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Modeling of Strength of Concrete Produced with Fine Aggregates from Different Sources

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***Abstract:** In this study, the compressive strength of concrete was determined from concrete made with fine aggregate sourced from three different locations. Fine aggregates were sourced from Onitsha, Uli, (Anambra State) and Njaba (Imo State) and constrain to several tests namely: sieve analysis, initial and final setting time. The mix ratio of 1:1.5:3and the water/cement ratio of 0.6 were used to produce these concrete samples. Both the slump test and compressive strength test were carried out on these samples. A total of Thirty-six (36) concrete cubes (150mm x 150mm x150mm) were cast, cured and tested after 7, 14, 21and 28 days of curing for each of the fine aggregates. The results for the mean compressive strength of the concrete produced, showed that all of them had average strength greater than 20N/mm^2, with fine aggregate from Uli having the highest mean at 33.2N/mm^2 after 28days of curing. Thus, any fine aggregates could be used to produce structural light weight concrete, but fine aggregate from is highly recommended for projects that requires higher strength. A mathematical models used for the prediction of the compressive strength of concrete produced with different fine aggregate were also created by the Response Surface Method (RSM) using the design Expert Software Application. The optimizations were done and the results were validated.*
***Keywords:** Concrete, Compressive Strength, Fine Aggregate, Modeling.*

I. INTRODUTION

Concrete is one of most widely used artificial construction materials worldwide (Thandavamoorthy, 2014) and it is popular in Nigeria (Tsado, 2013). It is a composite material, and a significant component is natural aggregate. Cement, aggregate (coarse and fine) and water are traditionally combined in the right proportions to produce concrete, which then hardens to form a mass resembling rock (Gideon et al, 2015). This element affects the concrete's strength in a variety of ways (Deodhar, 2009). Additionally, for given water/cement ratio, the type of aggregate used to produce concrete affects its strength, stiffness, and fracture energy (Abdullahi, 2012). If the materials used in its production are not of good quality, its quality could be debilitated. Many factors, including the characteristics of the materials used during construction, have been linked to the collapse of structures (Ayininuola and olalusi, 2004, Ede 2010). Concrete's properties are influenced by the kind of cement, water, and aggregate used in its production. According to Talbot and Richart (1923), aggregate (coarse and fine) can make up to 70-75% of the volume of concrete; therefore, its quality must be determined. There are two types of aggregates used in concrete: fine aggregate and coarse aggregate. The word fine aggregate refers to aggregate with a size of 5mm or less, whereas the term coarse aggregate refers to aggregate with a size greater than 5mm.All aggregates used in concrete projects should be made up entirely of hard particles, devoid of any clay, loam, or plant debris. The main qualities of aggregates include cleanness, grading, hardness, and shape, which have an impact on the strength, durability and workability of concrete. The aggregates are typically more durable than the concrete from which they are formed. Concrete's strength will be decreased if the aggregate has a layer of dust or dirt on it because it prevents the aggregate from properly bonding to the mortar. To produce cost-effective concrete of high quality, a well-graded aggregate mix is necessary. If the mix is poorly graded, even clean, sound aggregates will require too much water to be workable, lowering the strength or the mix will need too much cement to generate a given strength. Fine aggregate is one of the essential components of concrete that helps to ensure the strength of the concrete produced (Gupta and Gupta, 2014). In the production of concrete, numerous types of fine aggregates are used. The type of fine aggregate used alters the geometric properties of cement paste and has an impact on the qualities of both concrete and shell formation during heat treatments (Abdullahi et al., 2017).The ratio of fine to coarse aggregate will affect how concrete is packed. It has an impact on concrete's workability in the fresh stages as well. Increased cohesiveness but less consistency can result from higher sand to coarse aggregate ratios. The most efficient way to increase the cohesiveness of concrete is to increase the proportion of sand to coarse aggregate (Li, 2011).

Sharp sand, which can be obtained from river or a natural deposit, is the term used to describe the fine aggregate that is frequently used in Nigeria. This is because it has been tested and meets the requirements of British standard regulation.

II. LITERATURE REVIEW

KavithaKarthikeyan (2017) made an attempt to partially replace concrete's coarse aggregate with Talipot palm seed. The only purpose of the seed is to be discarded as garbage. Villages were found to have an abundance of the seeds, which were gathered and used for this investigation. The Talipot palm seeds were discovered to have the following characteristics: Low impact value, low crushing strength, and light weight. Sized at 18mm and weighing 4 grams, per seed. The seeds were first used without being crushed. This was attempted with concrete of the M20 grade, and replacement amounts ranged between 10% and 20%. After seven days, the cubes made by partially substituting Talipot palm seeds displayed noticeable surface fissures. All of the samples exhibited the same cracking phenomenon, proving that despite having a smooth surface, the seeds lacked binding power when employed without crushing. In the second effort, coarse aggregate in concrete was replaced with crushed seeds to a percentage between 10% and 20%. The specimens did not develop any cracks after curing when the seeds were crushed and used. The strength levels were practically the same as those of standard concrete when tested for compressive strength. In this study, the use of Talipot Palm seeds as a substitute for coarse aggregate was examined. Although the compressive strength was found to be satisfactory, more research on the durability factors is required before it can be used in real life.

According to BU et al. (2017), the impact of employing 4 sand content on the compressive, flexural, and splitting-tensile strength of cement mortars was assessed. The pore structure of cement mortar was investigated by varying the sand amount and water/cement ratio. The pore size distribution, which quantified the changes in pore structure, was obtained using the MIP approach. The test findings demonstrate that, to a certain extent, the strength of cement mortar increases with increasing sand concentration. Traditional water/cement ratios can likewise be used with a minor change. The amount of sand in cement mortar was discovered to be a crucial factor affecting the pore structure. It was discovered that there is a good correlation between cement mortar strength and pore structure.

Research study on the impact of coconut shells and fibers (polypropylene and steel fibers) on M30 grade concrete was presented by Naresh Kumar et al. (2017). Polypropylene and steel hook-end fibers measuring 0.5 mm in diameter and 60 mm in length were employed in this project. The study found that the strength qualities diminish as the fraction of coconut shell replacement with coarse aggregate rises. The strength properties of concrete are slightly improved, but not significantly better than with regular concrete, with the addition of fibers like polypropylene and steel.

In order to ascertain the impact of aggregate size on the compressive strength of concrete, Vilane and Sabelo (2016) carried out an experiment. The aggregate sizes in the experiment 9.5 mm, 13.2 mm, and 19.0 mm as well as the control were divided into three treatments. Throughout the experiment, a 1:2:4 mix with a 0.5 water/cement ratio was used. The compressive strength test and the slump test were both performed. The workability (slump) of concrete was shown to be directly correlated with aggregate size. The average concrete's compressive strength increasing as aggregate size increased.

Karuna Devi et al. (2017), An experimental investigation on the use of E-waste is conducted. Particles used as coarse aggregates in concrete with a replacement rate of 0% to 20% based on the M20 Concrete strength requirements. Concrete's compressive strength, tensile strength, and flexural strength were measured with and without e-waste as aggregates, and the results show a significant increase in strength.

Manjunath (2017) Using the use of sea sand and desert sand in place of some of the river sand as a fine aggregate, an experimental investigation is conducted on the strength characteristics of cement mortar. To create cement mortar blocks and test them, various fine aggregate materials (SS, DS, and RS) were utilized in proportions of 10%, 20%, 30%, 40%, and 100%. Cement mortar blocks were cast for each proportion of fine aggregates (FA) and tested for compressive strength after 3, 7, 28, and 56 days of curing. Plotting compressive strength v/s curing period was used to visually depict the data, and compressive strengths of replacements were prepared as tabular data.

In this experiment, according to Ayushi R. Sharma (2016), an effort has been made to discuss the qualities of concrete formed by substituting artificial sand for natural sand at various replacement levels (0%, 20%, 40%, 60%, 80%, and 100%). The project's goal is to compare the strength and durability of concrete manufactured using natural sand versus concrete made with synthetic sand.

Experimental research was done by Somani et al. (2016) to determine the effects of replacing some of the coarse aggregate with demolition debris. Performance metrics included compressive and workable strengths. Compressive strengths during 3, 7, and 28 days were measured for the study. According to a prior study on the subject, conventional concrete's compressive strength is comparable to destroyed aggregate concrete if up to 30% of it is employed. In this study, concrete cubes were created using the destroyed concrete aggregate, which was then subjected to further tests like workability and compressive strength. The results showed that the demolished concrete aggregate performed similarly to conventional concrete in both of these areas.

According to Azhahendran et al. (2016), Talipot palm seeds had a low impact value and crushing strength, making them lightweight materials. Each seed typically weighs 4 grams and measures 18mm in size. According to the study, the compressive strength values were nearly identical to those of regular concrete. Following a durability investigation, the study suggested using Talipot Palm seeds because the compressive strength was deemed adequate for actual application. Although the study's attempt to explore the potential use of Talipot Palm seeds as a substitute for coarse aggregate was successful in terms of compressive strength, a longer-term investigation of the durability element is necessary before it can be successfully applied practically.

Chabbara et al. 2015 investigated the characteristics of concrete made with fly ash, recycled aggregate, glass powder, and crumb rubber. The project was split into two parts, the first of which was Research Program One, which featured concrete made from recycled aggregate, fly ash, and glass powder. Fly ash made up 30% of the cement replacement, recycled concrete made up 40% of the coarse aggregate replacement, and glass powder made up 15% to 25% of the fine aggregate replacement, ranging by 5% increments. In the subsequent research program, fly ash replaced 30% of the cement, recycled concrete replaced 40% of the coarse aggregate, and crumb rubber replaced the fine aggregate to different degrees, from 5% to 10% at intervals of 2-3%.

Mahla and Mahla (2015) conducted a study to systematically analyze several characteristics required for the formulation of a concrete mix utilizing coarse tyre rubber chips as an aggregate material. For the purpose of conducting the experimental research, M-20 grade concrete was used. For the investigation, recycled rubber chips were used in place of the usual coarse aggregate.

In this experiment by Suribabu et al. (2015), quarry rock dust is employed as a complete replacement for natural sand in concrete. For both conventional concrete and concrete made with quarry dust, mix designs for the M25 and M40 grades have been created utilizing design approach IS.

The strength of concrete made of quarry rock dust was tested on beams and cubes, and the results were compared to concrete cast with natural sand concrete. It has been determined that concrete manufactured from quarry rock dust has flexural and compressive strengths that are nearly 10% higher than those of conventional concrete. Experiments were also done on cubes and beams that were subjected to 300°C for one hour and three hours, respectively.

In a study conducted by Babu and Mahendran in 2014, blast furnace slag from two locations was substituted with fine aggregate, and the qualities of concrete were examined. The ideal percentages for replacing these materials were discovered. The outcome promotes the usage of these materials as a fine aggregate replacement material.

According to Suganthy et al. (2013), HDPE (High-Density Polyethylene) was considered since it was widely accessible and had a higher density than other varieties. To produce plastic granules measuring about 1mm in size, the spent plastics were collected, broken up into smaller pieces, melted, and crushed.

Plastic that had been ground up was discovered to have a density of 460 kg/m3 and a specific gravity of 0.46. Around 75% of the polymers that were subjected to sieve analysis fell within the 1–1.7mm range. 45 pieces of 15 cm by 15 cm by 15 cm cement concrete In place of 0%, 25%, 50%, 75%, and 100% of the sand, pulverized plastic material was substituted in 1:1:2 (M 25) mix cubes. The density of the plastic material was too low, so volumetric proportioning was used instead of design mix. There were measurements made for the cubes' weight, compressive strength, and workability.

In a study by Joseph et al. (2012), lateritic sand and quarry dust were used as a full replacement for traditional river sand fine aggregate to examine the structural properties of concrete. Using different amounts of quarry dust and laterite as fine aggregate, concrete samples in the shape of cubes were created. At intervals of 25%, varying from 0 to 100%, the amount of laterite was adjusted against quarry dust. After being hydrated for predetermined amounts of time, the samples underwent compressive strength testing in the lab.

The ideal w/c ratios for 1:1:2, 1:1.5:3 and 1:2:4 ratio blends were determined from earlier workability studies. It was discovered that for a 1:1:2 mix, a water/cement ratio of 0.5 produced higher compressive strengths, while a ratio of 0.6 produced better workability for a 1:1.5:3 mix proportion. Compressive strength for the adopted mixes ranged from 17 to 34.2 N/mm^2. As compared to standard concrete's outcomes, these findings are favorable. It was determined that the concrete was adequate for usage as structural members for buildings and associated constructions when the laterite percentage did not exceed 50%. Abuamer, Sadat et al. (2017) carried out a case study in Istanbul using traffic data. On the volume count and speed measurements collected from radar sensors, statistical analyses were run. As a result, in this study, statistical analysis was done on data made up of the compressive and tensile strengths of the sample cubes.

According to Manatkar and Deshmukkh (2016), the production of e-waste is a major problem around the world. India produced close to 650000MT of electronic trash in 2014, which comprises all used electrical and electronic equipment (TVs, computers, sound systems, refrigerators etc). The improper disposal of this garbage eventually has negative effects on the environment, human health, and storage issues.

This debris will be used as concrete's coarse aggregate. Avoiding pollution and giving coarse aggregate replacement material are both beneficial. Thier study analyzed the compressive strength of concrete of the M20 and M25 grades by substituting coarse aggregate with nonmetallic e-waste in amounts ranging from 0% to 20%. It was shown that some nonmetallic e-waste can be used as coarse aggregate in concrete.

III. MATERIALS AND METHODOLOGY

A. *Materials*

1) *Fine Aggregate:* River sand was used as the fine aggregate in this investigation and came from several distinct places in the states of Anambra and Imo, as listed below: Sample A (Sharp Sand) was sourced from River Niger beach at Onitsha, which is located at latitude 6. Sample B (Local sand) was sourced from Njaba River in Imo State, which is located at latitude 5^{o} 43'42.0"N and longitude 7^{o} 03'35.0"E. Sample C (Semi-Sharp Sand) sourced from Atamiri River in Uli, which is located at latitude 5^{o} 46'57.4"N and longitude 6^{o} 51'42.8"E. All of the fine particles were moisture-free prior to being used to produce concrete
2) *Coarse Aggregate:* The local store on the timber market route in Uli, Anambra State, provided the coarse aggregate used in this study. The coarse aggregate used was a graphite.
3) *Cement:* Common Portland cement was utilized in this experiment. It meets with BS EN 197-1 (2011) requirements and was acquired from a cement shop on Timber Market Road in Uli, Anambra State.
4) *Portable Water:* Water used for the study was sourced from Chukwuemeka Odumegwu University borehole in Uli, Anambra State. The water conformed to the requirement as stated in BS EN 1008: (2002) for a portable water. It is suitable for both production and curing of concrete since it satisfies the requirements for drinking.

B. *Methodology*

1) *Sieve Analysis:* The test samples were dried to a consistent weight at (110 + 5) degrees Celsius. The three samples were weighed after drying. A stack of sieves with varying aperture sizes were assembled and placed on the mechanical sieve shaker. The samples were sieved for a predetermined amount of time (10-25 minutes) using the mechanical sieve shaker. Following sieving, the contents of each sieve were weighed and recorded. Calculations were made to determine the proportion of the sample weight that overall passed through each sieve.
2) *Batching of Materials:* The materials were batched according to a mix ratio of 1:1.5:3 (Cement: Sand: Coarse Aggregate) and water-cement ratio of 0.6. The various materials used (cement, coarse aggregates, fine aggregates and water) were batched by weight using a weighing machine. Each material was place on the weighing machine one after the other in three different batches for Sample A (River Niger sand), Sample B(Njaba), Sample C(Uli).
3) *Mixing of Materials:* The mixing was done manually with shovels for a period of about 5- 10 minutes. The cement, sand and coarse aggregate were mixed first before adding the batched water and finally mixing again. We ensured a proper and smooth mixture was observed before casting the concrete into the mold.
4) *Placing/Compacting of Concrete:* The fresh concrete was placed into the mold in three layers respectively. After every layer, the concrete was compacted using a vibrator to ensure the concrete is free from air voids. The vibrator removes voids from the concrete and ensures it is well compacted. The processes were done for the three samples (Sample A, Sample B and Sample C).
5) *Slump Test:* A thin layer of oil was applied after thoroughly cleaning the interior surface of the mold (Cone). A horizontal, smooth, rigid, non-absorbent surface was chosen for the mold to be placed on. The mold was then filled with four freshly mixed layers of concrete, each one roughly one-fourth the height of the mold(cone).Every layer was 25 times tapped with the rounded end of the tamping rod (strokes are distributed evenly over the cross-section).The mold (cone) was then filled with the concrete and the concrete was allowed to slump. The slump value was obtained using a measuring tape and the tampering rod. After the measurement was taken, the concrete was removed from the level with a towel after rodding the top layer. The concrete mold was removed.
6) *Setting/Curing of Concrete:* After the concrete was compacted, it was left in the mold for about 24 hours to enable the concrete harden and set properly. The mold on the concrete was then remove and the concrete cubes was taken to the curing tank for curing process. The curing tank contained portable water. The concrete cubes were left in the curing tank for 7 days, 14 days, 21 days and 28 days respectively.
7) *Crushing of Concrete:* The concrete cubes were crushed in the crushing machine after 7 days, 14 days, 21 days and 28 days of curing respectively. The compressive strength values were obtained and recorded after each crushing.

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IV. RESULTS AND DISCUSSION

The samples were put through the test listed below on the indicated samples.

A. *Sieve Analysis Test (Particle Size Distribution Test)*

Table 1: results of sieve analysis (Onitsha Sample)

Weight of test sample = 500 gms.					
S/N	SIEVE SIZE (MM)	WEIGHT RETAINED (G)	PERCENTAGE RETAINED	CUMULATIVE % PASSING	CUNULATIVE % RETAINED
1	4.75	18.45	3.69	96.31	3.69
2	2.00	64.45	12.89	83.42	16.58
3	1.00	138.85	27.77	55.65	44.35
4	0.60	94.70	18.94	36.71	63.29
5	0.300	102.85	20.57	16.13	83.87
6	0.150	53.55	10.71	5.43	94.57
7	0.075	23.60	4.72	0.71	99.29
8	Pan	3.55	0.71	0.68	99.97

Table: 2 sieve analysis (Atamiri sample)

Weight of Test Sample = 500 gms					
S/N	SIEVE SIZE (MM)	WEIGHT RETAINED (G)	CUMULATIVE WEIGHT RETAINED	CUMULATIVE WEIGHT RETAINED %	CUNULATIVE WEIGHT PASSING %
1	4.75	1.06	1.06	0.212	99.8
2	2.00	24.46	25.52	5.104	94.9
3	1.00	69.61	95.13	19.062	75.6
4	0.60	93.87	189.0	37.800	62.2
5	0.300	176.89	365.89	73.180	26.8
6	0.150	118.06	483.95	96.790	3.2
7	0.075	13.40	497.35	99.470	0.5
8	Pan	1.82	499.17	99.800	0

Table 3: sieve analysis of fine aggregates (Njaba sample)

Observation and calculation Total weight 500g					
S/N	IS Sieve size	Weight of fine aggregate (gms)	Percentage Retained	Cumulative Percentage Retained	Percentage passing
1	4.75mm	7.5	1.5	1.5	98.5
2	2.36mm	34.5	6.9	8.4	91.6
3	1.18mm	89.8	17.96	26.36	73.64
4	0.60mm	38.15	7.63	33.99	66.01
5	0.30mm	71.80	14.36	48.35	51.65
6	0.150mm	223.5	44.7	93.05	6.95
7	0.075	31.15	6.23	99.28	0.72
8	Pan	3.6	0.72	99.98	0.02

We conducted sieve analysis to determine the proportion of various grain sizes in a soil and also the percentage of different sized grains that is present in a soil. The particle size distribution test was performed with fine aggregate that was sourced from Onitsha, Uli, and Njaba, Anambra Central, Anambra South, and Oru East. Using IS: 1498-1970 as a guide, this test was carried out.
It was observed from above tables that the fine aggregates used for the experiment was well graded.

B. Slump Test

This test was done to see how the three distinct fine aggregates might work together.
These are some of the outcomes that were obtained.
Mixing ratio: 1:1.5:3
Cement Grade: M20 0.5 water to cement

Table 4: slump test result

Specimen sample	Fine aggregate (location)	Trial	Water/ Cement Ratio	Height of cone	Height of slump concrete	Slump value	Type of slump
1	Uli	1	0.5	300mm	270mm	20mm	True slump
2	Njaba	1	0.5	300mm	280mm	25mm	True slump
3	Onitsha	1	0.5	300mm	275mm	30mm	True slump

From the results obtained from table 4, it was observed that the Uli sample produced slump value of 20mm which is very low, Njaba sample produced slump value of 25mm which is low and recommended for foundations with light reinforcement while Onitsha sample produced slump value of 30mm which is low in terms of workability.

C. Test of Compressive Strength

This test was done to find out how strong the coarse particles were in concrete mixtures that were 7, 14, 21, and 28 days old, respectively. The procedure for carrying out this test is laid forth in chapter three of this project work.
The mix ratio utilized for the compressive strength test was 1:1.5:3

Table 5: Compressive Strength Test Result

S/no	Sample Locations (Fine Aggregates)	Design Compressive Strength (N/mm^2)			
		7 Days	14 Days	21 Days	28 Days
1	Sample 1 (Uli)	17.32	22.82	25.16	33.02
2	Sample 2 (Onitsha)	16.75	21.65	24.55	31.15
3	Sample 3 (Njaba)	15.65	20.55	23.95	28.65

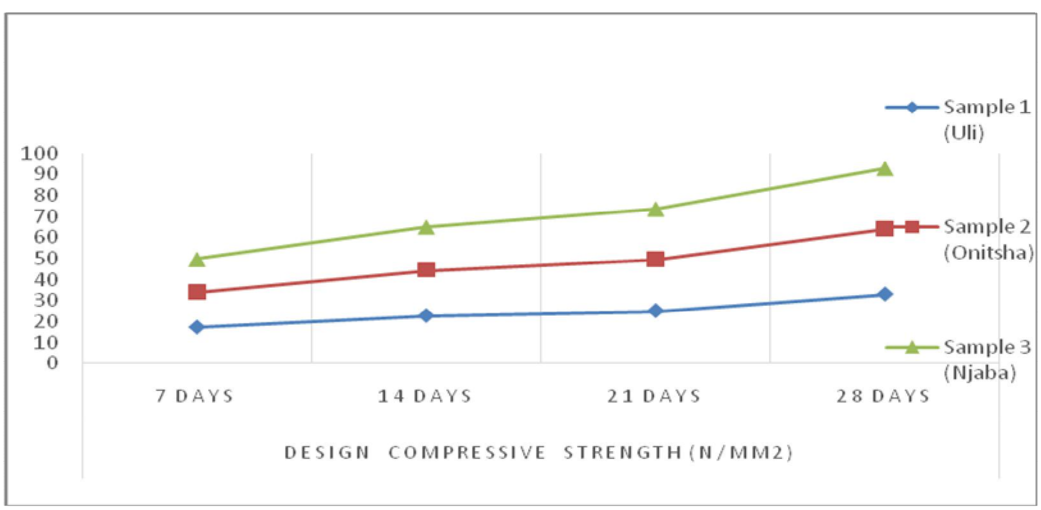

Figure1: Design compressive strength

Table 6: Design Matrix

Run	Factor A: Samples ()Aggregates) and Location	Factor B: Time (Days)	Compressive Strength (N/mm^2)
1	Sample 1 (Uli)	21	25.16
2	Sample 3 (Njaba)	7	15.65
3	Sample 3 (Njaba)	21	23.95
4	Sample 3 (Njaba)	28	28.65
5	Sample 2 (Onitsha)	7	16.75
6	Sample 3 (Njaba)	14	20.55
7	Sample 2 (Onitsha)	21	24.55
8	Sample 2 (Onitsha)	28	31.15
9	Sample 1 (Uli)	14	22.82
10	Sample 2 (Onitsha)	14	21.65
11	Sample 1 (Uli)	28	33.02
12	Sample 1 (Uli)	7	17.32

Table 6: shows the design matrix used for the development of the model analysis.

Table 7 :ANOVA for Response Surface Linear model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	328.45	2	164.23	160.70	< 0.0001	Significant
A-Samples (Uli, Onitsha & Njaba)	*11.33*	*1*	*11.33*	*11.09*	*0.0088*	
B-Time	*317.12*	*1*	*317.12*	*310.32*	*< 0.0001*	
Residual	9.20	9	1.02			
Cor Total	337.65	11				

The analysis table of variance model for compressive strength of concrete done with 95% confidence is displayed in table 7. …. The F – value of 160.70 and the P –value of < 0.0001 indicates the model is significant.

Table 8: Mathematical model for Compressive Strength of concrete

Factor	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	23.44	1	0.29	22.77	24.10	
A-Samples (Uli, Onitsha & Njaba)	-1.19	1	0.36	-2.00	-0.38	1.00
B-Time	6.90	1	0.39	6.01	7.78	1.00

Mathematical Model Equation for Compressive Strength of Concrete
Equation 1.0 is the mathematical model equation of compressive strength of concrete in terms of the coded factor.

Mathematical Model Equation for Compressive Strength of Concrete (*f*)

$$f = +23.44 - 1.19A + 6.90B \qquad (1.0)$$

Where A= Samples, B=Time

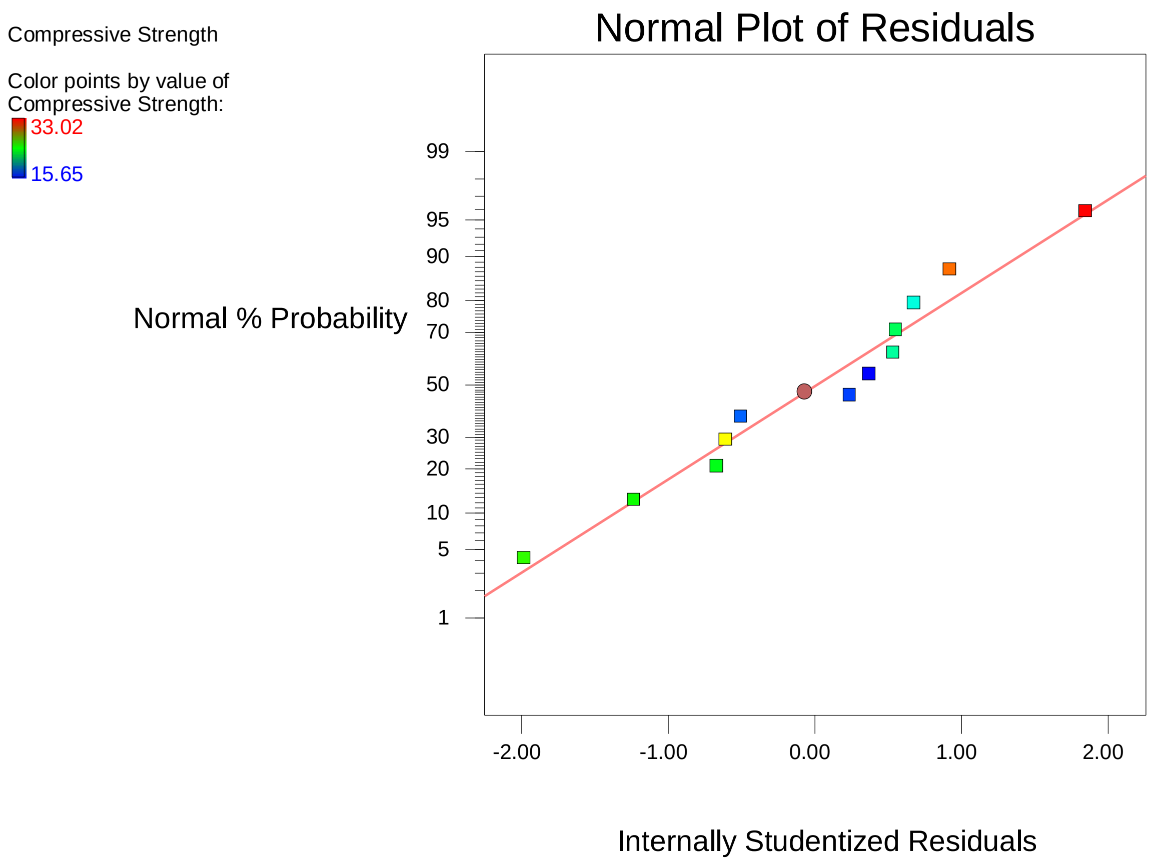

Figure 2:Graph of Normal Plot of Residuals.

Figure 2 shows the details and strong relationship between the Normal % probability and Internally Residuals for the compressive strength test of concrete.

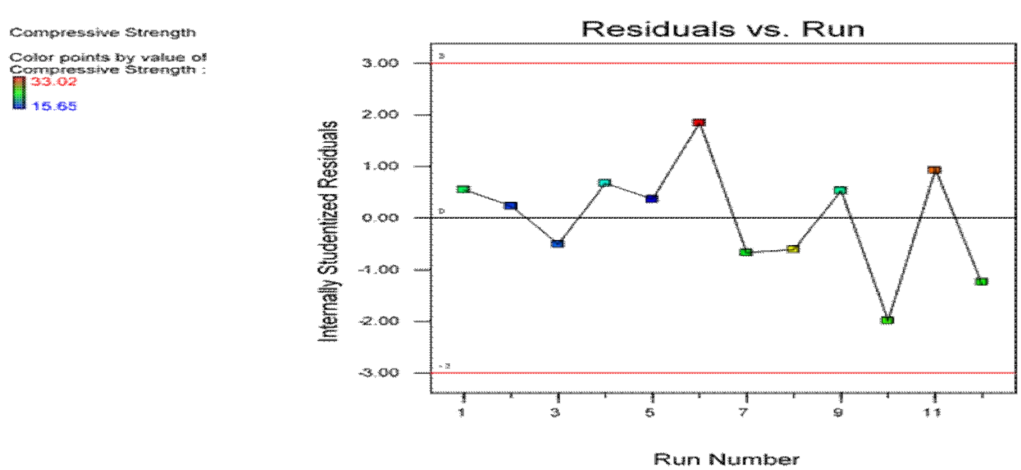

Figure 3**:** Graph of Residuals vs. Run.

Figure 3: shows the details graph of Residuals vs. Run for the compressive strength test of concrete.

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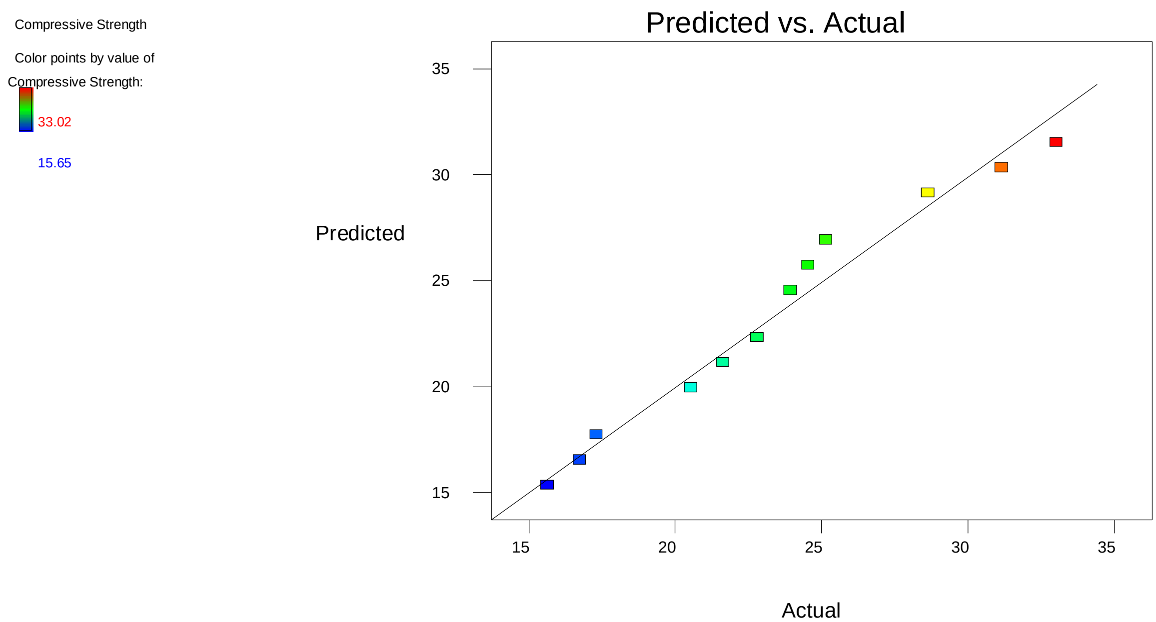
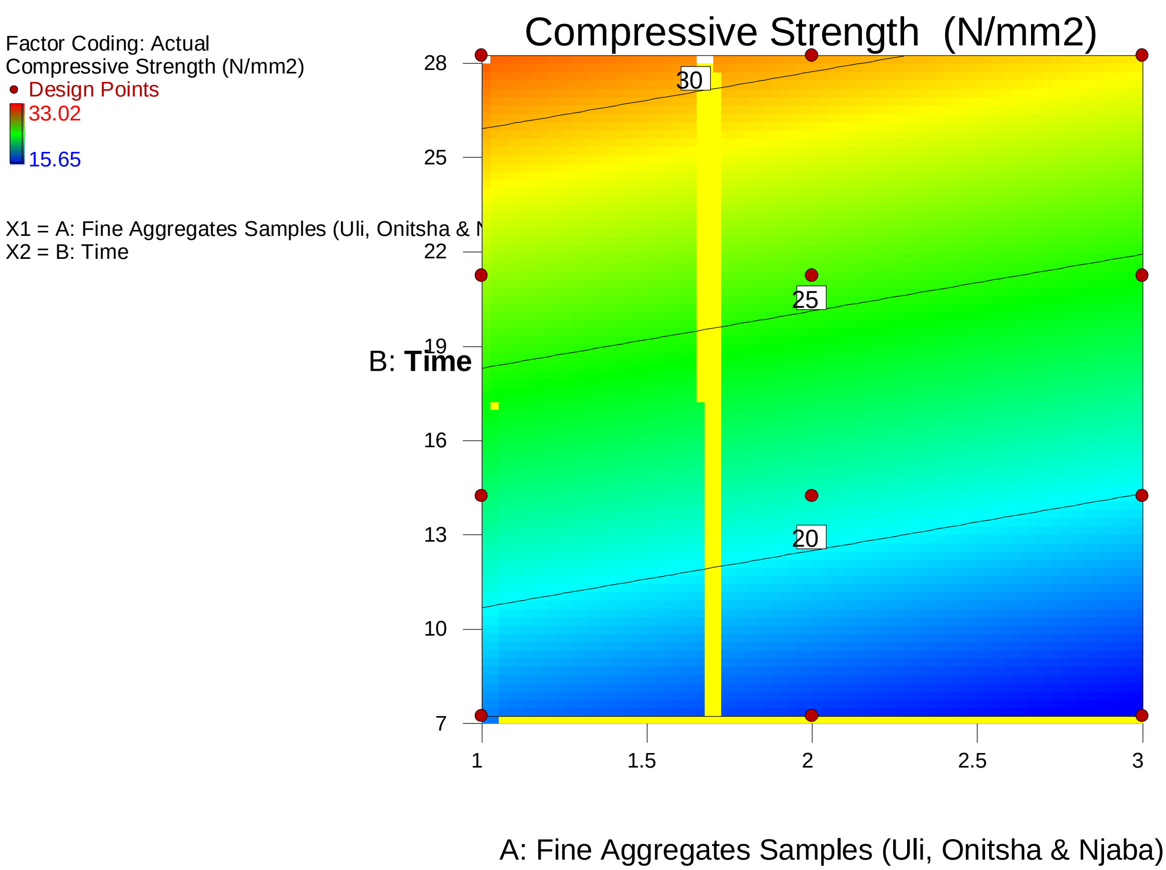


Figure 4: Graph of Predicted vs. Actual.

Figure 4: show strong correlations between the predicted and actual details for the compressive strength concrete. The maximum strength of compressive strength is 33.02 N/mm^2 and the minimum compressive strength is 15.65 N/mm^2.



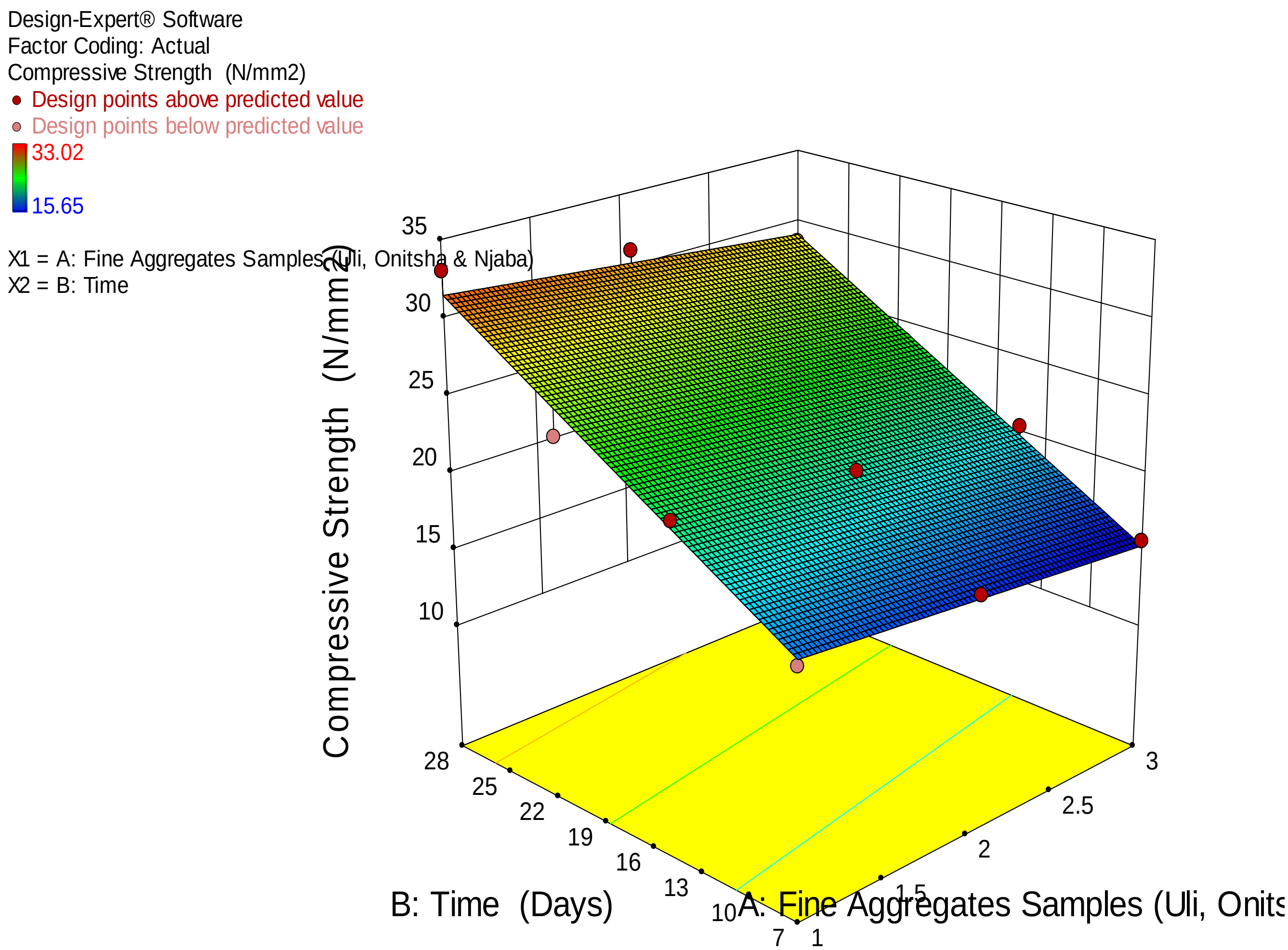


Figure 3.6: 3Dimensional Contour of Compressive Strength.

Figure 3.5 and 3.6 shows 2 & 3 Dimensional contour of factor on compressive strength test response. The figures show strong interactions between the factors on the model.

V. CONCLUSION

It was observed that at 28 days of curing Onitsha sample produced strength of 31.15N/mm^2, Njaba sample produced strength of 28.65N/mm^2 while Uli sample produced sample of 33.02N/mm^2. It then means that all the aggregates could be used in the production of structural light weight concrete but Uli sample is recommended heavily for structures that requires high strength.

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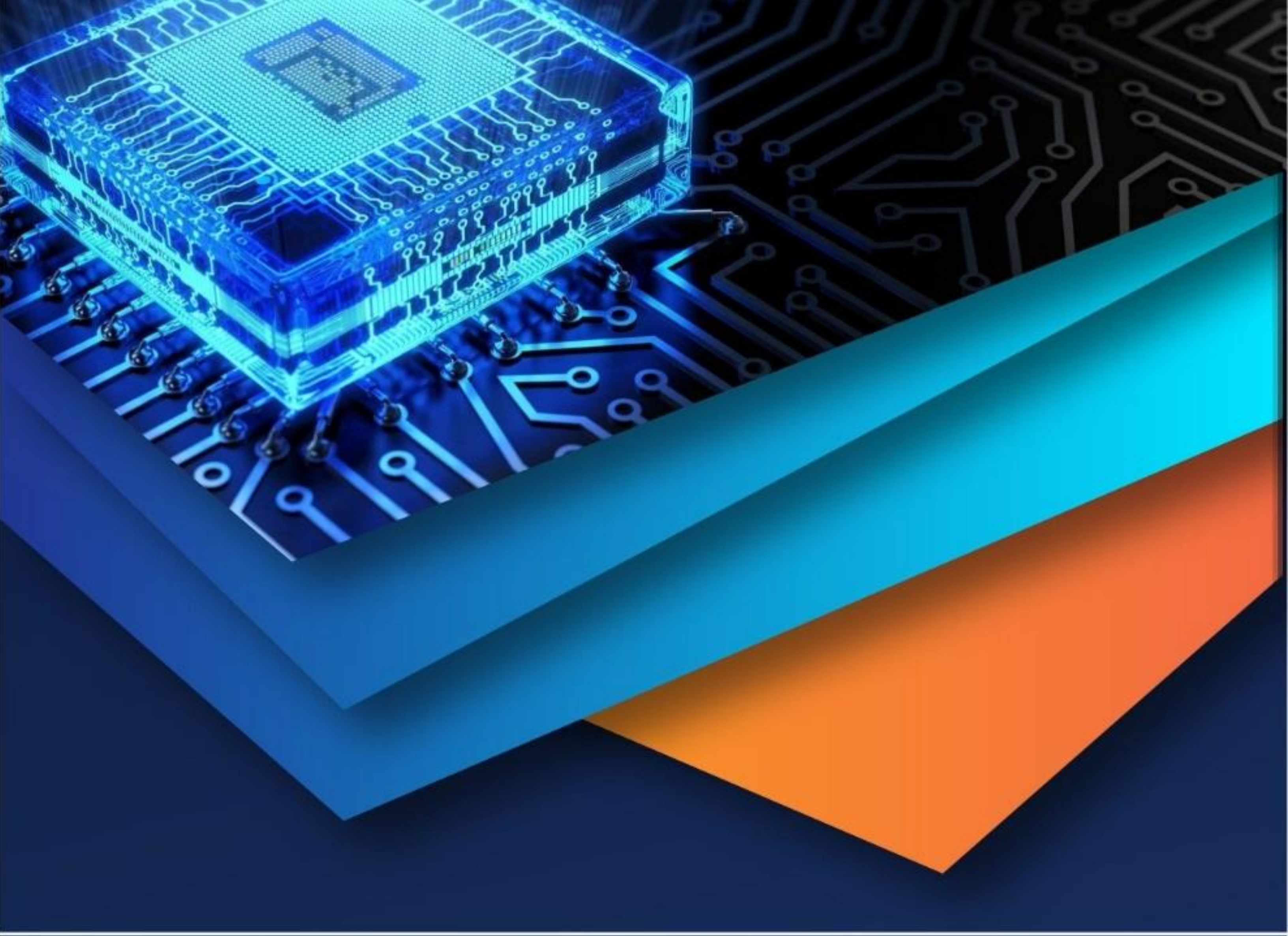

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