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DESIGN STANDARDS FOR THE PRODUCTION OF EFFECTIVE INTERLOCKING CONCRETE TILES USING PIT GRAVEL AS COARSE AGGREGATES

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1.1 INTRODUCTION

Interlocking Concrete Tiles are essentially unreinforced precast modular concrete units used in the construction of pavements for a wide variety of purposes. Quite often these units are given fair-finished sides and wearing surfaces to improve their beauty and appeal. The concept of constructing road pavements from modular masonry units started in the Old Roman Empire. Sections of the famous Roman Appian Way (Figure 1.1) show road pavements constructed from stones and masonry units set in lime or bitumen mortar and some of these roads have existed for the past 3000 years. After the Second World War, the construction of pavements from precast modular units was refined and resuscitated; thus leading to the modern concept of high quality, precision manufactured concrete interlocking tiles.

Figure 1.1: Sections of the Roman Appian Way

Presently in Europe, the conventional methods for the design and construction of flexible pavements have been fully adapted to the concept and use of interlocking concrete pavements. In the United Kingdom for example, full British Standards and Specifications exist for Precast Concrete Paving Blocks. BS 6717–1 (1993) specifies requirements for precast concrete paving blocks intended for the construction of low speed roads, industrial and other paved surfaces subjected to all categories of static and vehicular loading and pedestrian traffic. This Code of

Practice therefore provides for interlocking concrete tiles (or paving blocks) that are structural elements for the surfacing of pavements that can withstand all categories of vehicular and pedestrian traffic load. Numerous pavements of private buildings and compounds, parks, shopping centers, industrial complexes, sea ports and airports exist all over Europe and more are still being constructed. Figure 1.2 show typical pavements made with different designs of interlocking concrete tiles.

Figure 1.2: Typical Interlocking Concrete Pavements

In North America, the present predominant use of interlocking concrete pavements is for residential and architectural purposes. Interlocking concrete pavements are increasingly being used as alternative to asphalt and in-situ concrete pavements. Although aesthetic appeal has a great influence in the North American market for interlocking concrete pavements, the recognized load-carrying abilities of these pavements, combined with their ride quality and favorable safety characteristics have combined to make them choice pavements for streets, industrial parking areas, multimodal facilities and airport taxiways and aprons. The American Society for Testing and Materials (ASTM) Standard C 936 (2001) – Standard Specification for Solid Concrete Interlocking Paving Units – provides specifications covering the requirements for interlocking concrete pavers manufactured for the construction of paved surfaces (that is, pavements).The use of interlocking concrete tiles have been entrenched in Europe and America for a very long period, while the situation is quite the opposite in Nigeria. Although, the use of this material has been on the increase in Nigeria within the last twenty years or so, it has largely been limited to the initiatives of private developers that use them mostly in private capacities. Interlocking concrete tiled roads, streets and pavements have not reached its full potential in Nigeria at present. However, Nigeria being a developing country and with the vision of the Federal Government of Nigeria to get the country within the league of the 20 most developed economies in the world by the year 2020, a lot of infrastructural developments are currently going on in Nigeria. Majority of the current infrastructural needs of Nigeria are engineering in nature; and more than 60% of these are Civil Engineering infrastructure, which include roads, buildings, bridges and pavements. Interlocking concrete tiles certainly have a contribution to make in the Nigerian quest for infrastructural development.

A major step to guiding the development of this material is the establishment of standards and specification that are Nigerian in content. At present, no engineering standards exist for the design and manufacture of interlocking concrete tiles in Nigeria, as well as for their use in the construction of pavements. While the Standards Organization of Nigeria (SON) is still hoping to develop one, the local interlocking concrete tiles industry is awash with unregulated individuals trying to produce anything in the name of interlocking concrete tiles. This has led to many failed pavements dotting the compounds and parking lots of many private residences, shopping malls and super markets.

It has been shown that good quality concrete can be produced from raw materials – cement coarse aggregates, fine aggregates, water and probably, admixture – available in any locality; the achievement of this goal however demands proper management and quality control measures. This is more so as bad or poor quality concrete most often have the same ingredients as good quality concrete, the only difference being the lack of knowledge and 'know-how' in the principles of concrete technology (Neville, 1996; Shetty, 2005; Mbajiorgu, 2002).

The conventional practice in the production of interlocking Concrete Tiles is to use 10mm or 12mm single size Crushed Rock Chipping as Coarse Aggregates, Sharp Sand and Cement. Interlocking Concrete Tiles as Unreinforced precast units are susceptible to failure in flexure and the interlocking Concrete Tile producers therefore avoid the use of other types of Coarse aggregate that are locally available. Despite the increased cost implication of this approach; the challenge of applying concrete in a locality is ignored.

This research work is therefore aimed at designing concrete mixes using Pit Gravel from Ugwuaji in Enugu South Local Government Area of Enugu State as the Coarse Aggregate; and using these concrete mixes to produce interlocking Concrete Tiles.

MATERIALS AND METHOD

2.1 MATERIALS

The main materials in this research work are cement, water, fine aggregates, granite chippings and pit gravel. The materials and their sources are discussed below;

2.1.1 WATER

The water used for the production of concrete samples is portable water gotten from the Maintech Materials Laboratory Republic Layout Enugu. The source of the water is from Ninth Mile Ngwo Enugu through a Water Tanker. It is portable drinking water free from sulphates and deleterious materials.

2.1.2 CEMENT

The cement used is Ibeto brand of OPC obtained from the local market.

2.1.4 PIT GRAVEL

The local stone (pit gravel) was sourced from Ugwuaji in Enugu South Local Government Area and its environs. The gravel was washed and processed for the research work.

2.2 METHODS

The tests carried out during this project were done in accordance to specification of the appropriate BS codes, (BS 812 – 103.1 1985: method for determination of particle size distribution e.t.c).

2.2.1 DETERMINATION OF PARTICLE SIZE DISTRIBUTION FOR COARSE AND FINE AGGREGATE

This operation is used to divide a sample of aggregate into various fraction; each consisting of particles of the same size.

APPARATUS

- **i.** Set of test; 9.5mm, 4.75mm, 2.36mm, 1.18mm, 600μm, 150mm (for fine aggregate), 33mm, 18mm, 9.5mm, 4.75mm (for coarse aggregate).
- **ii.** Weighing balance
- **iii.** Wire brush
- **iv.** Oven

PROCEDURE

Sufficient representative sample was collect from the stockpile and was reduced by quartering to obtain the quantity for test. The sample was washed with water several times until the water become clear; it was then dried in the oven for 24hours. On the following day the sample was removed from the oven and allowed to cool; sieving commenced as soon as sample had cooled using 500g; the sieves were arranged in descending order starting with sieve 9.5mm down for the fine aggregate and sieve 33mm down for coarse aggregate. The sample was introduced into the arranged sieves with a receiver at the bottom and covered. It was shaken very well using hand, the sample retained in each sieves were then collected and weighed.

2.2.2 DETERMINATION OF SPECIFIC GRAVITY OF AGGREGATE (FINE AND COARSE)

Specific gravity of aggregate is used in design calculations of concrete mixes. It is defined as the ratio of the density of a material to the density of distilled water. For this project the specific gravity of aggregate were determined on saturated and surface dry (SSD) basis.

APPARATUS

- **i.** Weighing balance
- **ii.** Pychnometer bottle
- **iii.** Sieves (75μm for fine aggregate and 4.75mm for coarse aggregate)
- **iv.** Absorbent cloth
- **v.** Distilled water

PROCEDURE

Sufficient representative sample was collected from the stockpile and quartered. The sample was sieved using sieve 75μm and 4.75mm for the respective aggregates were collected and washed thoroughly until the water was clear. After washing, the samples soaked in distilled water for 24hours, the following day the water was decanted and the samples were spread on a metal plate to surface dry.
Once the sample was dry, it was divided into four portions for the test. The weight of the pyknometer bottle was determined after it was dried with hand towel, then one portion of the sample was introduced into the empty bottle and weighed. The bottle with the sample was filled with water and weighed. The specific gravity is calculated from the results and the sequence is repeated for the second portion.

2.2.3 MIX DESIGN

From the values obtained from particle size and specific gravity tests, several concrete mixes were designed using specific characteristic concrete strength $20\mathrm{N/mm^2}$, $25\mathrm{N/mm^2}$, $30\mathrm{N/mm^2}$, $35\mathrm{N/mm^2}$, $40\mathrm{N/mm^2}$ standard deviation of 4 $\mathrm{N/mm^2}$ and slump ranges 30-60mm with the aid of scale 149 software.

2.2.4 MIX RATIO/PROPORTIONING

The proportioning was done by weight. After the trial mixes were cast and their slumps recorded, adjustments were made with respect to water and cement content per mould. From these adjustments, samples were caste for to be tested after curing for 28 days.

2.2.5 PROCEDURE FOR PRODUCTION OF CONCRETE SAMPLES

2.2.5.1 BATCHING

The different components of the concrete, cement, water, fine aggregate and coarse aggregate (local stone) were measured out using an electronic weighing balance for the different quantities as determined by the mix design for each of the experimental points.

2.2.5.2 MIXING

Cement was first mixed with the fine aggregate using masons trowel in a mixing pan. The mixing was to ensure thorough and consistent mixing. Coarse aggregate (local stones) were added and the mixing continued. Lastly, water was added and mixed properly ensuring that the mix is consistent and uniform. This is done by observation ensuring that all the components are uniformly distributed throughout the mass.

2.2.5.3 PLACING AND COMPACTION

The placing was done using mason’s trowel ensuring as closer packing during placement as possible. Due to the small size of the moulds, aggregation of the concrete is obviously not a problem. To ensure good compaction, the concrete was agitated using tamping rod and given at least 25 blow for each layer. Three layers were adopted. The surface is then finished, leveled and troweled. After the initial set (about 1hr) a slight identification mark was made on the concrete top surface. The process was repeated for each of the trial mixes including the control mix. Sixty-nine cubes produced were from 23 mixes. Each mix gave three cubes. The mix ratios are shown in Table 3.2.

Preparation of Samples of Interlocking tiles

2.2.5.4 CURING

Twenty-four hours after the production of the cubes, they were placed in a drum filled with potable water obtained from the borehole water source of the laboratory. The cubes were totally immersed in water for twenty eight (28) days. After twenty eight (28) days, each of the samples was removed and crushed to determine the strength.

Demolding and Curing of Interlocking Tiles in the Laboratory

2.2.6 SLUMP TEST

A portion of the mixed concrete was placed in a slump cone. The concrete was tapped gently for at least 25 blows on the sides all around the cone for each of the three layers. This is to ensure the proper compaction of the concrete inside the cone. After the compaction, the cone was gently lifted up; the fresh concrete bulged sideways with a resultant reduction in the height of the concrete frustum. The new height was measured; the difference between the height of the frustum and the concrete frustum after removal was determined.

2.2.7 COMPRESSIVE STRENGTH

After curing for twenty eight days, the concrete cubes were removed from the water, cleaned and crushed using compression machine. The cube was placed in the concrete testing machine in between the crushing plates. The concrete testing machine was switched on and force was exerted on the cubes by the crushing plates. The force at which the cube fails was divided by the cross section area of the cube to obtain the compressive strength.


Compressive Strength Testing of Interlocking Tiles in the Laboratory

$$\text{Compressive Strength} = \frac{\text{Failure load}}{\text{Gross section area}} \qquad 3.1$$

This was done for each of the three samples for each mix. The value for each replicate was recorded and the mean strength calculated.

3.0 RESULTS, ANALYSES AND DISCUSSIONS

The laboratory tests results on the aggregates and concrete samples are presented and analyzed in this chapter. It is being represented by the use of line graph, tables and histograms to aid visualization.

3.1 PRESENTATION OF RESULT

The results of various tests conducted in this research work are presented as follows:

3.1.1 PHYSICAL PROPERTY TEST

The physical tests on the material used are presented thus:
3.1.1.1 Grain size distribution
3.1.1.1.1 Sand

Table 3.1 Average Sieve Analysis Result for Fine Aggregate

Sieve Size (mm)	Weight Retained (g)	%Weight Retained	Cumulative % Retained	Cumulative % Passing
9.500	0	0	0	100
4.750	3	0.598	0.598	99.40
2.380	5.9	1.176	1.774	98.23
1.180	47.9	9.549	11.321	88.68
0.600	91.5	18.24	29.559	70.44
0.300	262.3	52.22	81.842	18.16
0.150	87.9	17.52	99.362	0.64
0.075	3.2	0.638	100	0
$\sum$	501.7		324.46	

Fineness Modulus $\frac{324.46}{100} = 3.24$

Percentage passing sieve 600 Sieve is 70.44%, the aggregate falls under zone 3.

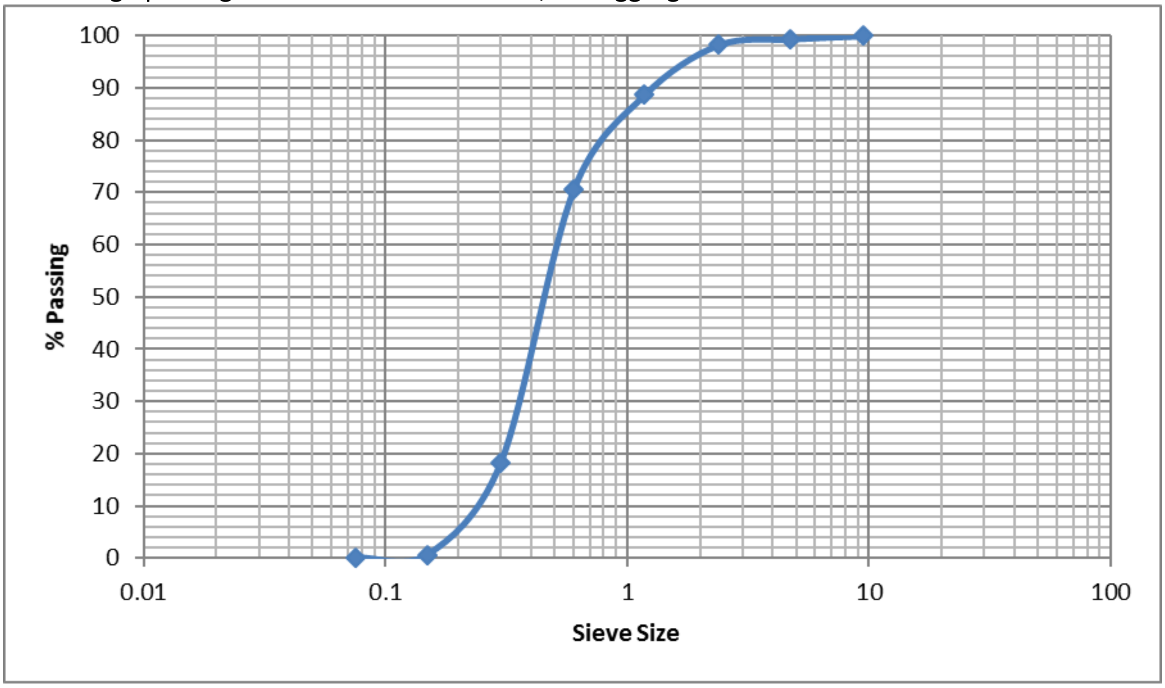


Figure 3.1 Sieve Analysis Graph (River Sand)

3.1.1.1.3 COARSE AGGREGATE

Table 3.2 Sieve Analysis Result for Coarse Granite Aggregate

Sieve Size (mm)	Mass Retained (g)	% Mass Retained	Cumulative % Retained	Cumulative % Passing
13	0	0	0	100
12	95	19	17	81
9.5	125	25	44	56
4.75	260	52	96	4
2.38	20	4	100	0
Σ	500			

89

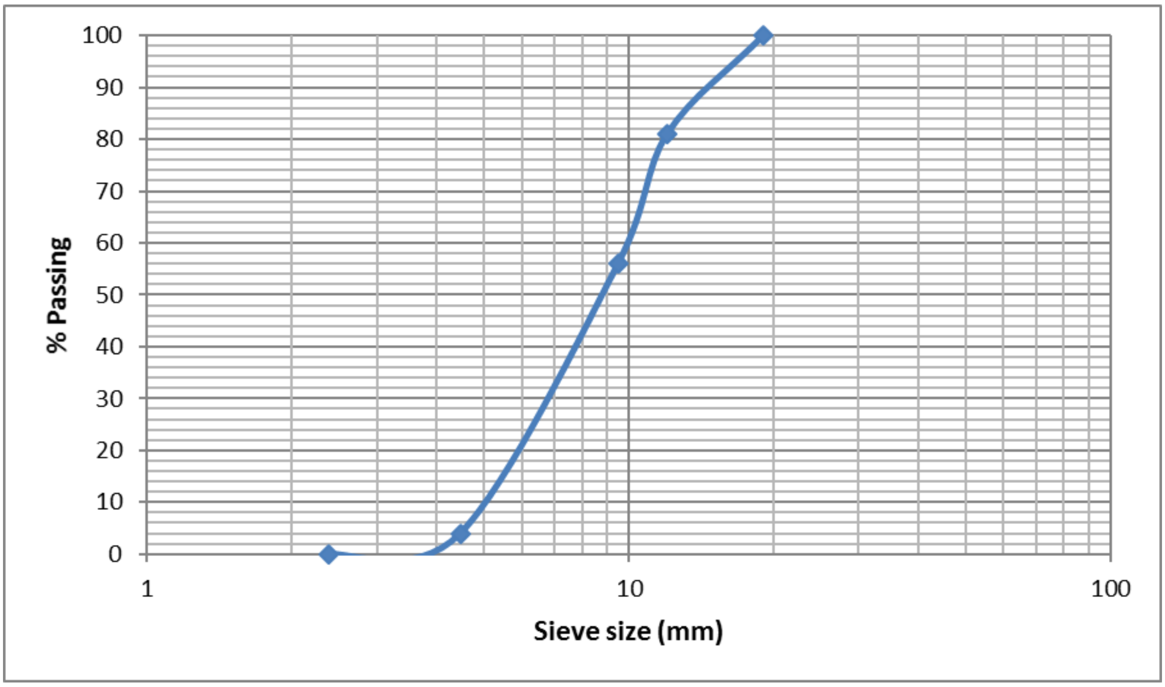


Figure 3.2 Sieve Analysis Graph (Coarse Granite Aggregate)

From Table 3.2, it was observed that the coarse aggregate had a 0% content of aggregate size larger than 12mm and a 96% content of aggregate size larger than 4.75mm.

Table 3.3 Sieve Analysis Result for Coarse Pit Gravel Aggregate

Sieve Size (mm)	Weight Retained (g)	% Weight Retained	Cumulative % Retained	Cumulative % Passing
12mm	0	0	0	100
9.50mm	49.5	5.85	5.85	94.15
4.75mm	683.7	80.77	86.62	13.38
2.5mm	113.3	13.38	–	0
	846.5			

This result was specifically based on aggregates not more than 12mm in size and not lesser than 2.5mm in size.

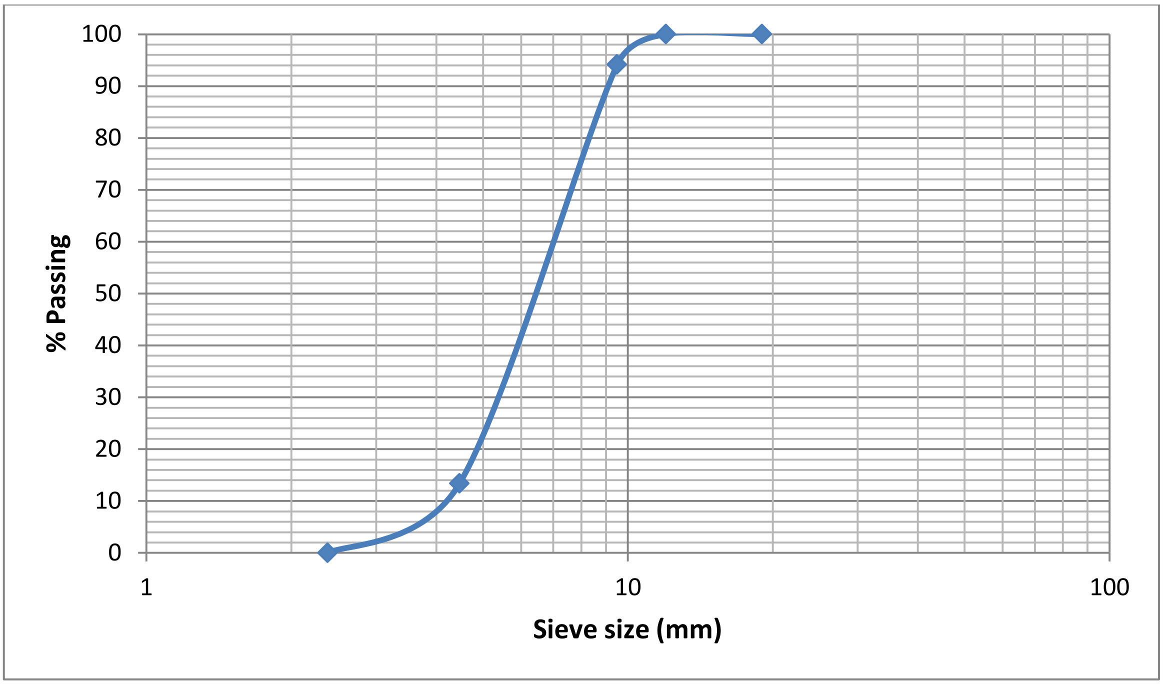


Figure 3.3 Sieve Analysis Graph (Coarse Pit Gravel)

3.1.1.2 SPECIFIC GRAVITY

$\text{Weight of empty bottle} = X$
$\text{Weight of empty bottle} + \text{sample} = K$
$\text{Sample weight} = K - X = A$
$\text{Weight of bottle} + \text{Sample} + \text{water} = B$
$\text{Weight of bottle} + \text{water} = C$

3.1.1.2.1 SPECIFIC GRAVITY SAND

Table 4.4 Specific Gravity Result for Fine Sand (4 Samples)

Sample ID	Weight (g)			
	Sample 1	Sample 2	Sample 3	Sample 4
Empty wt. Of bottle, X (g)	441.5	441.5	441.5	441.5
Wt of bottle. + sample, K (g)	941.5	938	997.5	1044
Sample weight: K-X =A (g)	500	496.5	556	602.5
Wt of bottle. + sample + H2O = B (g)	1773.3	1773.5	1812.2	1834
Wt of bottle. + H_2O = C (g)	1472.5	1472.5	1472.5	1472.5

$$\text{SPECIFIC GRAVITY ON SSD BASIS} = \frac{A}{A - (B - C)}$$

$A = 500 + 495.5 + 556 + 602.5 = 2154$
$B = 1773.3 + 1773.5 + 1812.2 + 1834 = 7193$
$C = 1472.5 + 1472.5 + 1472.5 + 1472.5 = 5890$

$$S.G = \frac{2154}{2154 - (7193 - 5890)} = 2.53$$

3.1.1.2.2 SPECIFIC GRAVITY COARSE AGGREGATE

Table 3.5 Specific Gravity for Coarse Pit Gravel (4 Samples)

Sample ID	Weight (g)			
	Sample 1	Sample 2	Sample 3	Sample 4
Empty wt. Of bottle, X (g)	441.5	441.5	44.15	441.5
Wt of bottle. + sample, K (g)	992	951.5	1068.5	1041.8
Sample weight: K-X =A (g)	550.5	510	627	600.3
Wt of bottle. + sample + H2O = B (g)	1828.5	1806	1879.5	1860.7
Wt of bottle. + H_2O = C (g)	1472.5	1472.5	1472.5	1472.5

Specific gravity on SSD basis

$$A = \frac{A}{A-(B-C)}$$

$$1 = \frac{550.5}{550.5-(1828.5-1472.5)} = 2.78$$

$$2 = \frac{510}{510-(1806-1472.5)} = 2.89$$

$$3 = \frac{627}{627-(1879.5-1472.5)} = 2.85$$

$$4 = \frac{603}{603-(1860.7-1472.5)} = 2.80$$

$$\text{Average SG} = \frac{2.78+2.89+2.85+2.80}{4} = 2.83$$

Table 3.6: Specific Gravity for Coarse Granite Aggregate

Sample ID	Weight (g)			
	Sample 1	Sample 2	Sample 3	Sample 4
Empty wt. Of bottle, X (g)	460	460	460	460
Wt of bottle. + sample, K (g)	1270	1375	1320	1365
Sample weight: K-X =A (g)	810	915	860	905
Wt of bottle. + sample + H2O = B (g)	2105	2170	2145	2180
Wt of bottle. + H_2O = C (g)	1600	1600	1600	1600

Specific Gravity on Saturated Surface Dry (SSD) Basis

$$A = \frac{A}{A-(B-C)}$$

$$1 = \frac{810}{810-(2105-1600)} = 2.66$$

$$2 = \frac{915}{915 - (2170 - 1600)} = 2.65$$

$$3 = \frac{860}{860 - (2145 - 1600)} = 2.73$$

$$4 = \frac{905}{905 - (2170 - 1600)} = 2.70$$

$$\text{Average} = \frac{2.66 + 2.65 + 2.73 + 2.70}{4} = 2.685$$

$$\text{Combined Specific Gravity} = \frac{2.53 + 2.83 + 2.685}{3} = 2.68$$

3.1.2 COMPRESSIVE TEST RESULT

The result obtained from compressive test of the interlock concrete tiles at different levels of substitutions of granite with local pit gravel after 28 days curing period is as presented in Table 3.7 while the graphic representation of the effect of the level of substitution of granite with local pit gravel on the compressive strength of interlock concrete tiles is presented in Fig.3.1

Table 3.7 Mean values of the concrete tiles properties at various mix ratios

S/N	Cement	w/c ratio	Rivers Sand	Coarse Aggregate Granite	Local Stone	% age Local Stone	f_m (N/mm^2)	f_{ck} (N/mm^2)	Slump (mm)	Density kg/m^3
1	1	0.5	1.53	3.72	0	0	41.46	34.43	30	2341.7
2	1	0.5	1.53	3.53	0.19	5	38.81	31.76	35	2362.3
3	1	0.5	1.53	3.35	0.38	10	35.50	29.46	50	2397.2
4	1	0.5	1.53	3.16	0.56	15	33.87	27.15	60	398.4
5	1	0.5	1.53	3.00	0.75	20	30.91	24.19	65	2386.1
6	1	0.5	1.53	2.79	0.93	25	28.78	20.18	75	2378.6
7	1	0.5	1.53	2.61	1.11	30	28.12	20.02	75	2374.4
8	1	0.5	1.53	2.42	1.30	35	27.56	20.57	83	2366.5
9	1	0.5	1.53	2.24	1.49	40	25.72	19.86	95	2373.3

F_m = mean strength of sample; f_{ck} = characteristic strength

3.1.2.1 EFFECT OF THE LEVELS OF SUBSTITUTION OF GRANITE WITH LOCAL PIT GRAVEL ON THE COMPRESSIVE STRENGTH OF INTERLOCK CONCRETE TILES

The relationship between the levels of substitution of granite with local pit gravel and the concrete compressive strength is as illustrated in Fig 3.1

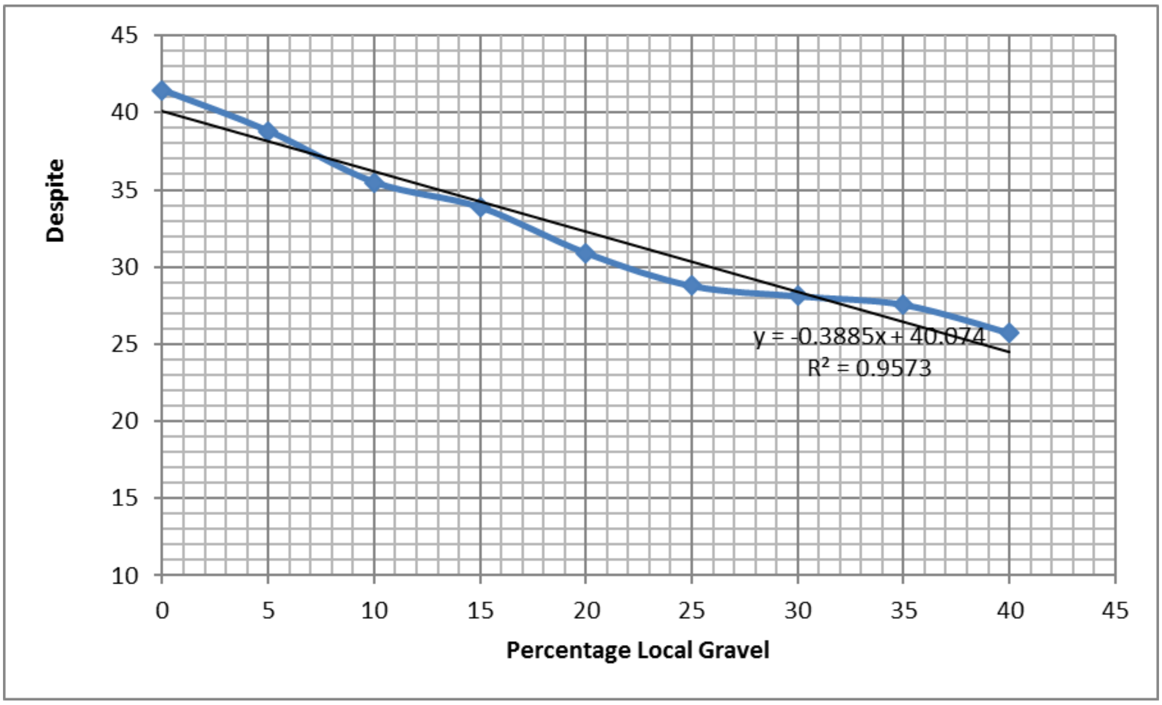


Fig.3.1 Effect of the level of substitution of granite with local pit gravel on the compressive strength of interlock concrete tiles

It can be observed from the graph that the mean compressive strength decreases with increase in the level of substitution of the granite with the local pit gravel. Despite the decreased strength with increasing substitution level the strength values obtained at 40% substitution is still within the acceptable limit of structural concrete.

3.1.2.1 EFFECT OF SUBSTITUTION LEVEL OF GRANITE WITH LOCAL PIT GRAVEL ON THE WORKABILITY OF CONCRETE

The effect of substitution level of granite with local pit gravel on the workability of concrete is as presented in Fig.3.2 below.

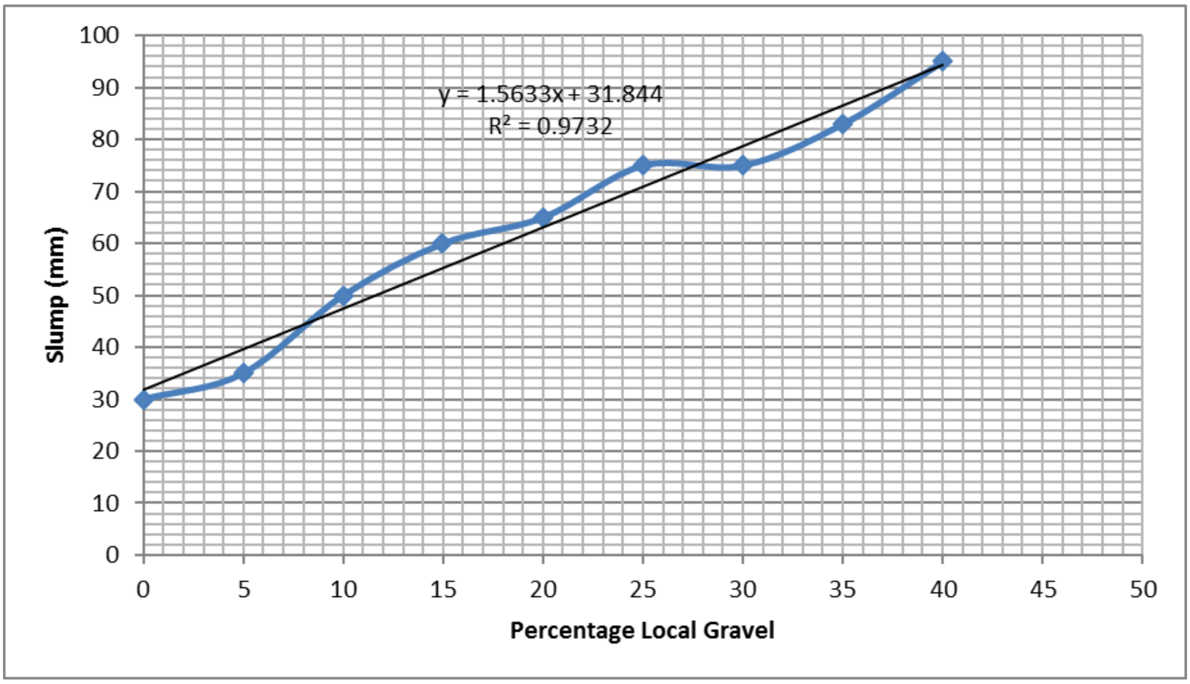


Figure 3.2 Effect of level of substitution on Slump

It can be observed from Fig 3.2 above, that the slump increases with increase in the level of substitution of granite with local gravel. This observation is of great importance to producers of interlocking concrete tiles at mix design stage as water/cement ratio of concrete mix that contains local gravel as coarse aggregate should be reduced to some extent during mix design so as to improve the compressive strength of interlocking tiles produced.

3.1.2.2 THE RELATIONSHIP BETWEEN THE SLUMP OF GRANITE/LOCAL PIT GRAVEL CONCRETE AND THE MEAN STRENGTH OF CONCRETE

The relationship between the slump of granite/local pit gravel Concrete and its mean Strength is as presented in Fig 3.3 below.

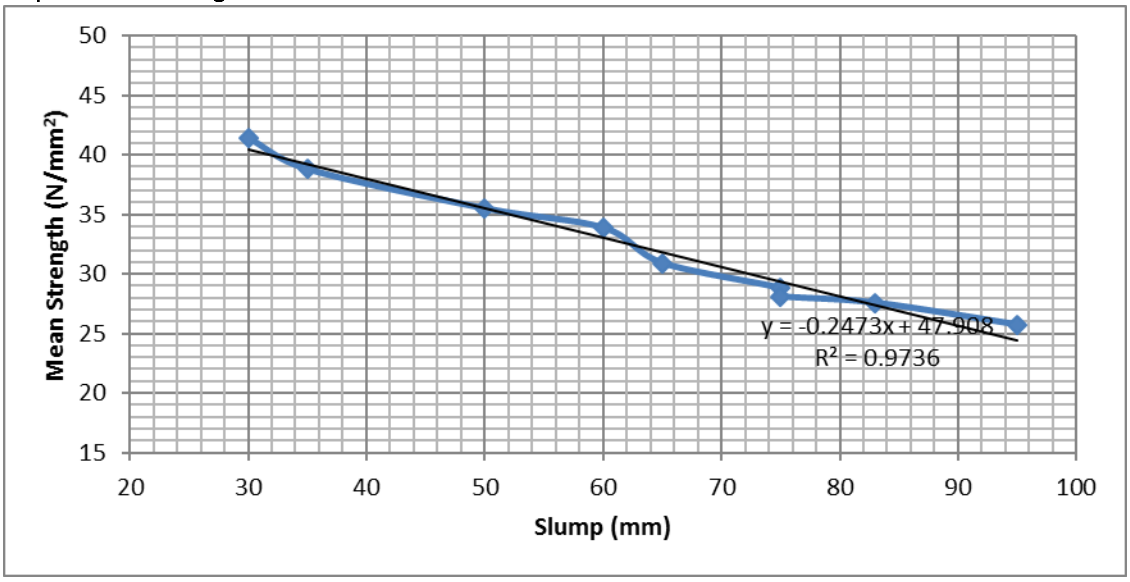
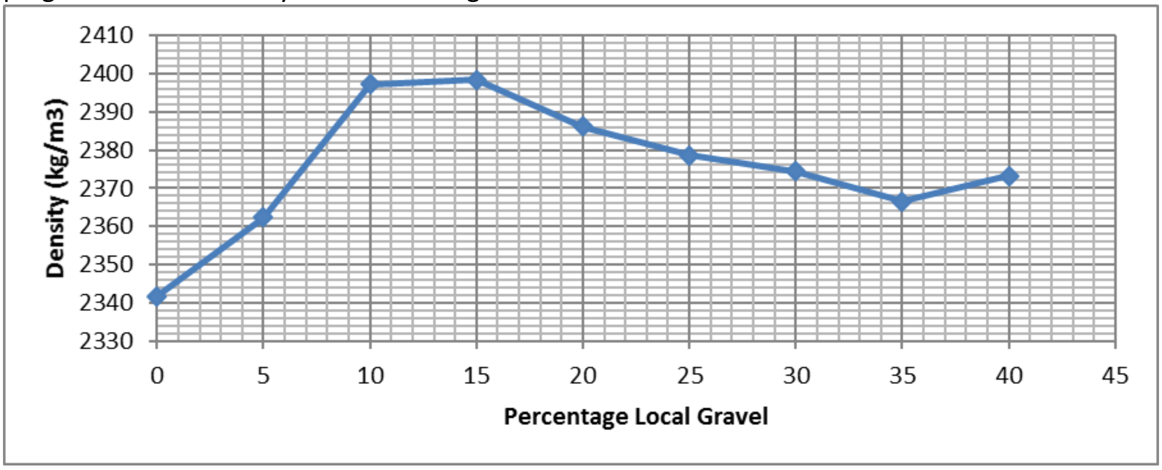


Fig 3.3: the relationship between slump and mean strength of concrete

It can be observed from the graph that as the slump of the concrete increases, its Strength decreases. This is agreement with the fact that increase in water content of a mix leads to a decrease in strength due to the possibility of bleeding of concrete. This bleeding takes away some important cement ingredient which will weaken the resulting concrete.

3.1.2.3 EFFECT OF SUBSTITUTION LEVEL OF GRANITE WITH LOCAL PIT GRAVEL ON CONCRETE DENSITY

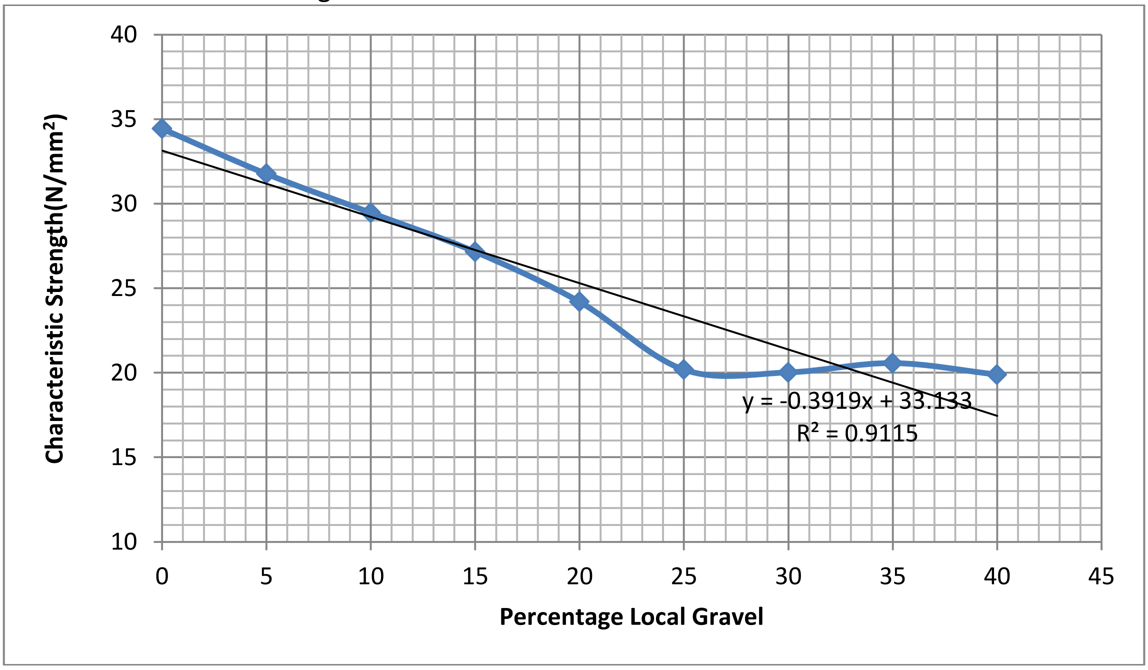
Fig.3.4 below illustrates the effect of substitution level of substitution level of granite with local pit gravel on the density of the resulting concrete.



The density of the concrete increases as the percentage replacement of granite with Local pit gravel increases up to a peak level of 15 % replacement after which it declines with further increase in percentage replacement.

3.1.2.5 EFFECT OF SUBSTITUTION LEVEL OF GRANITE WITH LOCAL PIT GRAVEL ON THE CHARACTERISTIC STRENGTH OF CONCRETE

The effect of substitution level of granite with local pit gravel on characteristic Strength of concrete is illustrated in Fig.3.5



The graph indicated that the characteristic strength of the concrete tiles decreases progressively with increase in the substitution level.

4.0 CONCLUSION AND RECOMMENDATION

Production of interlocking concrete tiles mix with partial replacement of granite using local pit gravel is not just feasible but also competes favorably with those made from only granite in some engineering properties of concrete like compressive strength and density. However, as the percentage of Pit Gravel increases, workability increases at the same water/cement ratio.
Interlocking concrete tile producers are therefore encouraged to substitute granites with local pit gravel up to 40% level since the compressive strength of the concrete produced at this substitution level is still within the acceptable limit of structural concrete.
In situations where workability of concrete poses a major challenge, the use of Pit gravel as a partial replacement of granite should be encouraged, since an increase in the percentage of local pit gravel leads to an increase in workability.

REFERENCES

Aïtcin, P.C. (2003), The Durability of High-Performance Concrete: A review, Cement and Concrete Composite, Vol. 25, No. 4-5, pp. 417-424.
Aïtcin, P.C. (2003), The Durability of High-Performance Concrete: A review, Cement and Concrete Composite, Vol. 25, No. 4-5, pp. 417-424.
Baalbaki, W., Aitcin, P. C. andBallivy, G. (1992), Predicting modulus of elasticity in high-strength concrete: ACI Materials Journal, 89(5), 517-520.
Babu K.K., Radhakrishnan R. and Nambiar E.K.K. (1997), Compressive Strength of Brick Masonry with Alternative - Aggregate Mortar: CE and CR Journal, New Delhi. pp. 25-29
Ben-Bassat, et al, (1990)
British Standard Institute, Composition specification and Conformity criteria for common Cement: BSI London, BS EN 197-1: 2000.
British Standard Institute, Concrete- Specification, Performance, Production and Conformity: BSI London, BS EN 206-1: 2000
British Standard Institute, Specification Aggregates from Natural Sources for Concrete: BSI London, BS 882: 1992.
British Standard Institute, Testing Aggregate, Method of Determination of Density: BSI London, BS 812: Part 2: 1995
British Standard Institute, Testing Aggregate, Method of Determination of Particle Size Distribution: BSI London, BS 812: Part 103, 1985, 1983.
British Standard Institute, Testing Concrete Method for Determining the Density of hardened Concrete: BSI London, BS 1881: Part 116.
British Standard Institute, Testing of Hardened Concrete, Compressive Strength of Test Specimen: BSI London, BS En 12390-3: 2000.
British Standard Institute, Testing of Hardened Concrete, Shape, Dimension and other requirements for Specimens and Moulds: BSI London, BS EN 12390-1: 2000.
British Standard Institute, the Code of Practice for Structural Use of Masonry, BS 5628: Part 1, 1978.
Celik T. and Marar K. (1996), Effects of crushed stone dust on some properties of concrete: Cement Concrete Res., Vol.26 No. 7 pp. 1121-1130.
Cramer H. (1946), mathematical method of statistics: Princeton University Press, Princeton .N. J.
Danso A. K. (2005), Engineering Properties of Ghanaian Sandcrete Blocks: Un-published Thesis for the Award of PH.D in Civil Engineering, Kwame Nkrumah University of Sciencee and Technology, Ghana.

Dehwah H.A.F. (2012), Mechanical properties of self-compacting concrete incorporating quarry dust powder, silica fume or fly ash: Construction and Building Materials, Vol. 26, No 1, pp 547-551.
Devi M andKannan K. (2011), Strength and corrosion resistive properties of concrete containing quarry dust as fine aggregate with GGBFS: Advanced Materials Research, Vol. 243-249, pp 5775-5778.
Drapper N.R and Smith H. (1996), Applied Regression Analysis: John Wiley and Sons, New York.
Drapper N.R and Smith H.(1996), Applied Regression Analysis: John Wiley and Sons, New York.
Elayesh S. M. 2009. Performance of laterite Aggregate Concrete: Un-published M. Eng. Thesis. University Technology, Malaysia.
Fedorov V. V. (1972), Theory of Optimal Experiment: Academic Press New York.
FelekogluBurak(2007), Utilisation of high volumes of limestone quarry wastes in concrete industry (self-compacting concrete case): Resources, Conservation and Recycling, Vol. 51, No. 4, pp 770-791.
Galetakis .M, Alevizos .G and LeventakisK. (2012), Evaluation of fine limestone quarry by-products, for the production of building elements - An experimental approach: Construction and Building Materials, Vol. 26, No. 1, pp 122-130.
Gambhir M.L. (1995), Concrete Technology-Second Edition: Tata McGraw-Hill Publishing
Haque, M.N. (1980), Some Effect of Silt Contents on the Strength of All-in-Aggregate Content: Cement and Concrete Research, vol. 10, part 1, pp13-22.
Hicks C. R. (1964), Fundermental Concepts in the Design of Experiment: Holt, Rinahart and Winston, New York.
Higgins D. (2007), GGBS and Sustainability: Proceed. ICE, Construction Mater, Vol. 160 No. 3 pp 99-101.
Hudson B.P. (1997), manufactured sand for Concrete: The Indian Concrete Journal. pp. 237-240.
Ilangovan R. and Nagamani K. (2006), Application of quarry Rock dust as fine aggregate in concrete construction: National Journal on construction Management: NICMR. Pune. December. pp. 5-13.
Ilangovan R. and Nagamani K. (2006), Studies on Strength and Behavior of Concrete by using Quarry Dust as Fine Aggregate. CE and CR Journal, New Delhi. October, pp. 40-42.
Jackson N. and Dhir R.K (1978), Civil Engineering Material First Edition: Macmillan Press LMT, London.
Lohani et al (2012), Optimum Utilization of Quarry Dust as Partial Replacement of Sand in Concrete: journal of Applied Engineering Research, vol. 1, No. 2.
Mbajiorgu M. S. W. (2002), Philosophy and practice of Structural Concrete Design – A review of Construction Practices in South Eastern Nigeria. Proceedings of the Fifth International Conference in Structural Engineering Analysis and Modeling (SEAM 5), Accra, Ghana, Vol. 1, 101-116.
Nagaraj T.S. (2000), Proportioning Concrete Mix with Rock Dust as Fine Aggregate: CE and CR Journal. pp. 27-31.
Nagaraj T.S. and Zahida Banu (1996), Efficient Utilization of rock dust and pebbles as Aggregates in Portland Cement Concrete: The Indian Concrete Journal. pp. 53-56.
Nalimov V. (1960), the Use Mathematical Statistic in Material Analysis: Physmat-giz Publishers.
Narasimhan C., Patil B.T. and Sankar H. S. (1999), Performance of Concrete with Quarry Dust as Fine Aggregate-An Experimental Study. CE and CR Journal. pp. 19-24.
Nataraja M.C., Nagaraj T.S. and Reddy A. (2001), Proportioning Concrete Mix with Quarry Wastes Cement: Concrete and Aggregate Journal, ASTMVol. 23 No. 2, pp 81-87.
Neville A.M. (1987), Properties of Concrete: ELBS Edition of Fourth Edition, Addison Wesley Longman Limited, Edinburgh Harlow Essex CM20 2JE, England.
Nisnevich M. Sirotin G. and Eshel Y. (2003), Light weight concrete containing thermal power station and stone quarry waste: Magazine of Concrete Research. pp. 313-320.
Nisnevich, et al, (2003)

Okere C. E. (2012), Structural Characteristics of Soilcrete Blocks: Un-published Thesis for the Award of PH.D in Structural Engineering, Federal University of Technology, Owerri Nigeria.
Omane Achamfuor, (2002), Comparative Study of the Compressive Strength and Cost of Sandcrete Blocks Manufactured in Various Part of Ghana: Bsc Thesis, Kwame Nkrumah University of Science and Technology, Kumasi Ghana, p65.
Orie O. U. (2008), Five Component Concrete Mix Optimization Using Scheffe's Theory – A Case Study of Mould Soil as Mix Proportion: Un-published Ph.D Thesis, Civil Engineering Department, University of Benin, Nigeria.
Osunade, J.A. (2002), Effect of Replacement of Laterite Soils with Granite Fines on the Compressive and Tensile Strengths of Laterized Concrete: Building and Environment, Vol. 37, No. 5, pp.491-496.

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