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Establishing Threshold Level for Gravel Inclusion in Concrete Production

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Abstract
The paper investigated the threshold level for gravel inclusion in concrete production. Concrete was produced using granite/gravel combination in varying percentages of 90/10, 80/20, 70/30, 60/40, 50/50, 40/60, 30/70, 20/80 and 10/90. Concrete made from 100 % granite and 100 % gravel served as controls while other constituents of the concrete were kept constant. Two different mix ratios of 1:2:4 and 1:3:6 were employed. Sieve analysis was carried out on the aggregates while slump and compaction factor tests were carried out on fresh concrete. Compressive and splitting tensile strength tests were performed on hardened concrete. Specimens were produced using 150 mm cubes and 150 mm × 300 mm cylinders for compressive and tensile strength tests respectively. The size analysis results show that the coefficient of uniformity for sand, gravel and granite are 2.29, 2.95 and 4.07 respectively an indication that the fine and coarse aggregates were well graded. The slump and compactive factor increased with increasing gravel content. Compressive strength tests showed that 60/40 and 70/30 percentage of granite/gravel combination with values of 21.15 N/mm^2 and 15.17 N/mm^2 respectively for mix ratios 1:2:4 and 1:3:6 at 28 days was quite satisfactory. The minimum requirement of 20 N/mm^2 and 15 N/mm^2 for 1:2:4 and 1:3:6 mix ratio respectively as specified by BS 8110:Part 1 (1997), EN 1992-1-1 (2004) were satisfied . The splitting tensile strength of 70/30 percentage of granite/gravel combination for 1:2:4 and 1:3:6 mix ratios were 10.50 N/mm and 4.70 N/mm^2 respectively. The study concluded that the thresholds corresponding to 60 % and 70 % granite contents are suitable for 1:2:4 and 1:3:6 concrete mix proportions respectively.
Keywords: Threshold level, granite, gravel, compressive strength and splitting tensile strength.

1. Introduction
Construction materials are either naturally occurring or manufactured in factories. Example of materials in the first category are timber, sand, granite and gravel, while those in the latter category are steel, cement and roofing sheets. Some material are a combination of composite materials. An example of composite materials is concrete. Aggregates, which are prominent material in concrete, constitute 60-80 % of total concrete constituent (Neville 2000). Coarse aggregates consist of one or a combination of gravels or crushed stone with particles predominantly larger 5 mm and generally between 9.5 mm and 37.5 mm (Kasmatka *et al.,* 2003). The composition, shape and size of aggregates have significant impact on workability, durability, strength, weight and shrinkage of the concrete. Gravel is in abundance and easily accessible when compared to granite. Adebayo *et al.* (2001) investigated the effect of different aggregate types on the strength of concrete. Three types of aggregates namely granite, gravel and laterite were studied. It was reported that granite concrete gives the highest compressive strength followed by concrete made from gravel and lastly the one from laterite. Raheem and Aderonmu (2002) investigated the effect of aggregate sizes on the compressive strength of concrete. The study revealed that compressive strength increases with increase in sizes of coarse aggregates up to a maximum of 25 mm. Raheem and Abinbola (2006) investigated the effect of specimen size on the compressive strength of concrete and reported that the smaller the sizes of concrete test specimenthe higher the compressive strength. This study is therefore meant to establish a particular percentage of gravel that could be added to granite without compromising the compressive strength requirements for concrete production.

2. Materials and Method
Materials used for this study were gravel and granite as coarse aggregates; and natural river sand as fine aggregate. Elephant brand of Ordinary Portland cement was used . The gravel was obtained from Igbo- Ile, Oyo State. Crushed granite was obtained from RCC quarry at Ipeba, Oyo state. Fine aggregate and water were obtained from Ogbomoso. The Ordinary Portland cement used in this research work was produced by WAPCO, Sagamu. For the concrete mixes 1:2:4 and 1:3:6. A total of 322 concrete 150 mm cubes and 264 of 150 mm × 300 mm cylinders concrete specimens were produced and tested for compressive and tensile strength respectively in accordance with BS 1881: Part 116:1970 and BS 1881:Part117 :1983 using very-Denison Universal Testing Machine at structure Laboratory of Department of Civil Engineering, LAUTECH, Ogbomoso. Percentages of gravel in replacement for granite were 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 %. For each percentage replacement experimented three (3) concrete cubes were tested after curing for 3,7,14,21 and 28 days

and mean values represented the true compressive strength of the cubes were obtained.
Particle distribution analysis were carried out for coarse and fine aggregates in accordance with BS 812:1985 and BS 882:1992.The maximum sizes of aggregates adopted are 19 mm to 25 mm and 2.36 mm for coarse aggregates (granite and gravel) and fine aggregates (sharp sand) respectively
The slump test was conducted in accordance with BS 1881:Part 102: 1983,to measure the consistency of concrete. The effect of the different percentages of granite/gravel on the consistency of concrete was studied. The slump mould was greased and filled with fresh concrete in three layers with each layer being compacted with 25 blows by a 16 mm diameter steel rod. The mould was then lifted up slowly and the difference between the original and final height gave the slump value. This was repeated for all cubes with different percentages granite/gravel. The water binder ratios of the trial mixes were in the range of 0.6 – 0.7.

3. Results and Discussion

The slump test results given in Table 1 indicated that the workability increases with decrease in granite content at a constant water/cement ratio. This informed higher workability values for concrete mix 1:3:6 over 1:2:4.

Table 1. Slump values for various percentage replacements

%of Granite/Gravel	Average slump for 1:2:4 mix (mm)	Average slump for 1:3:6 mix (mm)
100/0	2.6	9.6
90/10	5.4	16.1
80/20	8.1	24.4
70/30	13.5	28.9
60/40	16.2	32.1
50/50	16.2	34.1
40/60	18.8	38.6
30/70	24.2	38.6
20/80	29.6	41.7
10/90	32.3	45.0
0/100	35.0	45.0

In addition, slump was greatly increased as the gravel content increased. This indicated that the concrete would become more workable as the gravel content increased. The high demand for water is due to the increase in gravel content.
The compressive strength of concrete cubes with 1:3:6 and 1:2:4 mix ratios are shown in Tables 2 and 3 respectively.

Table 2. Summary of compressive strength of concrete (mix ratio 1:3:6)

% proportion of Granite/Gravel	Compressive Strength (N/mm^2)				
	3 days	7 days	14 days	21 days	28 days
100/0	7.19	9.93	10.89	13.36	18.64
90/10	6.59	9.63	10.61	13.18	15.38
80/20	6.53	9.53	10.50	12.10	15.20
70/30	6.52	9.64	10.59	11.85	15.17
60/40	6.37	9.30	10.09	11.21	14.10
50/50	6.19	9.35	9.59	10.66	13.64
40/60	6.04	9.00	9.09	10.16	13.18
30/70	5.67	8.33	8.58	9.16	12.68
20/80	5.21	8.00	8.08	8.56	11.80
10/90	4.58	6.90	7.57	8.00	11.20
0/100	4.12	6.70	7.10	7.50	10.90

Table 3. Summary of compressive strength of concrete (mix ratio 1:2:4)

% proportion of Granite/Gravel	Compressive Strength (N/mm^2) 3 days	7 days	14 days	21 days	28 days
100/0	11.48	14.22	19.15	21.33	24.96
90/10	11.38	14.37	18.69	20.21	22.90
80/20	10.74	14.10	18.20	17.67	22.26
70/30	10.42	14.16	17.81	19.20	21.60
60/40	10.21`	14.04	17.40	18.80	21.15
50/50	8.92	13.73	17.00	18.40	19.95
40/60	8.65	11.96	16.67	18.00	19.54
30/70	8.19	11.67	16.20	17.60	19.22
20/80	7.53	11.08	15.90	17.20	18.85
10/90	6.76	10.34	15.20	16.44	18.10
0/100	5.90	8.92	13.96	15.04	17.63

The compressive strength decreases as percentage of gravel increases. The 60/40 percentages of granite /gravel combination gave a value of 21.15 N/mm^2 for mix ratio 1:2:4 and 70/30 with 15.17 N/mm^2 for 1:3:6 mix ratio at 28 days. The minimum requirement of 20 N/mm^2 and 15 N/mm^2 for 1:2:4 and 1:3:6 mix ratio respectively as specified by BS 8110: Part 1 (1997) and EN 1992-1-1 (2004) were satisfied.

Figures 1 and 2 showed the threshold lines for compressive strength of concrete with 1:3:6 and 1:2:4 mix proportions respectively. This threshold line demarcates the reliable granite content from the unsatisfactory ones. For 1:2:4 mix ratio, minimum of 60 %/40% granite/gravel combination and up to 100 % granite are reliable for concrete mix production. Other mix proportions which fall below the 20 N/mm^2 threshold line undoubtedly pass the test for 1:3:6 mix proportion as they are all of characteristic strength greater than 16 N/mm^2. From Figures 1 and 2, it could be observed that 1:2:4 concrete mix with 100 % gravel content with compressive strength of 10.9 N/mm^2 is still reliably suitable for 1:3:6 concrete mix proportion requirement. Furthermore, it could be observed from Figure 1 that 70 %/30 % granite and gravel combination is the minimum requirement for the fulfillment of 15.00 N/mm^2 characteristic strength. Gravel content greater than 30 % in a 1:3:6 proportion can be safely applied for light-weight concrete structure.

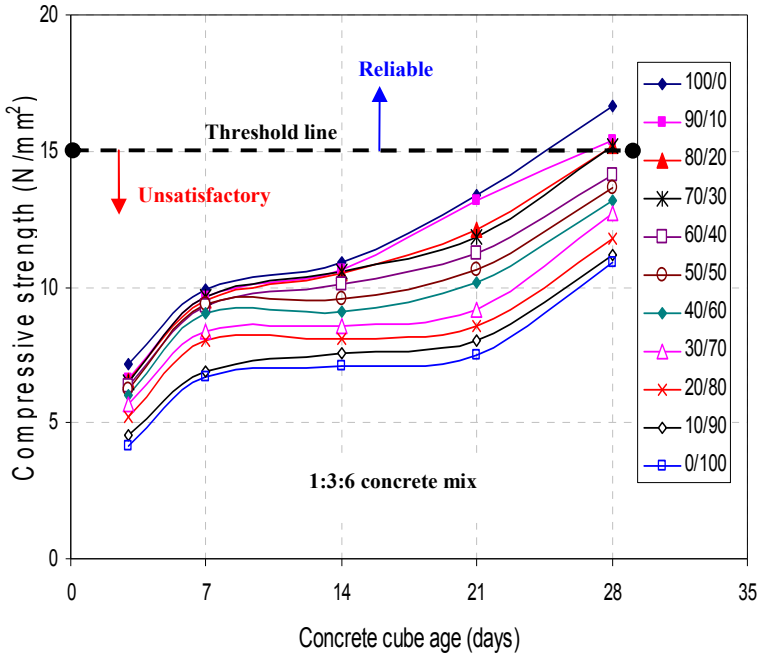

Figure 1: Behaviour of compressive strength of concrete cubes for different granite/gravel combinations (mix ratio 1:3:6).

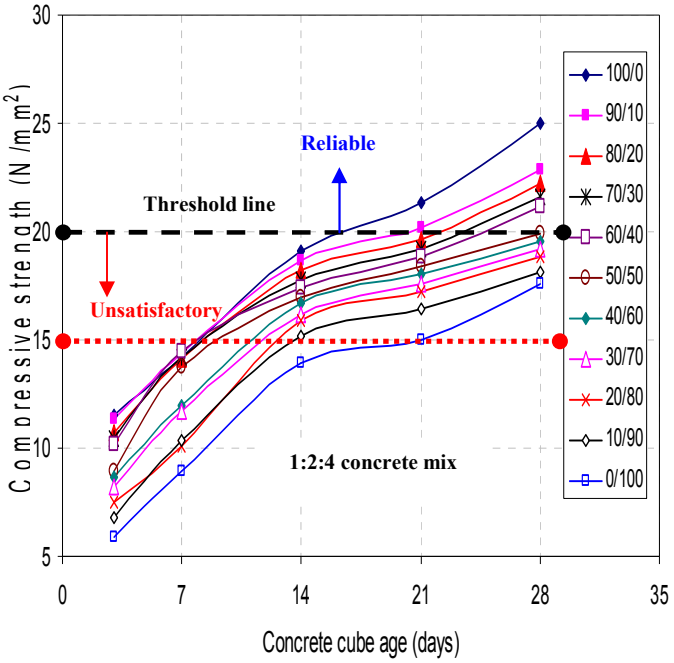

Figure 2:. Behaviour of compressive strength of concrete cubes for different granite/gravel combinations (mix ratio 1:2:4)

The summary results of the mean splitting tensile strength for concrete cylinders made with granite/gravel combinations are given in Tables 4 and 5 for 1:3:6 and 1:2:4 mix ratios respectively. The splitting tensile strengths of 70 %/30 % granite/gravel combination were 10.50 N/mm^2 and 4.70 N/mm^2 for 1:2:4 and 1:3:6 mix ratios respectively. These values are above the minimum 10 % of compressive strength recommended by available standards. It was also observed that gravel incorporation at various percentages decreases the splitting tensile strength with respect to control. In Table 4 it was observed that there was a significant reduction in tensile strength as gravel percentage increases beyond 40 % for 1:3:6 mix ratio. The results confirm that the higher the percentage of gravel the lower the tensile strength. Similar trends were observed for 1:2:4 mix ratio as indicated in Table 5, the tensile strength for 100 % granite at 28 days is 11.44 N/mm^{-2}

Table 4: Summary of splitting tensile strength test (mix ratio 1:3:6)

% proportion of Granite/Gravel	Splitting Tensile Strength (N/mm^2)			
	7 days	14 days	21 days	28 days
100/0	3.50	5.18	5.80	6.25
90/10	3.22	4.65	5.32	5.77
80/20	3.10	4.22	4.85	5.20
70/30	3.04	3.80	4.38	4.70
60/40	3.08	3.45	3.97	4.25
50/50	3.04	3.10	3.57	3.80
40/60	2.69	2.97	3.38	3.57
30/70	2.46	2.68	3.18	3.37
20/80	2.23	4.09	4.17	5.11
10/90	1.93	2.28	2.85	3.01
0/100	2.99	2.18	2.87	3.00

Table 5: Summary of Splitting Tensile Strength Test for mix ratio 1:2:4

% proportion of Granite/Gravel	Splitting Tensile Strength (N/mm^2)			
	7 days	14 days	21 days	28 days
100/0	8.05	8.90	9.94	11.44
90/10	7.73	8.69	9.59	10.98
80/20	7.60	8.41	9.27	10.62
70/30	7.52	8.26	9.13	10.50
60/40	7.23	8.12	9.01	10.36
50/50	6.86	7.88	8.54	9.90
40/60	6.60	7.67	8.01	9.26
30/70	5.34	7.60	7.84	8.73
20/80	5.04	7.15	7.40	8.38
10/90	4.30	6.92	7.00	8.01
0/100	6.00	6.19	6.39	7.98

Shetty (2001) recommended minimum tensile strength of 10 N/mm^{-2} for 1:2:4 mix proportion at 28 days and 4.4 N/mm^2 for 1:3:6 mix proportion at 28 days. Raheem and Abimbola (2006) produced 9.26 Nmm^{-2} at 28 days for 100 % granite for 1:2:4 mix proportion and 4.41 Nmm^{-2} at 28 days for 1:3:6 mix ratio and 100 % granite. The present study produced 11.44 Nmm^{-2} for 1:2:4 and 6.25 Nmm^{-2} for 1:3:6 mix proportion at 28 days with 100 % granite. From Table 4, 70 % / 30 % of granite/gravel combination are reliable for 1:3:6 mix proportion based on Shetty (2001) submission of 100 % granite which produced 4.4 Nmm^{-2} at 28 days while this study produced 4.7 Nmm^{-2} during the same period.

4. Conclusion

From the findings in this study the following conclusions were arrived at:

(i) The workability of concrete increases with increase in the percentage of gravel content
(ii) The density of concrete decrease with an increase in proportion of gravel.
(iii) The compressive strength of concrete produced from the combination of granite and gravel as coarse aggregates decreases as the proportion of gravel increases. The percentage of granite/gravel content that satisfied the minimum strength requirement at 28days for 1:2:4 and 1:3:6 mix proportions are 60/40 and 70/30 respectively.
(iv) For tensile strength, the reliable percentages of granite/gravel content satisfying the minimum strength requirements at 28days for 1:2:4 and 1:3:6 mix ratio are 60/40% for both mix.

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