: The physical properties of fine and coarse aggregates

S/No	Physical Properties	Fine Aggregate River Sand	Coarse Aggregate 19 mm Granite
1	Percent of particles retained on the 4.75 mm sieve	1	95
2	Percent of particles passing the 4.75 mm sieve	99	5
3	Percent of particles passing the 0.075 mm sieve	2.8	0
4	Fineness modulus	2.74	3.75
5	Coefficient of uniformity (Cu)	2	2
6	Coefficient of curvature (Cc)	1	1
7	Bulk density	1655	1650
8	Specific gravity	2.67	2.67
9	Moisture (water) absorption (%)	1.12	0.5
10	Aggregate crushing value (%)	-	18
11	Aggregate impact value (%)	-	13
12	Los Angeles Abrasion Value (%)	-	19

Table 9: Workability Tests Results

Concrete Mix Identification	Superplasticizer Master Rheobuild 850 (% by weight of cement)	Slump Values (mm)	Compaction factor
Type A0	0.0	45	0.89
Type A1	1.0	50	0.90
Type A2	1.25	55	0.91
Type A3	1.5	60	0.92

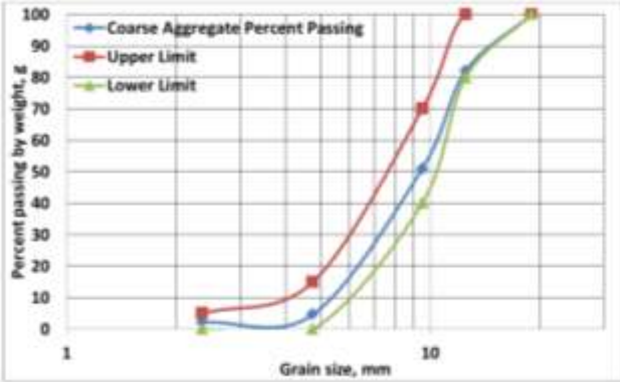

Figure 2: Semi-log coarse aggregate gradation chart

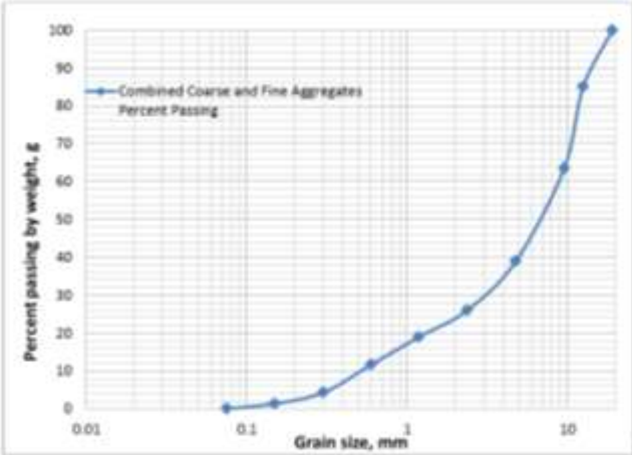

Figure 3: Semi-log combined aggregates gradation chart

3.4 Hardened Concrete Properties

The strengths values of each of the superplasticized concrete flexural, compressive and tensile based upon water curing periods are shown in Figures 6 through 8 individually. It is obviously seen in each of the three charts shows that as the moist curing period per day is increasing each one of the strength value is also increasing. Similarly, one could observe that in each of the chart the highest strength value for each of the experimental results is obtained from specimens cured in water for 120 days. Each of the line graphs of Figures 6 through 8 shows that the rate of strength reduces as the moist curing period increases. The rate of increment of each of the strengths between 90 and 120 days of moist curing is marginal.

The effects of superplasticizer quantity variations by way of affecting concrete strengths development as experimented in this study have been displayed in Figure 9 through Figure 11. These figures are showing that within the limits of the experiments carried in this study and for concrete flexural, compressive and tensile strengths developed, the higher the amount the superplasticizer dosage the higher the strength. It is obviously also seen that the rate of strength is increasing as the dosage of the superplasticizer is increasing. The highest value of strength is obtained at a dosage of 1.5% by weight of cement while for the trend the concrete with 0% of concrete is having the lowest strength value. In this experimental study, results of concrete flexural, compressive and tensile strengths are of similar trend of strength development.

The strength developmental trend for normal concrete; A0 in relationship to superplasticized concrete; A1, A2 and A3 are shown in Table 10 through Table 12. For each testing day for flexural, compressive and tensile strengths there is percentage increase of individual strength as the percent of superplasticizer in the concrete mix is increasing from that of the normal concrete. Significant increase in flexural strength, compressive strength and tensile strength were observed as the as superplasticizer dosage increase, when compare to normal concrete without superplasticizer.

The trend of strength development by normal and superplasticized concretes A0, A1, A2 and A3 at 28-day moist cured are shown in Table 13 through Table 15. It is obviously seen that the flexural strength development at 7-day moist cured of the normal and superplasticized concrete is at the average of 90% of same at 28-day moist curing.

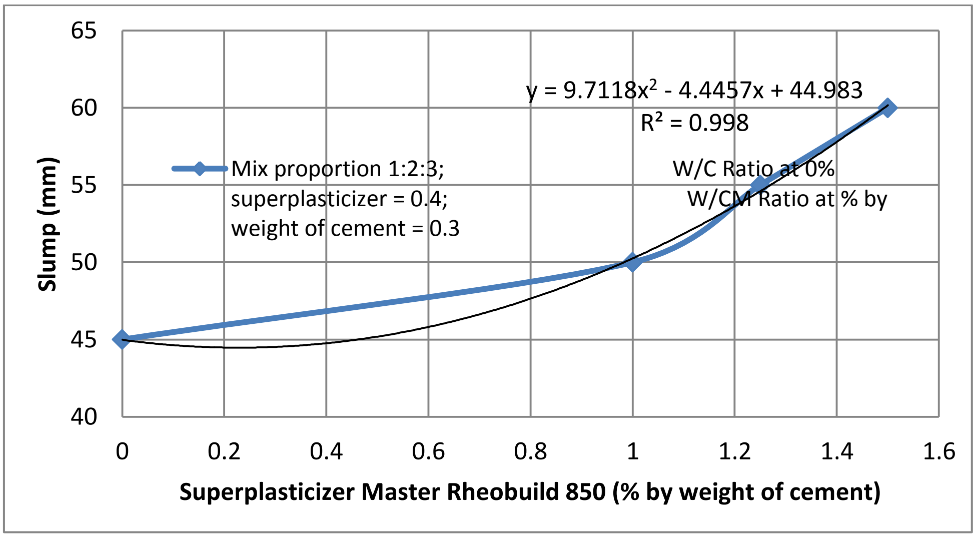

Figure 4: Workability chart for slump values

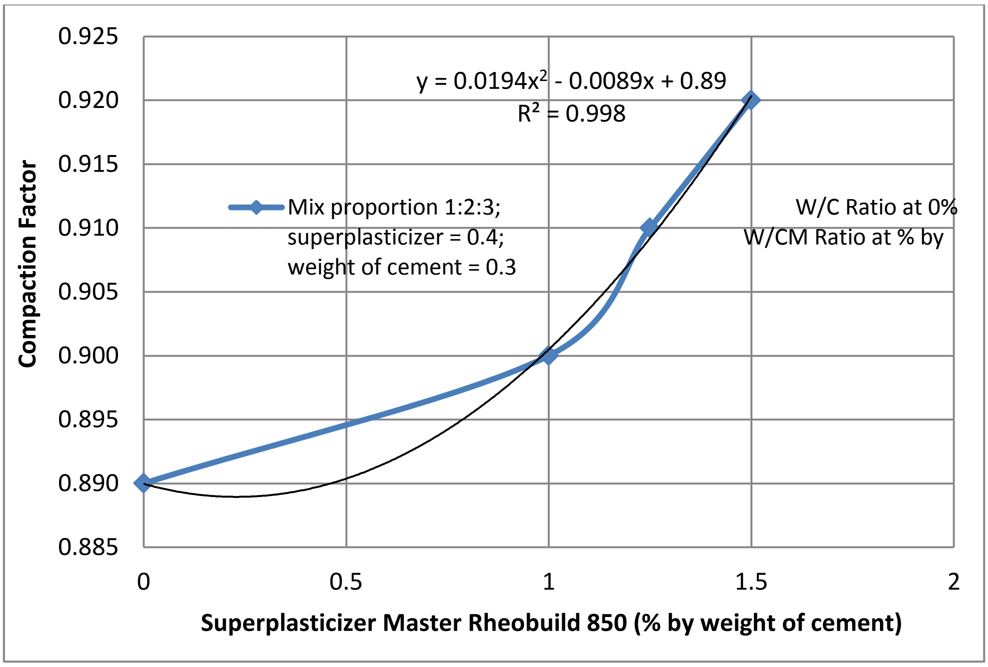

Figure 5: Workability chart for compaction factors

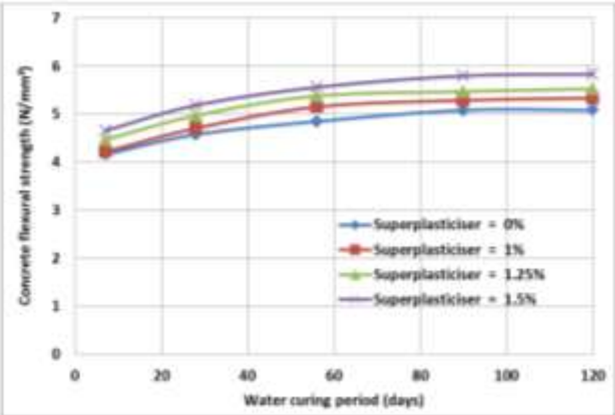

Figure 6: Water curing period-flexural strength in relationship to super plasticized concrete

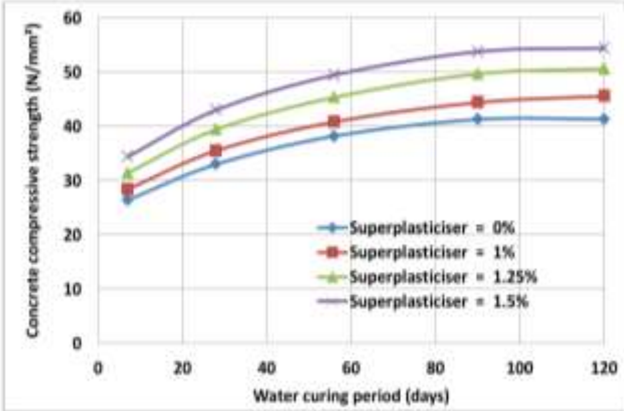

Figure 7: Water curing period-compressive strength in relationship to superplasticized concrete

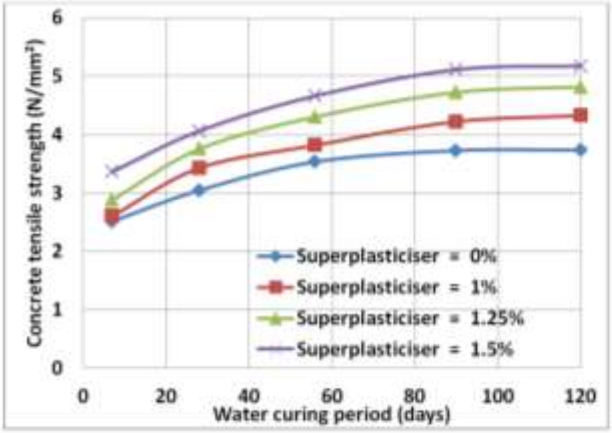

Figure 8: Water curing period-tensile strength in relationship to superplasticized concrete

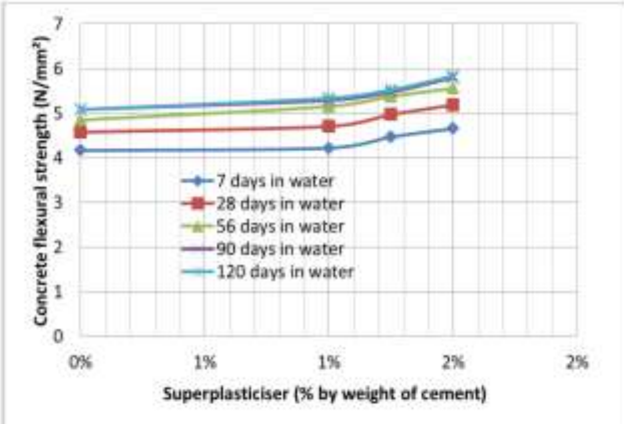

Figure 9: Super plasticizer dosage-flexural strength relationship

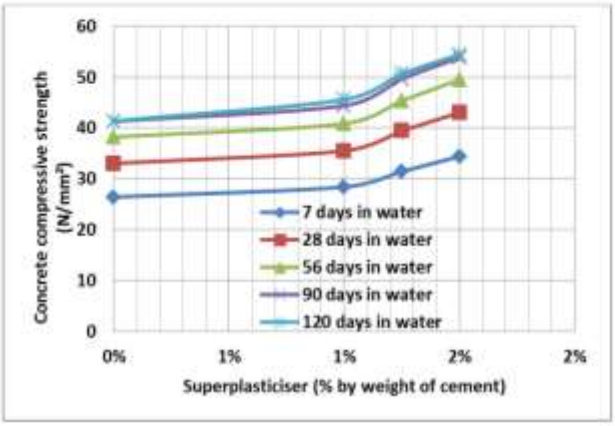

Figure 10: Superplasticizer dosage-compressive strength relationship

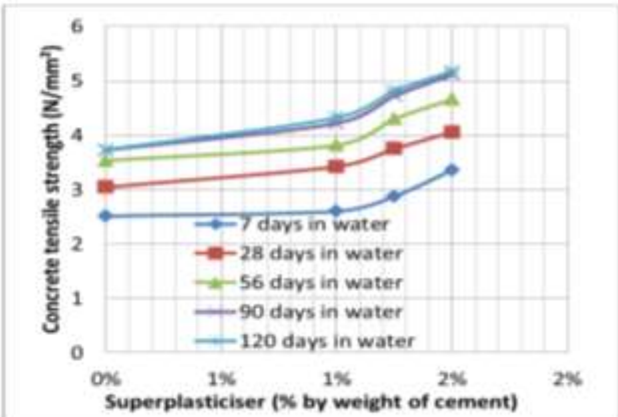

Figure 11: Superplasticizer dosage-tensile strength relationship

Whereas the compressive and flexural strengths development individually at 7-day moist cured for normal and superplasticized concrete is at the average of 80% of same at 28-day moist curing. Table 16 is showing the relationship of concrete strengths in percent of 90-day moist cured to the 28-day while considering flexural, compressive and tensile strengths individually. This Table 16 compares the strengths of the concrete at 90-day moist cured as100 percent to the 28-day of which is having the average of 90% for flexural strength whereas the average of 80% is obtained for compressive and tensile strengths individually.

Since compressive strength test is the most commonly considered in terms of hardened concrete, its values are considered in this study as reference. In this study a relation between flexural strength and compressive strength as contained in [17] is given as

Equation 2 which is well related to Equation 1 has been used for required average flexural strength. Flexural strength is:

$$R = 0.83x\sqrt{f'_c} \qquad (2)$$

Also, the relationship of tensile strength value to compressive strength as contained in [17] and given as Equation 3 has been used in this study for the required average tensile strength based upon required average compressive strength. Tensile splitting strength,

$$T = 10\%\ f'_c \qquad (3)$$

Table 17 has it that at 28-day moist cured specimens design strengths did not satisfy the required average compressive strength as required by Table 1. However at Table 17 is found by the way how 90-day moist cured specimens design strength satisfied the required average compressive strength as required by Table 1.

Correspondingly as shown in Table 18, the 28-day moist cured specimens' design strengths did not satisfy the required average flexural strength as required by Equation 2. Nevertheless as seen Table 18, the 90-day moist cured specimens design strength satisfied the required average compressive strength for specified grade of concrete C35 only.

Moreover as shown in Table 19, the 28-day moist cured specimens' design strengths did not satisfy the required average flexural strength as required by Equation 3. Conversely as seen Table 19, the 90-day moist cured specimens design strength satisfied the required average compressive strength for specified grade of concrete C35 and C40 only.

Table 10: Relative flexural strength of concrete produced as affected by type of concrete mix

Type of Concrete mix	Flexural strength (% of strength of Type A0 concrete mix)				
	7 days	28 days	56 days	90 days	120 days
A0	100	100	100	100	100
A1	101	103	106	104	105
A2	107	109	111	108	109
A3	112	113	115	114	115

Table 11: Relative compressive strength of concrete produced as affected by type of concrete mix

Type of Concrete mix	Compressive strength (% of strength of Type A0 concrete mix)				
	7 days	28 days	56 days	90 days	120 days
A0	100	100	100	100	100
A1	108	108	107	108	109
A2	119	119	119	120	121
A3	130	130	129	130	131

Table 12: Relative tensile strength of concrete produced as affected by type of concrete mix

Type of Concrete mix	Tensile strength (percent of strength of Type A0 concrete mix identification)				
	7 days	28 days	56 days	90 days	120 days
A0	100	100	100	100	100
A1	104	113	108	113	116
A2	115	123	122	127	129
A3	134	133	132	137	139

Table 13: Relationship of flexural strength in percent of 28 day moist cured of concrete produced as affected by curing days

Type of Concrete mix	Flexural strength (percent of strength of 28 days curing by moist curing)				
	7 days	28 days	56 days	90 days	120 days
A0	91	100	106	111	111
A1	90	100	110	112	113
A2	90	100	108	110	111
A3	90	100	107	112	112

Table 14: Relationship of compressive strength in percent of 28-day moist cured of concrete produced as affected by curing days

Type of Concrete mix	Compressive strength (percent of strength of 28 days curing by moist curing)				
	7 days	28 days	56 days	90 days	120 days
A0	80	100	116	125	127
A1	80	100	115	125	128
A2	80	100	115	126	128
A3	80	100	115	125	128

Table 15: Relationship of tensile strength in percent of 28-day moist cured of concrete produced as affected by curing days

Type of Concrete mix	Tensile strength (percent of strength of 28 days curing by moist curing)				
	7 days	28 days	56 days	90 days	120 days
A0	83	100	116	122	123
A1	76	100	111	123	126
A2	77	100	115	126	128
A3	83	100	115	126	127

Table 16: Relationship of concrete strengths in percent of 90-day moist cured to that of 28-day

Type of Concrete mix	Flexural strength		Compressive strength		Tensile strength	
	28 days	90 days	28 days	90 days	28 days	90 days
A0	90	100	80	100	82	100
A1	89	100	80	100	81	100
A2	91	100	79	100	79	100
A3	89	100	80	100	79	100

Table 17: Required average compressive strength, f'cr

Specified grade of concrete	Required average compressive strength, N/mm²	28-day moist cured compressive strength	90-day moist cured compressive strength
C35	45	Required average compressive strength is not satisfied	50 N/mm² @ 1.25% Superplasticizer dosage
C40	50	Required average compressive strength is not satisfied	50 N/mm² @ 1.25% Superplasticizer dosage
C45	55	Required average compressive strength is not satisfied	55 N/mm² @ 1.5% Superplasticizer dosage

Table 18: Required average flexural strength, R

Specified grade of concrete	Required average compressive strength, N/mm²	Required average flexural strength, N/mm²	28-day moist cured flexural strength	90-day moist cured flexural strength
C35	45	5.57	Required average flexural strength is not satisfied	5.79 N/mm² @ 1.5% Superplasticizer dosage
C40	50	5.87	Required average flexural strength is not satisfied	Required average flexural strength is not satisfied
C45	55	6.16	Required average flexural strength is not satisfied	Required average flexural strength is not satisfied

Table 19: Required average tensile strength, T

Specified grade of concrete	Required average compressive strength, N/mm²	Required average tensile strength, N/mm²	28-day moist cured tensile strength	90-day moist cured tensile strength
C35	45	4.5	Required average tensile strength is not satisfied	4.7 N/mm² @ 1.25% Superplasticizer dosage
C40	50	5.0	Required average tensile strength is not satisfied	5.11 N/mm² @ 1.5% Superplasticizer dosage
C45	55	5.5	Required average tensile strength is not satisfied	Required average tensile strength is not satisfied

4. CONCLUSIONS AND RECOMMENDATIONS

This paper presents the experimental details for the characteristics and effects of a superplasticizer called MasterRheobuild quantity variation at 0%, 1%, 1.25% and 1.5% of cement upon concrete flexural, compressive and tensile splitting strengths optimization. The water cement ratio (w/c) for the normal concrete is 0.4% while the water cementitious materials ratio (w/cm) for the other three superplasticized concretes is 0.3%. The following main conclusions and recommendations are drawn based on the obtained results for using 19 mm maximum normal size aggregate with the 1:2:3 mix ratio.

4.1. Conclusions

- The normal concrete produced at 0.4% water cement ratio (w/c) and superplasticized concretes manufactured at 0.3% water cementitious materials ratio (w/cm) at fresh condition gave concretes having medium degree of workability.
- The superplasticizer used has significant effect on the fresh concretes workability because the

higher the amount of superplasticizer the higher the value of slump and that of compacting value.

- The fresh concrete values of workability ranged between 45 – 60 mm slumps whilst the compacting factor amounts were ranging from 0.89 to 0.92. As the amount of superplasticizer was increasing slump value was increasing and also that of the compacting factor value.
- For the hardened concretes, the higher the value of superplasticizer the higher the compressive, flexural and tensile strengths individually.
- The design strength of concretes attained in this study could not satisfy the required average compressive strength for the specified grade of concrete C35, C40 and C45 at 28 days moist cured but satisfied same at 90 days moisture curing.
- The design strength of concretes attained in this study could not satisfy the required average flexural strength for the specified grade of concrete C35, C40 and C45 at 28 days moist cured but satisfied same at 90 days moisture curing only for C35.
- The design strength of concretes attained in this study could not satisfy the required average tensile strength for the specified grade of concrete C35, C40 and C45 at 28 days moist cured but satisfied same at 90 days moisture curing for C35 and C40.

4.2. Recommendations

- The use of superplasticizer should be encouraged for it gives higher workability and higher strength than normal concrete.
- The use of 19 mm maximum normal size aggregate with the 1:2:3 mix ratio as experimented in this study should not be encouraged for highway rigid pavement design for the specified grade of concrete C35, C40 and C45 at 28 days moist cured for it will lead to premature failure of the highway.
- Notwithstanding concrete produced in the course of this study only has its use for highway rigid pavement design for the specified grade of concrete C35 at 90-day moist cured design strength.

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