Nigerian Research Journal of Engineering and Environmental Sciences 6(1) 2021 pp. 96-112

Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

RJEES

Original Research Article

Influence of Superplasticized Concrete on the Compressive Strength of Highway Pavements

***Akiije, I. and Ajenifuja, A.N.**

Department of Civil and Environmental Engineering, Faculty of Engineering, University of Lagos, Akoka, Lagos State, Nigeria.
*iakiije@unilag.edu.ng; toroajenifuja10@gmail.com

ARTICLE INFORMATION

Article history:
Received 21 Mar, 2021
Revised 21 Apr, 2021
Accepted 23 Apr, 2021
Available Online 30 Jun, 2021

Keywords:
Rigid pavement
Flexible pavement
Superplasticized concrete
Paving blocks
Compressive strength

ABSTRACT

A quest for highly durable rigid and flexible pavements has led to the need to investigate superplasticized concretes as a way to economically prevent accidents on roads. In this study, superplasticized concrete cube as well as I-shape, Z-shape and rectangular shaped paver samples were made as specimens in the laboratory. The superplasticized concretes were produced using MasterGlenium SKY 504-BASF superplasticizer with five different types of made in Nigeria cement brands. The grades of the cement used were of 53N, 43N, 43R, 33N and 33R. Each production had 0.3 water cementitious ratio using 1.5% superplasticizer and a ratio of 1:1:2 concrete mixtures per each brand of cement. The results showed that the cube models had the highest strength values compared with the other three types of paver samples. Among paver samples, Z-shape pavers had the highest compressive strength values for 7, 28, 56 and 91 days curing followed by rectangular pavers and I-shape pavers. The characterization of the five different types of superplasticized concretes investigated revealed that only the cube models and Z-shape pavers produced with grade 53N cement satisfied the required pavement comprehensive strengths of 45 N/mm^2 and 55N/mm^2 for use as medium and heavy to very heavy traffic categories respectively.

1. INTRODUCTION

The deplorable condition of roads by not fulfilling the required design age could be easily traceable to pavements that do not satisfy the standard construction specification requirements (Agbonkhese et al., 2013; Akiije 2017). This has resulted to early road failures that could lead to accidents, loss of lives and properties. The possibility of mitigating accident causers during highway pavement design, construction and maintenance is important to transportation safety. Gorea (2016) claimed that road traffic accidents (RTA) are a global problem resulting in deaths, physical injuries, psychological problems and financial losses that are having immediate and long-term consequences on the victims and their families. Agbonkhese et al. (2013) claimed that based on the 2013 highway traffic study in Nigeria, the nation has the 2nd highest rate of accident in a list of 198 countries. They further recommended that conditions of vehicles, pavements roads environment and that of driver's behaviour should be taken care of to prevent accidents on roads.

The growth in the world's transportation sector has caused an increase in traffic and haulage subjecting the pavements to undue stress (Neero et al., 2013). They further claimed that where highway pavements are well designed and constructed, they also require proper maintenance. Otherwise, different distresses like fatigue cracking, bleeding, rutting, potholes etc. will occur in the pavements. The occurrence of distresses could be oftentimes become more complex because of several factors such as rainfall, overloaded traffic, uncontrollably road cutting and any other flagrant development on or under the pavement. Ragnol et al. (2018) claimed that the road pavement conditions affect safety besides comfort, traffic in addition to travel times, vehicles operating cost, and emission levels. They further claimed that in order to optimize the road pavement management and to satisfy all the road users, road managers should consider pavement management system (PMS) as an effective tool. Tighe et al. (2000) submitted that improving road safety through proper pavement engineering and maintenance should be one of the major objectives of pavement management systems. They also asserted that when pavements are evaluated in terms of safety, a number of factors related to pavement engineering properties should be considered.

Water and aggregates are usually obtained naturally but superplasticizer and cement are usually manufactured. A superplasticizer is an admixture, which can be a water reducer in cement concrete production in order to improve the workability and consistency when fresh and strength when hardened. It is also pertinent to note that superplasticizer comes in a different brand that can be used differently also for self-consolidating superplasticized concrete with high-performance strength. Cement is a binder which occurred in the presence of water for hydration and with due workability and consistency in early concrete production stage (Marotta, 2005). Cement production is a chemical procedure that requires heating limestone, clay, marl, shale, chalk, sand, and bauxite as well as iron ore materials to a temperature of 1450^{o}C and then cooling same down. Marotta (2005) asserted that aggregate can be fine or coarse of which it is commonly considered inert filler of concrete and which amounts to 60 - 80% of the volume or 70 - 85 % of the weight. Fine aggregate such as sand occurs naturally and is composed of fine rock material and mineral particles that is usually less than 4.75 mm whilst coarse aggregate is usually greater than 4.75 mm (Akiije, 2018). Coarse aggregate may be of gravel, crushed gravel, crushed stone, air-cooled blast furnace slag, or crushed concrete, or a combination of with particles generally larger than 4.75 mm. Aggregates are classified as lightweight that weighs less than 1,100 kg/m^3, normal-weight is having the weight between 1,520 – 1,680 kg/m^3 and heavyweights weigh more than 2080 kg/m^3. The compressive strength of concrete increases with increasing aggregate size up to 12.5 mm, while the concrete produced using 20 mm had greater compressive strength than those produced using 25 mm aggregate as asserted by (Ogundipe et al., 2018). Cement concrete ingredients includes water, cement, sand as fine aggregate and natural gravel or crushed stone as coarse aggregate. Superplasticized concrete is produced when all the materials are all mixed together appropriately according to design specifications. Superplasticized concrete has addition of superplasticizer in liquid or powder forms whilst considering cement concrete (Akiije, 2019).

Highway flexible and rigid pavements as shown in Figures 1-2 can be made from normal or superplasticized concrete which is the current trend. The use of pavers as the highway road surface make it flexible pavement while rigid pavement has concrete or reinforced concrete surfacing (Mudiyono et al., 2007).

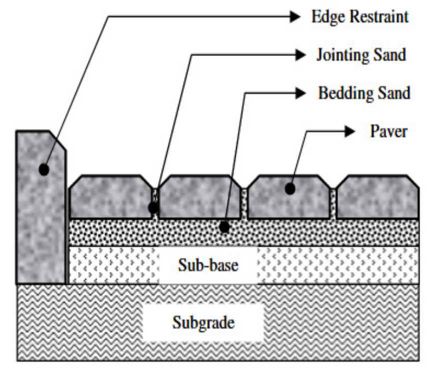

Figure 1: Flexible pavement structure (Mudiyono et al., 2007)

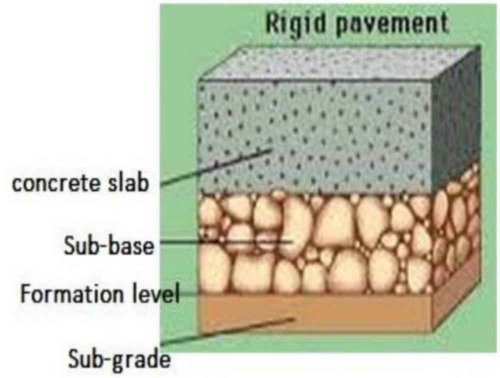

Figure 2: Rigid pavement structure (Srikanth et al., 2013)

Srikanth et al. (2013) gave the advantages of rigid pavements as of low maintenance costs, long life with extreme durability and high value as a base for future resurfacing with asphalt. Also, load distribution over a wide area, decreasing base and sub grade requirements, ability to be placed directly on poor soils, no damage from oils and greases and strong edges. They also asserted the rigid pavement disadvantages as of high initial costs, joints required for contraction and expansion, generally rough riding quality and high repair costs. Nar (2018) considered paver blocks as one of the most popular flexible pavement surfacing options with low maintenance, durability and with hard wearing surface. It has also been publicized by them that paver blocks are versatile of different shapes, colour, textures and finishes. It was also revealed that paver blocks are very quick to install with cost saving, safe, high weather resistance whilst maintenance is very easy.

Many researchers have reported the possibilities of getting fresh workable and high strength harden concrete using superplasticizer (Falade, et al., 2017; Claudius and Duna 2017; Mattam, et al., 2018; Akiije 2019a). However, much has to be done whilst considering its influence on the use of different brands of cement in Nigeria environment. Therefore, this study aimed at investigating independently the use of five different brands of cement produced in Nigeria. It also investigated their individual capability in the production of superplasticized concretes for the attainment of the required strength for highway pavement.

2. MATERIALS AND METHODS

2.1. Materials Collection

Water was collected from the tap inside the concrete laboratory of the Civil and Environmental Engineering Department, Faculty of Engineering, University of Lagos, Nigeria. The tap water was considered good safe and of no impurities. The MasterGlenium SKY 504-BASF superplasticizer used as concrete admixtures was supplied for use by a company. Five different brands of cement were purchase in 50 kg bags from a store at near Akoka, Lagos. The five brands of cement used were tested independently for their bulk density, specific gravity, fineness, initial setting time, final setting time, chemical and compound composition. Granite and sand aggregates were obtained from a construction materials market at Bariga tipper garage, Lagos and were separately air dried in bits inside the laboratory before use.

2.2. Sample Characterization

MasterGlenium SKY 504-BASF superplasticizer specific properties and chloride content tests were carried out in accordance with the standard specification by BS EN 934 (2018). The five brands of cements were tested for bulk density individually in accordance to ASTM C29/C29M (2017) standard specification. The specific gravity for each of the five brands cement was tested in accordance to standard specification of ASTM C128 (2015). Based upon standard specification ASTM C204 (2018), the fineness of the five brands of hydraulic cements were tested by Air-permeability apparatus. Testing the time of setting of the five brands of the hydraulic cement was based upon ASTM C191 (2019) standard specification. Test methods by chemical analysis of hydraulic cement in accordance to ASTM C114 (2018) were employed to define the five brands of cement differently for their chemical and compound composition. Both granite and sand aggregates were subjected to gradation, coefficient of uniformity and curvature through laboratory tests according to AASHTO T 27 (2014). Also, according to ASTM C128 (2015) sand used was tested for moisture content, relative density, dry density and absorption values. Fine and coarse aggregates were separately tested for bulk densities in accordance to AASHTO T 19 (2014). In accordance to ASTM C127 (2015), the moisture content, specific gravity, dry density and absorption of the coarse aggregates used were determined. Los Angeles abrasion test as a standard specification methodology was employed in the laboratory to determine granite abrasion value as describe in ASTM C 131 (2016). Crushing and impact values were determined in accordance to ASTM C33/C33M (2018).

2.3. Superplasticized Concrete Constituents Proportioning

Superplasticized concrete materials proportioning in this study was based upon 1:1:2 mix ratio of cement, granite with sand and water cementitious ratio of 0.3. The five brands of cement used were of rapid (R) and normal (N) grades 43 R, 53 N, 43 N, 33 N and 33 R. Each cement brand was equally used by weight in the production of superplasticized concrete with water cement ratio of 0.285 and superplasticizer cement ratio 0.015 to make water cementitious ratio of 0.3.

Table 1 shows the superplasticized concrete mix proportion of superplasticized concrete for cement content of 50 kg per batch. The 5 types of superplasticized concrete mixtures are tagged MG43R, MG53N, MG43N, MG33N and MG33R separately based upon the cement brand used and the use of MasterGlenium SKY 504-BASF superplasticizer. Table 2 shows superplasticized concrete constituents' ratio per each of the cement brand.

Table 1: Mix proportion of superplasticized concrete for cement content of 50 kg per batch

Superplasticized concrete mix by cement brand	A batch of concrete production per each cement brand		Concrete mix proportions for cement content of 573 kg/m³ per each cement brand	
MG43R	Cement	= 50 kg	Cement	= 573 kg/m^3
MG53N	Sand	= 50 kg	Sand	= 573 kg/m^3
MG43N	Granite	= 100 kg	Granite	= 1146 kg/m^3
MG33N	Water	= 14.25 kg	Water	= 163 kg/m^3
MG33R	Superplasticizer	= 0.75 kg	Superplasticizer	= 8.59 kg/m^3

Table 2: Concrete constituents' ratio per each of the cement brand

Superplasticized concrete mix by cement brand	w/cm (Water/ superplasticizer)	Cement	Fine aggregate	Coarse aggregate
MG43R	0.3 (0.285/0.015)	1	1	2
MG53N	0.3 (0.285/0.015)	1	1	2
MG43N	0.3 (0.285/0.015)	1	1	2
MG33N	0.3 (0.285/0.015)	1	1	2
MG33R	0.3 (0.285/0.015)	1	1	2

2.4. Fresh Superplasticized Concretes Production and Testing

Fresh superplasticized concrete production was carried out using machine operated mixer per separate brand of cement. Each batch of superplasticized fresh concrete was tested for both slump and compacting factor tests. Slump of the superplasticized concrete was tested in accordance to (ASTM C143, 2020). Also, compacting factor test on the fresh superplasticizer concrete was carried out according to testing fresh concrete degree of compatibility BS EN 12350-4 (2019).

2.5. Making and Curing Concrete Test Specimens

Making and curing of concrete test specimens was carried out in the laboratory according to ASTM C192/C192M (2019). Table 3 shows the concrete specimens casting module for each brand of cement per batch. Fresh superplasticized concrete casting was made using pavers of I-section, rectangular section, Z-section and cube model. A total of 240 superplasticized concrete specimens in 4 different types by shape of 12 numbers each were cast in this study based upon 5 different brands of cement as shown in Table 4. After 24 hours of cast the specimens were demoulded and cured inside clean and clear water pond pending the testing.

Table 3: Concrete specimens casting module per each brand of cement

Specimen dimensions	Curing ages (days)	7	28	56	91	Total
Paver I section (220 x 110 x 80) mm	Number of concrete specimen per each test	3	3	3	3	12
Paver rect. section (200 x 100 x 80) mm	Number of concrete specimen per each test	3	3	3	3	12
Paver Z section (240 x 120 x 80) mm	Number of concrete specimen per each test	3	3	3	3	12
Concrete cubes (150 x 150 x 150) mm	Number of concrete specimen per each test	3	3	3	3	12

Table 4: Superplasticized concrete specimens casting numbers

Specimen dimensions	MG43R	MG53N	MG43N	MG33N	MG33R	Total
I - paver (220 x 110 x 80) mm	12	12	12	12	12	60
Rect. - paver (200 x 100 x 80) mm	12	12	12	12	12	60
Z - paver (240 x 120 x 80) mm	12	12	12	12	12	60
Cube (150 x 150 x 150) mm	12	12	12	12	12	60

2.6. Hardened Concrete Tests

Specimens cast were subjected to compression test individually based upon schedule of 7, 28, 56 and 91 days of water curing as shown in Table 3. The average compressive strength of three specimens tested was considered to be the achieved value that will be related to the standard required value based on the scheduled day. Both cube models and paver samples individually were tested using hydraulic compression testing machine powered with electricity.

3. RESULTS AND DISCUSSION

The values of the results of the examinations carried out on concrete constituents, fresh superplasticized concretes and hardened superplasticized concretes specimens produced as obtained in this study are discussed as follows:

3.1. Superplasticizer Properties

Table 5 shows the values of specific gravity and chloride contents of the MasterGlenium SKY 504-BASF superplasticizer used for each batch of production. The results are similar to that of the BS EN 934 (2018) admixtures for concrete, mortar and grout.

Table 5: Properties of MasterGlenium SKY 504-BASF superplasticizer

Tests	MasterGlenium SKY 504-BASF superplasticizer	BS EN 934 (2018)
Specific gravity	1.114	1.115
Chloride content	0.000	Free

3.2. Cement Properties

Physical, chemical and compound composition properties of the five cements used individually were tested according to America Society for Testing and Materials (ASTM) standards are presented in Tables 6, 7 and 8. The results as shown in Table 6 defined the physical properties of the five cements used individually in the production of concretes in this study. From the results, the higher the value of cement grade the lower the cement values of fineness, consistency, setting time, loss on ignition and insoluble residue. Although the specific gravity of each brand of cement is equal, yet the higher the value of cement bulk density the higher the grade. Each brand of cement used satisfied the standard specification requirements by being within the acceptable limits of satisfaction for physical properties. Table 7 shows the chemical composition of the five cements used individually. It is observed in the table that the higher the value of the cement grade the higher the value of calcium oxide and that of iron oxide.

Table 6: Physical properties of the five cements used individually

Physical properties	Made in Nigeria Portland cement					Specification requirements content
	43 R Grade	53 N Grade	43 N Grade	33 N Grade	33 R Grade	
Fineness, percent retained on 45 µm (%)	3	2	3	4	4	10
Specific gravity	3.15	3.15	3.15	3.15	3.15	3.13-3.15
Bulk density (kg/m³)	1439.87	1440	1439.76	1439.54	1439.67	1440
Standard consistency (%)	28	27	29	32	31	25-35
Initial setting time (seconds)	120	115	130	211	200	30 minimum
Final setting time (seconds)	260	246	271	438	418	600
Loss on ignition (%)	0.05	0.04	0.05	0.05	0.05	0.04-0.05
Insoluble residue (%)	0.03	0.02	0.04	0.04	0.04	0.02-0.04

Table 7: Chemical composition of the five cements used individually

Chemical composition	Made in Nigeria Portland cement					Specification requirements content (%)
	43 R Grade	53 N Grade	43 N Grade Powerrmax	33 N Grade	33 R Grade	
Silicon dioxide (SiO_2)	18.71	18.54	22.13	21.4	20.02	18.7 – 22.0
Aluminium oxide (Al_2O_3)	5.59	5.23	6.11	5.73	5.64	4.7 – 6.3
Iron oxide (Fe_2O_3)	2.90	3.64	1.29	2.49	2.43	1.6 – 4.4
Calcium oxide (CaO)	65.79	66.05	63.78	63.5	64.98	60.6 -66.3
Magnesium oxide (MgO)	1.60	2.50	2.81	1.76	1.63	0.7 – 4.2
Sulphur trioxide (SO_3)	2.56	2.45	2.35	2.66	2.59	1.8 – 4.6
Sodium oxide (Na_2O)	0.59	0.51	0.60	0.62	0.60	0.11 -1.2
Potassium oxide (K_2O)	0.32	0.29	0.40	0.56	0.43	0.11 -1.2

On the other hand, the higher the value of cement grade, the lower the value of silicon dioxide, aluminium oxide, sodium oxide and potassium oxide. It is worthy of note that each brand of cement used are within the acceptable limits of standard specification requirements for chemical composition. Table 8 is showing the compound composition values of the five cements used individually. The values of Tricalcium Silicate, (C_3S) for 53N and 43R grades are higher than the specification requirements. On the other hand, C_3S value of cement grade 43N is lower than the specification while for those of 33N and 33R are within the standard values. Dicalcium Silicate, (C_2S) values of the four cement brands are within the standard specification but only cement grade of Tricalcium Aluminate, (C_3A) that is higher than the specification. Tetracalcium aluminate, (C_4AF) value for each of the four cement grades satisfied the specification requirements appropriately.

Table 8: Compound composition of the five cements used individually

Compound composition	Made in Nigeria Portland Cement					Specification requirements content (%)
	43 R Grade	53 N Grade	43 N Grade	33 N Grade	33 R Grade	
Tricalcium silicate (C_3S)	76.56	80.59	41.80	46.16	63.56	45-75
Dicalcium silicate (C_2S)	4.17	3.49	15.46	13.58	8.52	7-32
Tricalcium aluminate (C_3A)	9.91	7.71	14.01	10.98	10.84	0-13
Tetracalcium aluminate (C_4AF)	8.82	11.07	3.92	7.57	7.39	0-18

3.3. Aggregate Properties

Properties of fine and coarse aggregates used were tested according to America Society for Testing and Materials (ASTM) standards and results are presented in Table 9. Figure 3 shows fine aggregate gradation chart while Figure 4 displays coarse aggregate gradation chart. The results of test upon the properties of fine and coarse aggregates shown in Table 9 are within the acceptable limits of standard specifications. Comparison of the fine aggregate gradation chart with same of the coarse aggregate as in Figures 3 and 4 is showing that the former satisfied standard specification than the later.

Table 9: Properties of fine and coarse aggregates

Tests	Fine aggregate		Coarse aggregate	
	Results	Specifications	Results	Specifications
Maximum size of the aggregate (mm)	4.75	4.75	9.5	9.5
Fineness modulus (%)	2.77	2.00-4.00	6.99	6.75-8.00
Specific gravity	2.67	2.5-3.0	2.70	2.5-3.0
Bulk density (kg/m^3)	1670	1520-1680	1660	1200-1750
Percentage voids (%)	57.24	45 minimum	33.45	30-40
Maximum percentage of bulking (%)	18.8	20	-	-
Corresponding moisture content (%)	2.2	3	-	-
Water absorption (%)	2.11	3 maximum	1.06	2 maximum

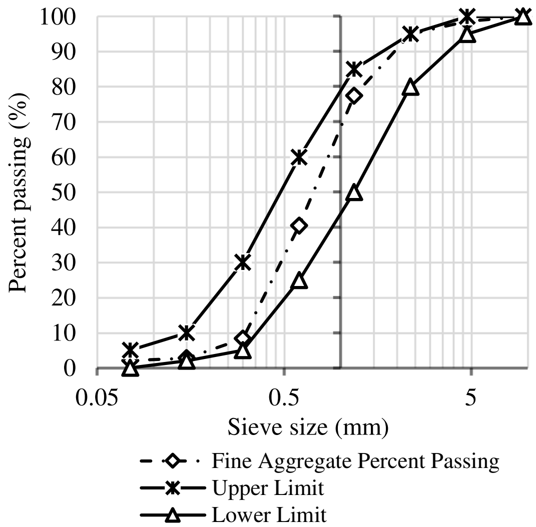

Figure 3: Fine aggregate gradation chart

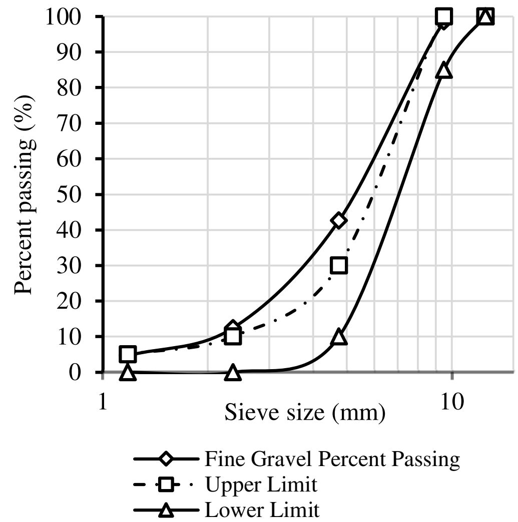

Figure 4: Coarse aggregate gradation chart

3.4. Fresh superplasticized concrete properties

In Table 10, the values of the results of the slump and compaction factor tests are shown depicting the characteristics of the fresh concrete's workability produced for the superplasticized concrete mix. The superplasticized concrete mixes are identified respectively as MG43R, MG53N, MG43N, MG33N and MG33R by cement brand whilst are subjected to equal value of superplasticizer dosage by 1.5 % cement content. The slump values of each fresh concrete varies from 10 mm to 15 mm while the compacting factor values vary from 0.85 to 0.87 indicating low level state of workability.

Table 10: Fresh superplasticized concrete levels of workability

Superplasticized concrete mix by cement brand identification	Superplasticizer dosage in % of cement content	Slump values (mm)	Compaction factor
MG43R	1.5	15	0.86
MG53N	1.5	15	0.85
MG43N	1.5	20	0.87
MG33N	1.5	25	0.89
MG33R	1.5	20	0.87

3.5. Hardened Superplasticized Concrete Properties

3.5.1. Concrete compressive strength as affected by water curing

The values of concrete compressive strength of the superplasticized concretes as affected by water curing in days are shown in Figures 5 through 9. In each figure, the compressive strengths of the specimens were increasing in the same trend as the days of curing increased from 7 to 91 days. The rate of compressive strengths was noticed to be similar but the highest was observed for between 7 to 28 days curing. However, the rates of strengths development between days 28, 56 and 91 were very small compared to the rate of same between 7 and 28 days. It could also be observed that the cube models strength in each figure was higher than those of the three paver samples. However, the highest compressive strength among the three pavers was realized in Z-shape followed by rectangular shape while the I-shape had the least. I-shape paver has hollow each by the side of the web (Akiije, 2019b) that contributed to lowering of its compressive strength when compared to those of rectangular and Z-shape pavers. Z-shape paver has higher area and volume than that of rectangular shape contributed to former having higher compressive strength than the later.

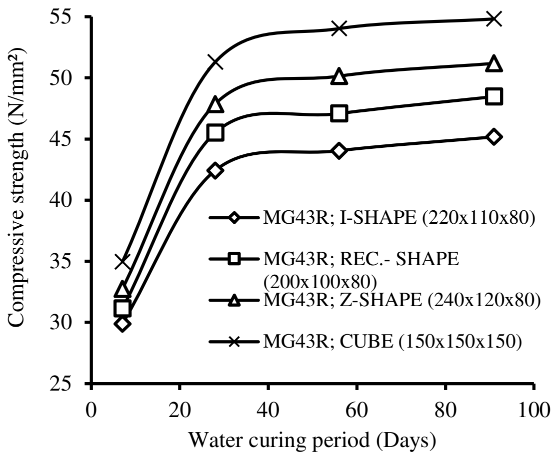

Figure 5: Compressive strength-water curing period effect for MG43R specimens

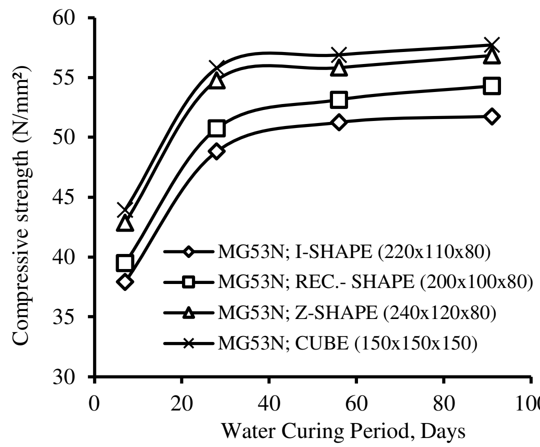

Figure 6: Compressive strength-water curing period effect for MG53N specimens

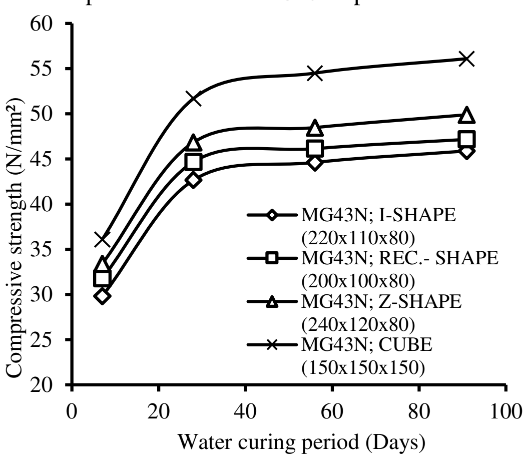

Figure 7: Compressive strength-water curing period effect for MG43N specimens

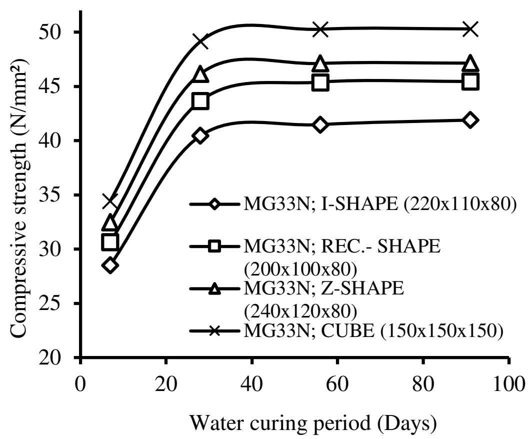

Figure 8: Compressive strength-water curing period effect for MG33N specimens

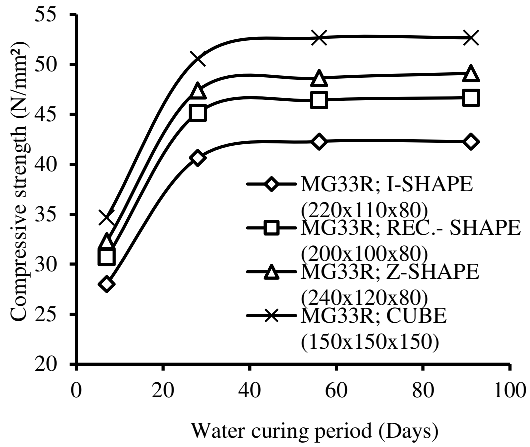

Figure 9: Compressive strength-water curing period effect for MG33R specimens

3.5.2. Relativity effect of compressive strengths by cement brands

Figure 10 gives the comparison among the five types of cements employed in the production of the superplasticized concretes that are described as MG43R, MG53N, MG43N, MG33N and MG33R. The results of the study show that the use of normal 53N grade cement with MasterGlenium SKY 504-BASF that produced the superplasticized concrete tagged MG53N gave the highest compressive strength as seen in Figure 10. This is followed by the use of rapid 43R grade cement with MasterGlenium SKY 504-BASF tagged MG43R and others followed thus of MG43N, MG33R and MG33N. Grade 53N cement has amount of Tricalcium Silicate, (C_3S) at a very high value that is higher than other cement grades and this contributed to its concrete strength to be the highest. Considering the values of cement compound composition of Table 8 it could be seen that the higher the value of Tricalcium Silicate, (C_3S) the higher the compressive strength.

3.5.3. Relativity effect of compressive strengths by specimen shapes

Figure 10 gives the comparison among the five types of superplasticized concrete employed which are MG43R, MG53N, MG43N, MG33N and MG33R while producing four types specimen as I-shape, rectangular shape, Z-shape and Cube.

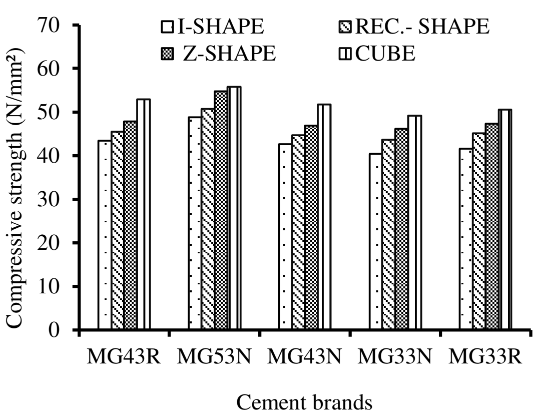

Figure 10: Comparision of compressive strengths advanced by cement brand

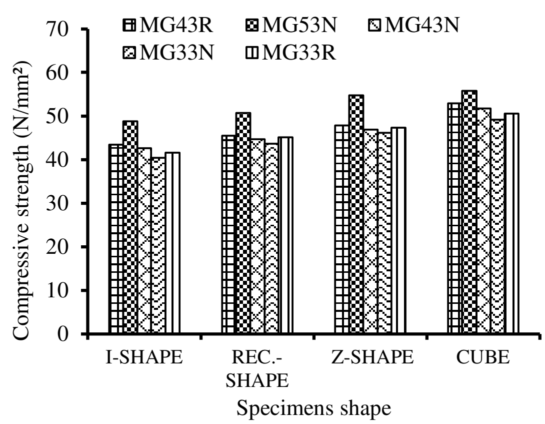

Figure 11: Comparision of compressive strength advanced by specimens shape

The results of the study show that superplasticized concrete specimen tagged MG53N gave the highest compressive strength compared to other five types as shown in Figure 10. Figure 11 gives the comparison among the four types of specimen shapes employed in the production of the superplasticized concretes that are described as I-shape, Rectangular shape, Z-shape and Cube. The results of the study show that cube specimen gave the highest compressive strength compared to other three types of pavers as seen in Figure 11. Of the three types of pavers studied, Z-shape gave the highest value of compressive strength followed by Rectangular shape and then I-shape

3.5.4. Relativity effect of compressive strengths of cube to each paver

In Table 11 through Table 15 the superplasticized concrete cube models compressive strength developments were compared to other pavers' I-shape, rectangular shape and Z-shape upon same separately. Of which the strength comparison of the cube models to the three types of pavers was considered for 7, 28, 56 and 91 days moist curing. The volumes of the cube model as well as I-shape, rectangular shape and Z-shape pavers are of 3,375,000 mm^3, 1,936,000 mm^3, 1,600,000 mm^3 and 2,304,000 mm^3 respectively. It is notably observed in each of the tables that although the volume of I-shape paver is of higher value to that of rectangular shape, it is the compressive strength value of the later that is higher than that of the former. This phenomenon places rectangular shape pavers usage to be economical than that of the I-shape paving blocks. The use of Z-shape pavers therefore will be the most economical of the three types of pavers for flexible road. It is pertinent to note that using the cube model strength developed value for rigid pavement development is a worthy of optima capacity paradigm. Figures 11 through 13 fully displayed similar polynomial graphs in relationship to the results in Table12. The three figures showed relationship between concrete cube and the other three pavers' compressive strengths by the use of normal 53 grade cement and MasterGlenium SKY 504-BASF superplasticizer. The three separately displayed figures fully display similar polynomial graphs but with different quadratic equations which resulted to dissimilar coefficient of R-Square values of regression functions. Figure 13 gave the relationship between concrete cube and Z-shape compressive strengths by MG53N that proffered the optima.

Table 11: Relativity effect of specimen shapes based upon cement Type 43R

Specimen shapes	Developed superplasticized concrete compressive strength of the three pavers by percentage of cube			
	7 Days	28 Days	56 Days	91 Days
Cube	100	100	100	100
I-section	86	83	82	82
Rect.- section	89	89	87	88
Z-section	94	93	93	93

Table 12: Relativity effect of specimen shapes based upon cement Type 53N

Specimen shapes	Developed superplasticized concrete compressive strength of the three pavers by percentage of cube			
	7 Days	28 Days	56 Days	91 Days
Cube	100	100	100	100
I-section	86	88	90	90
Rect.-	90	91	93	94
Z-section	98	98	98	99

Table 13: Relativity effect of specimen shapes based upon cement Type 43N

Specimen shapes	Developed superplasticized concrete compressive strength of the three pavers by percentage of cube			
	7 Days	28 Days	56 Days	91 Days
Cube	100	100	100	100
I-Section	83	83	82	82
Rect.- Section	88	86	85	84
Z-Section	93	91	89	89

Table 14: Relativity effect of specimen shapes based upon cement Type 33N

Specimen shapes	Developed superplasticized concrete compressive strength of the three pavers by percentage of cube			
	7 Days	28 Days	56 Days	91 Days
Cube	100	100	100	100
I-Section	83	82	83	83
Rect.-	89	89	90	90
Z-Section	94	94	94	94

Table 15: Relativity effect of specimen shapes upon cement Type 33NR

Specimen shapes	Developed superplasticized concrete compressive strength of the three pavers by percentage of cube			
	7 Days	28 Days	56 Days	91 Days
CUBE	100	100	100	100
I-Section	81	80	80	80
Rect.- Section	89	89	88	89
Z-Section	93	94	92	93

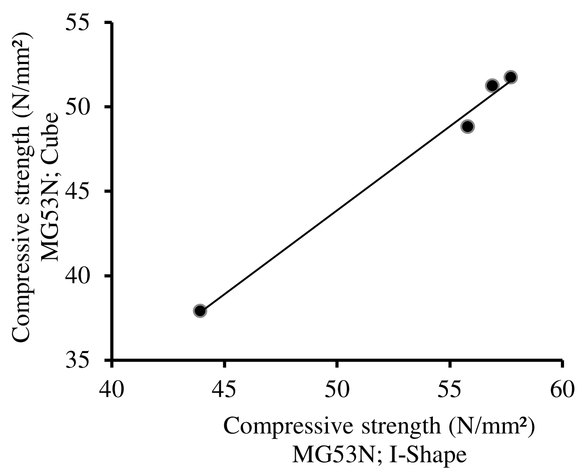

Figure 11: Concrete cube and I-shape compressive strengths by MG53N relationship (28 days curing)

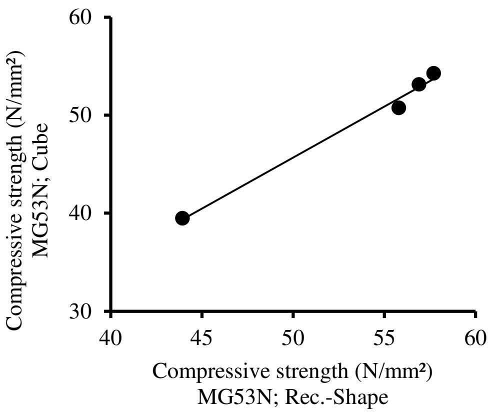

Figure 12: Concrete cube and rect.-shape compressive strengths by MG53N relaionship (28 days curing)

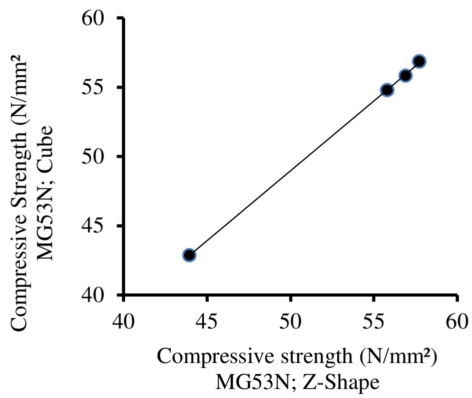

Figure 13: Concrete cube and Z-shape compressive strengths by MG53N relaionship (28 days curing)

The obtained values of the superplasticized concrete compressive strength according to the usage of the different types of cement grades 43R, 53N, 43N, 33N and 33R along with MasterGlenium SKY 504-BASF superplasticizer are shown in Tables 16 to 20. Each cement grade was used to separately produce superplasticized concretes tagged MG43R, MG53N, MG43N, MG33N and MG33R. In each table per a superplasticized concrete, the obtained compressive strength suitability of specimens at 28-day and 91-day moist cured are defined. They are related to the standard specification required compressive strength of 45 N/mm² for medium traffic category and 55 N/mm² for heavy to very heavy traffic category. The specimens are of I- shape, rectangular shape and Z-shape pavers together with cubes. Tables 16 to 20 indicate that the higher the value of cement grade the higher the developed compressive strength of the specimens. Superplasticized concrete MG53N specimens gave the highest values of comprehensive strength while considering the whole type of concretes experimented in this study. MG43R specimens gave higher compressive strength than that of MG43N. Also, specimens MG33R specimens cement grade gave higher compressive strength than that of MG33N Specimens. Table 17 shows MG53N specimens as the best superplasticized concrete produced in terms of compressive strength in this study.

Table 16: Obtained compressive strength at 28 and 91 days against level of satisfactory by MG43R specimens

Specified grade of concrete	Required compressive strength, (N/mm²)	MG43R specimens	28 Days strength, (N/mm²)	91 Days strength, (N/mm²)	28-Day moist cured specimen average compressive strength level of suitability	91-Day moist cured specimen average compressive strength level of suitability
C35 Medium traffic category	45	I- Shape	42	45	Unsatisfactory	Satisfactory
		Rect.- Shape	46	48	Satisfactory	Satisfactory
		Z- Shape	48	51	Satisfactory	Satisfactory
		Cube	51	55	Satisfactory	Satisfactory
C45 Heavy to very heavy traffic	55	I- Shape	42	45	Unsatisfactory	Unsatisfactory
		Rect.- Shape	46	48	Unsatisfactory	Unsatisfactory
		Z- Shape	48	51	Unsatisfactory	Unsatisfactory
		Cube	51	55	Unsatisfactory	Satisfactory

Table 17: Obtained compressive strength at 28 and 91 days against level of satisfactory by MG53N specimens

Specified grade of concrete	Required compressive strength (N/mm²)	MG53N specimens	28 Days strength, (N/mm²)	91 Days strength, (N/mm²)	28-Day moist cured specimen average compressive strength level of suitability	91-Day moist cured specimen average compressive strength level of suitability
C35 Medium traffic category	45	I- Shape	49	52	Satisfactory	Satisfactory
		Rect.- Shape	51	54	Satisfactory	Satisfactory
		Z- Shape	55	57	Satisfactory	Satisfactory
		Cube	56	58	Satisfactory	Satisfactory
C45 Heavy to very heavy traffic	55	I- Shape	49	52	Unsatisfactory	Unsatisfactory
		Rect.- Shape	51	54	Unsatisfactory	Unsatisfactory
		Z- Shape	55	57	Satisfactory	Satisfactory
		Cube	56	58	Satisfactory	Satisfactory

Table 18: Obtained compressive strength at 28 and 91 days against level of satisfactory by MG43N specimens

Specified grade of concrete	Required compressive strength, N/mm²	MG43N Specimens	28 Days strength, N/mm²	91 Days strength, N/mm²	28-Day moist cured specimen average compressive strength level of suitability	91-Day moist cured specimen average compressive strength level of suitability
C35 Medium traffic category	45	I- Shape	43	46	Unsatisfactory	Satisfactory
		Rect.- Shape	45	47	Satisfactory	Satisfactory
		Z- Shape	47	50	Satisfactory	Satisfactory
		Cube	52	56	Satisfactory	Satisfactory
C45 Heavy to very heavy traffic	55	I- Shape	43	46	Unsatisfactory	Unsatisfactory
		Rect.- Shape	45	47	Unsatisfactory	Unsatisfactory
		Z- Shape	47	50	Unsatisfactory	Unsatisfactory
		Cube	52	56	Unsatisfactory	Satisfactory

Table 19: Obtained compressive strength at 28 and 91 days against level of satisfactory by MG33N specimens

Specified grade of concrete	Required compressive strength, (N/mm²)	MG33N specimens	28 Days strength (N/mm²)	91 Days strength, (N/mm²)	28-Day moist cured specimen average compressive strength level of suitability	91-Day moist cured specimen average compressive strength level of suitability
C35 Medium traffic category	45	I- Shape	40	42	Unsatisfactory	Unsatisfactory
		Rect.- Shape	44	45	Unsatisfactory	Satisfactory
		Z- Shape	46	47	Satisfactory	Satisfactory
		Cube	49	50	Satisfactory	Satisfactory
C45 Heavy to very heavy traffic	55	I- Shape	40	42	Unsatisfactory	Unsatisfactory
		Rect.- Shape	44	45	Unsatisfactory	Unsatisfactory
		Z- Shape	46	47	Unsatisfactory	Unsatisfactory
		Cube	49	50	Unsatisfactory	Unsatisfactory

Table 20: Obtained compressive strength at 28 and 91 days against level of satisfactory by MG33R specimens

Specified grade of concrete	Required compressive strength (N/mm²)	MG33R specimens	28 Days strength, (N/mm²)	91 Days strength, (N/mm²)	28-Day moist cured specimen average compressive strength level of suitability	91-Day moist cured specimen average compressive strength level of suitability
C35 Medium traffic category	45	I- Shape	41	42	Unsatisfactory	Unsatisfactory
		Rect.- Shape	45	47	Satisfactory	Satisfactory
		Z- Shape	47	49	Satisfactory	Satisfactory
		Cube	51	53	Satisfactory	Satisfactory
C45 Heavy to very heavy traffic	55	I- Shape	41	42	Unsatisfactory	Unsatisfactory
		Rect.- Shape	45	47	Unsatisfactory	Unsatisfactory
		Z- Shape	47	49	Unsatisfactory	Unsatisfactory
		Cube	51	53	Unsatisfactory	Unsatisfactory

4. CONCLUSION

It could be concluded in this study as followings:

1. All the properties of concrete materials which were superplasticizer, cements, sand and granite used were within the required international standard specifications.
2. The five types of fresh superplasticized concrete produced exhibited slump values that vary from 15 mm to 25 mm and compaction factor values varied from 0.85 to 0.89.
3. The effect of moist curing conditions on the specimens of cubes along with I-shape, rectangular shape and Z-shape of MG43R, MG53N, MG43N, MG33N and MG33R superplasticized concretes exhibited differences in their compressive strengths development but of similar trend pattern.
4. It is recommended that superplasticized concretes MG33N and MG33R should not be used for both highway rigid and flexible pavements of heavy to very heavy traffic category. The use of superplasticized concretes of MG43N, MG33N and 33R should be limited to medium traffic category of road pavement. Superplasticized concrete MG53N could be considered for heavy to very heavy traffic category of rigid pavements. However, only Z-shape pavers of superplasticized concrete MG53N should be used for flexible pavement, as exhibited in this study.

5. ACKNOWLEDGMENT

The authors wish to acknowledge the assistance and contributions of the laboratory staff of Department of Civil and Environmental Engineering, Faculty of Engineering, toward the success of this work. The authors also wish to thank Purechem Manufacturing Limited for the supply of superplasticizer used.

6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

AASHTO T 19 (2014), Standard Method of Test for Bulk Density (Unit Weight) and Voids in Aggregate. American *Association of State Highway and Transportation Officials, Washington, D.C*

AASHTO T 27 (2020). Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates. *American Association of State Highway and Transportation Officials, Washington, D.C*

Agbonkhese, O., Yisa, G.L., Agbonkhese, E.G., Akanbi, D.O., Aka, E.O. and, Mondigha, E.B. (2013). Road Traffic Accidents in Nigeria: Causes and Preventive Measures. *Civil and Environmental Research*, 3(13), pp. 90-99

Akiije, I. (2017). An optimum evaluation of four different Nigerian Portland cements for highway rigid pavements. *International Journal of Advanced Research*, 5(11), pp. 1120-1133

Akiije, I. (2018). Characterization and effects of a 12.5 mm nominal maximum size aggregate in concrete strengths optimization. *International Journal of Engineering and Applied Sciences*, 5(7), pp. 21-28.

Akiije, I. (2019a). Characteristic and Effects of a Superplasticizer Quantity Variation in Some Concrete Strengths Optimization, *Nigerian Journal of Technology*, 38(1), pp. 81-92

Akiije, I. (2019b). Characterization of Superplasticized Microsilica Concrete, *Nigerian Research Journal of Engineering and Environmental Sciences,* 4(1), pp. 494-508

ASTM C 131 (2020). Test method for resistance to degradation of small-size coarse aggregate by abrasion and impact in the Los Angeles Machine. *American Society for Testing and Materials, 100*

ASTM C114 (2018). Standard Test Methods for Chemical Analysis of Hydraulic Cement. *American Society for Testing and Materials. 100 Barr Harbor Drive, West Conshohocken*

ASTM C127 (2015). Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate. *American Society for Testing and Materials. 100 Barr Harbor Drive, West Conshohocken*

ASTM C128 (2015). Standard Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate. *American Society for Testing and Materials. 100 Barr Harbor Drive, West Conshohocken*

ASTM C143/143M (2020). Standard Test Method for Slump of Hydraulic-Cement Concrete. *American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken*

ASTM C191 (2019). Standard Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle. *American Society for Testing and Materials.* 100 Barr Harbor Drive, West Conshohocken

ASTM C192/C192M (2019). Standard Practice for Making and Curing of Concrete Test Specimens in the laboratory. *American Society for Testing and Materials. 100 Barr Harbor Drive, West Conshohocken*

ASTM C204 (2018). Standard Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus. *American Society for Testing and Materials. 100 Barr Harbor Drive, West Conshohocken*

ASTM C29/C29M (2017). Standard Test Method for Bulk Density (Unit Weight) and Voids in Aggregate. *American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken*

ASTM C33/33M (2018). Standard Specification for Concrete Aggregates. *American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken*

BS EN 12350-4 (2019). Testing fresh concrete. Degree of compactability. *European Committee for Standardization, British Standard Institution, Management Centre: Avenue Marnix 17, B-1000 Brussels*

BS EN 934 (2018). Admixtures for concrete, mortar and grout. Part 2: Concrete admixtures-Definitions, requirements, conformity, making and labelling. *European Committee for Standardization, British Standard Institution, Management Centre: Avenue Marnix 17, B-1000 Brussels*

Claudius, K., Duna, S. (2017). Performance Evaluation of Calcined Termite Mound (CTM) Concrete with Sikament NN as Superplasticizer and Water Reducing Agent, *The International Journal of Engineering and Science,* 6(6) pp. 40-48Falade, F., Ukponu, B., and Ugbaja, O. J. (2017). Influence of Superplasticizer and Varying Aggregate Size on the Drying Shrinkage and Compressive Strength of Laterised Concrete, *Nigerian Journal of Technology, 36(3), pp. 734-739*

Gorea, R. K. (2016). Financial impact *of* road traffic accidents *on the* society. *International journal of Ethics Trauma & Victimolog*, *2*(*1*), pp. 6-9.

Marotta, T. W. (2005). Basic Construction Materials. *Pearson Education, Inc., Upper Saddle River, New Jersey.*

Mattam H. S., Paulose, R. K., Sherin Robert, S. and Mathew, V. (2018). A Study on Flow and Strength Characteristics of Superplasticized, *International Research Journal of Engineering and Technology, 5(2), pp. 2192-2195*

Mudiyono, R., Nor, H.M., Hainin, M.R. and, Ling, T.C. (2007). Performance of concrete paving blocks pavement on sloped road section. *International Journal of Pavement Engineering, 6 (1-2-3), pp. 136-145.*

Nar, P. (2018). What are the Advantages of Interlocking Paver Block*?* https://gharpedia.com/blog/advantages-of-interlocking-paver-block/ Assessed February 7, 2021

Neero, G. S., Thangmuansang, G. and Nungleppam, M. (2013). Pavement Distress: A Case Study. *International Journal of Innovative Research in Science, Engineering and Technology,* 3(4), pp. 274-284

Ogundipe, O. M., Akinkurolere, O. O., Nnochiri, E. S. and Ale, P. O. (2018): Effects of Coarse Aggregate Size on the Compressive Strength of Concrete. *Civil Engineering Journal,* 4(4), pp. 836-842

Ragnol, A., Rosaria De Blasiis, M. and Di Benedetto, A. (2018): Pavement Distress Detection Methods: A Review, *Infrastructures*. 3(4), pp. 1-19

Srikanth, T., Rajam, S. and Andhra, P. (2013). Pavement Design and Analysis for Overlaying of Flexible to Rigid Pavement. *International Journal of Engineering Research & Technology, 2(9), pp. 435-440*

Tighe, S. Li, N. Falls, L. C. Haas, R. (2000). Incorporating road safety into pavement management. *Transportation Research Record 1699.* Paper No. 00-043, pp. 1-10.