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# Compressive strength of re-vibrated concrete made from pebbles

*Auta* Samuel Mahuta[1*] and *Peter* Emmanuel Aku[1]

[1] Department of Civil Engineering, School of Infrastructures, Process Engineering and Technology, Federal University of Technology, P. M. B., 65, Minna. Niger State. Nigeria.

**Abstract.** The search for natural and readily available structural material to meet the growing demand for ecologically friendly and smart structures is an ongoing development. In this background, an experimental study into the compressive strength of re-vibrated concrete made from pebbles as coarse aggregate is presented. Fifty-six (56) concrete cubes were cast adopting a re-vibration time lag interval of 10minutes for one hour, with a target strength of 15N/mm$^2$. This comprised 28 cubes 100% granite and 28 cubes 100% pebbles as coarse aggregates respectively. Two curing ages were considered: 7 and 28 days. Results from the compressive strength tests of the cured specimens showed that: at successive time lag intervals there was an appreciable rise in compressive strength of concrete; observable was also a rise in the compressive strength with an increase of curing age. However, even though the maximum compressive strength of 25.64N/mm$^2$ for 100%granite was achieved, that of 100%pebbles attained 23.33N/mm$^2$, both at 60th minute of re-vibration time lag respectively. Hence, it can be suggested that 100% pebbles replacement for granite can be used to produce concrete with compressive strength of up to 23N/mm$^2$ when revibrated.

## 1 Introduction

The demand for concrete materials is continually in demand to meet with the rise in infrastructural development both in developing and developed nations across the globe. Hence researches continue to rise to discover readily available, economically building materials including the constituents of concrete. One of these thoughts is a substitute for granite as coarse aggregate checking their effects from mechanical properties [1,2].

Aggregates used in concrete production are of two categories, fine (sand) and coarse (gravel or crushed stone) aggregate. The first consideration in the design of concrete structures is that they should be strong enough to support the loads that they will carry. Nevertheless, strength usually gives an overall picture of the quality of concrete because strength is directly related to the structure of the hardened cement paste [3]. Other factors that considerably influence properties of concrete include aggregates used in the concrete [1], their sizes and their texture [4, 5], whether angular or subangular, other factors include the type of cement used, the water-cement ratio used the method of mixing and curing, relative humidity, temperature, etc. These

* Corresponding author: samuel.auta@futminna.edu.ng

factors must be adequately controlled or regulated to ensure that the desired concrete properties are achieved [6,7].

One other form of improving the strength quality of concrete is by subjecting fresh concrete to re-vibration within the final setting time [8-10]. Repeated vibration of fresh concrete after initial vibration is termed as re-vibration. This quality factor is achieved through the re-vibration process when these aggregate particles rearrange themselves, thus eliminating the entrapped water and air from under the aggregates. Consequently, full contact between mortar and coarse aggregates, between the steel and mortar and thus producing stronger water and airtight concrete [11]. Other researches that have in the recent past made exploration on the effect of re-vibration on concrete strength characteristic include Hirotsugu *et al*. [12] and Khor [13], in which the authors investigated re-vibration and bleeding of early age hardening concrete respectfully.

Furthermore, a study was presented by Zidhan *et al*. [14] on how portable and well water affect the mechanical properties of normal concrete made from recycled coarse aggregate. Its effect on mortar was also presented. These properties included compressive, splitting, and flexural strength [14]. Several concrete mixes were prepared and cured. Results of compressive, splitting, and flexural strength tests conducted showed that lower values of the flexural and splitting tensile strengths were obtained when well water was used, but the values of these properties appreciated when recycled coarse aggregate was used. It was also observed that, to maintain same slump value, a minimum of 10% water was required for concrete made from recycled coarse aggregate than in the concrete made from natural coarse aggregate. It was concluded that higher strength can be gained in recycled concrete, when admixtures were used to increase workability with the same amount of water [14].

Hirotsugu *et al*. [12] reported that 15% compressive strength gain, can be achieved when fresh concrete was subjected to 1-2 hours re-vibration even though it depended on the workability of the concrete. It was further observed that improvement in the strength is more pronounced at earlier ages and is greater in concretes liable to high bleeding since the trapped water is expelled by re-vibration.


**Fig. 1.** Coarse aggregate: (a) Pebbles – *Bida gravels*; (b) Crushed granite; *Source*: Department of civil engineering laboratory, F.U.T., Minna.

Considering the importance of pebbles (river stones): it is naturally existing aggregate; locally called "*Bida gravel*" was collected from the river bed in the locality of Bida town, Niger State of Nigeria; its shape enhances the workability of concrete; and made up of naturally formed surface (Fig.1.a) from a river bed, as against crushed granite (Fig.1.b) which generates dust that poses pollution hazards to human existence when in production at quarry sites. Pebbles in form of natural stones have been used to produce concrete [14], but re-vibration was never considered. Therefore, in this study, the compressive strength of re-vibrated concrete using pebbles (river stone) as a full substitute for granite is considered alongside the effect of re-vibration on the compressive strength.

# 2 Method

## 2.1 Materials

The materials used in this study include Ordinary Portland cement (OPC), sand, crushed granites, pebbles (river stone), and water. The aggregates were within the specification of BS 882 [15].

### *2.1.1 Ordinary Portland Cement*

The Ordinary Portland Cement was procured from Kpakungu town in Minna metropolis. This OPC is of grade 43, conforming to BS 12 [16] specifications.

### *2.1.2 Fine aggregate*

The fine aggregate (sand) was sourced from gates, while sand was obtained from the *Rafin Yashi* area in Minna metropolis, Niger State, Nigeria. This fine aggregate was prepared for gradation before usage in this study.

### *2.1.3 Granite*

The coarse aggregate used in this study were of 20mm maximum sizes. They were procured from Kpakungu town in Minna metropolis, Niger State.

### *2.1.4 Pebbles*

Pebbles (river stone) locally called *Bida gravels* (Fig.1a), were collected from Bida town (outskate of Minna) in the Niger State of Nigeria. The pebbles were of 20mm maximum sizes.

### *2.1.5 Water*

Water was collected from a borehole sited near the laboratory of Civil Engineering Department in the engineering complex.

## 2.2 Methods

Methods adopted for carrying out different tests in the laboratory were within specifications of standard codes applicable to each material and phenomenon. These components are presented and discussed in their respective section of this study.

### *2.2.1 Concrete and re-vibration process*

For this study, the concrete mix was by absolute volume targeting a concrete of 15N/mm$^2$ using the size of steel mold 150mm x 150mm x 150mm to cast concrete cube specimen. A total of fifty-six (56) concrete cubes were cast as follows: adopting a re-vibration time lag interval of

10minutes for one hour, twenty-eight (28) cubes 100% granite, and 28 cubes 100% pebbles as coarse aggregates were cast respectively. Fourteen cubes (14) were cast for each curing ages considered as presented in table 13. These concrete cubes were cast within the specifications of BS 1881 part 108 [17].

The re-vibration process was conducted using an electric vibrating table which could only accommodate two concrete cube molds at a time. After initial vibration of 40 seconds, another vibration (re-vibration) of 20 seconds was applied to the set of two cubes at an interval of 10 minutes. This interval was maintained successively with 20 second re-vibration till 60 minutes re-vibration process was achieved. These concrete cube molds, were later demolded and there after taken to the curing tank.

#### 2.2.2 *Curing of concrete cubes*

Curing followed immediately after demolding of the concrete cubes. These cubes were specially placed in the curing tank to be cured for seven (7) days and twenty-eight (28) days respectively. This was conducted according to specifications contained in BS 1881 part 111 [18].

#### *2.2.3 Compressive strength test of hardened concrete*

All hardened concrete cubes of seven (7) and twenty-eight (28) days curing were then tested for compressive strength. This was conducted and achieved within specifications contained in BS 1881 part 116 [19].

## 3 Results and discussion

The results of laboratory tests carried out on the aggregates, among others, primarily include compressive strength of hardened concrete cubes at age seven (7) and twenty-eight (28) days respectively. These results are presented in tables 1-7 and figures 2-3, which are discussed in their respective sections.

### 3.1 Properties fine aggregate (sand)

From the results obtained (Fig. 2, Tables 1) properties of fine aggregates (sand) used are summarised presented in table 1. The fineness of the aggregate falls into the category of coarse sand with a fine modulus of 2.38.

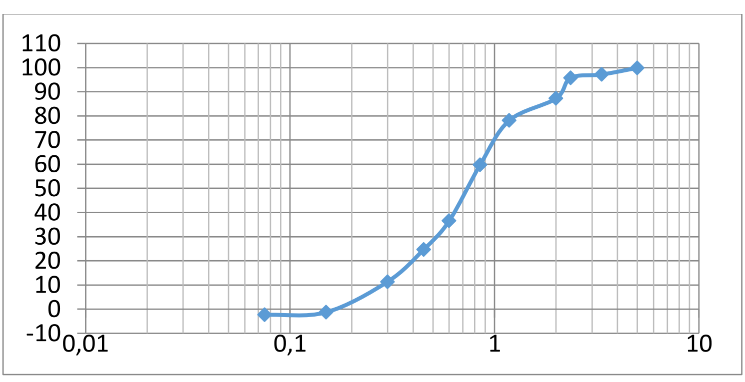


**Fig 2.** The particle size distribution of fine aggregate

**Table 1:** Physical Properties of Fine Aggregate

| No | Test | Results | Specification |
|---|---|---|---|
| 1 | Specific gravity | 2.6 | |
| 2 | Fineness modulus | 2.38 | 2.9-3.2 (For coarse sand) |
| 3 | Sieve analysis | | Conforming to grading according to BS 812 Part 103 [20] |

### 3.2 Particle size distribution of coarse aggregates

The results obtained from sieve analysis of coarse aggregates (granite and pebbles) are presented in figure 3, while their properties are presented in tables 2 and 3 respectively.

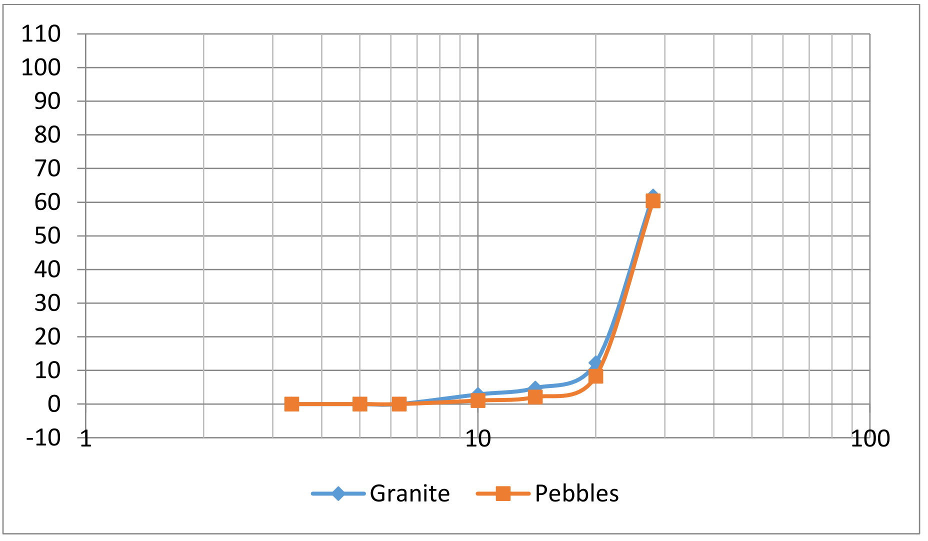


**Fig 3.** The particle size distribution of coarse aggregates, granite, and pebbles

**Table 2.** Physical Properties of Granite

| No | Test | Results | Specification |
|---|---|---|---|
| 1 | Specific gravity | 2.79 | 2.6-28 |
| 2 | Water absorption | 0.75 | 0.6% (maximum) |
| 3 | Impact value | 12.67 | 45% (Maximum) |
| 4 | Slump value | 60 | |
| 5 | Fineness modulus | 2.86 | |
| 6 | Sieve analysis | | Conforming to grading according to BS 812 Part 103 [20] |

**Table 3.** Physical properties of pebbles

| No | Test | Results | Specification |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 1 | Specific gravity | 2.60 | 2.6-2.8 |
| 2 | Water absorption | 1.62 | 0.6% (maximum) |
| 3 | Impact value | 18.45 | 45% (maximum) |
| 4 | Slump value | 20 | |
| 5 | Fineness modulus | 2.75 | |
| 6 | Sieve analysis | | Conforming to grading according to BS 882 [15] |

### 3.3. Water absorption

Results of water absorption indicate that pebbles absorbed more water than crushed granite aggregate which was 1.62% (Table 3) for pebbles and 0.75% (Table 2) for crushed granite as presented in tables 3 and 2 respectively. Nevertheless, the values are however not within the range specified for lightweight aggregates (5-20%) and but less than 2% for normal-weight aggregate as in BS 812 Part 109 [21].

### 3.4 Specific gravity

This test was carried out in compliance with specifications of BS 882 [15] and the results are presented in tables 2 and 3 for crushed granite and pebbles respectively. The specific gravity values of 2.79 and 2.6 obtained for crushed granite and pebbles (Table 2 & 3) respectively are nevertheless not within the range specified for lightweight aggregate, but normal weight aggregate, which must not be less than 2.6 for normal concrete.

### 3.5 Impact value

Aggregate impact value test that was carried out was done in compliance with BS 812 part 112 [23]. The result indicates that pebbles has higher impact value when put side by side with that of granite aggregate. This means that pebbles have low resistance to failure at impact, while granite has higher compressive strength.

### 3.6 Bulk density and void ratio of coarse aggregates

Bulk density and void ratio which were determined according specifications of BS 812 Part 2 [23], showed that granite aggregates have higher bulk density and lower void when compared with that of pebbles aggregate (Table 4). This is to say in bulk density and void ratio relationship, the higher the bulk density, the lower the void ratio and vice versa.

**Table 4.** Bulk density and void ratio of aggregate

| **Aggregate** | **Uncompacted Value ($Kg/m^3$)** | **Compacted value ($kg/m^3$)** | **Void ratio** |
|---|---|---|---|
| Fine aggregate | 1615.98 | 1719.08 | 0.53 |
| Coarse aggregate (granite) | 1580.89 | 1692.01 | 0.55 |
| Pebbles | 1557.50 | 1653.02 | 0.59 |

### 3.7 Compact factor of coarse aggregates

BS 1881 Part 103 [24] specifies that for any normal range of concrete, the compacting factor lies between 0.80 and 0.92. The results gotten are shown in table 5 and are within the range of specifications.

**Table 5.** Compaction factor test

| Item | Granite | Pebbles |
|---|---|---|
| Partly compacted (kg) | 12.38 | 10.60 |
| Fully compacted (kg) | 13.55 | 12.1 |
| Compaction factor | 0.92 | 0.86 |

### 3.8 Slump of fresh concrete

The results gotten from the workability test conducted according to BS 188 Part 102 [25], indicate that concrete made with pebbles has a lower slump value of 20mm than that from crushed granite aggregate of 60mm. This is a result of higher water absorption characteristics associated with pebbles than the crushed granite aggregates. This also indicates a higher degree of workability of pebbles as coarse aggregate to that of crushed granite, because of the smooth surface and round shape of pebbles.

### 3.9 Density of hardened concrete

After curing for seven (7) and twenty-eight (28) days, the average density of concrete made from pebbles as coarse aggregate was lower, when compared with the density concrete made with crushed granite. This is satisfied with the fact that lightweight concrete is concrete with a density lower than that of normal aggregate concrete according to BS 1881 Part 114 [26]. Again, the average densities for vibrated concrete show a higher value than that of re-vibrated concrete, which implies that re-vibration has reduced the density of concrete.

**Table 6.** The density of hardened concrete

| Item | Curing age | Densities of re-vibrated concrete (kg/m$^3$) Re-vibration time lag | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0th | 10th | 20th | 30th | 40th | 50th | 60th |
| 100% | 7 | 2490.37 | 2373.33 | 2360 | 2333.33 | 2240 | 2333.34 | 2208.89 |
| granite | 28 | 2536.30 | 2441.48 | 2404.44 | 2365.93 | 2315.56 | 2263.71 | 2244.45 |
| 100% | 7 | 2488.89 | 2410.37 | 2362.97 | 2363.96 | 2388.15 | 2333.35 | 2357.04 |
| pebble | 28 | 2560 | 2367.41 | 2315.56 | 2321.48 | 2259.29 | 2229.63 | 2222.23 |

### 3.10 Compressive strength of hardened concrete

The results of all tests conducted on the compressive strength of concrete produced from crushed granite and pebbles are presented in table 7. All values for 28 days aged concrete was higher than 7 days aged concrete and all revibrated concrete attained higher values than the vibrated (0th re-vibration) concrete for both coarse aggregates. However, the values obtained for granite concrete were relatively higher than the values obtained from pebble concrete in both 7days and 28days ages.

Re- vibration appears to have enhanced increase in compressive strength due to the reduction effect of re- vibration which helps to reduce entrapped air voids giving rise to a higher compressive strength of the concrete attesting and affirming the reports of Krishna *et al* [8], Auta *et al*., [9] and Auta [10].

**Table 7.** Compressive strength of hardened concrete

| Item | Age (days) | Compressive strength of re-vibrated concrete ($N/mm^2$) Re-vibration time-lag | | | | | | | Total cube cast |
|---|---|---|---|---|---|---|---|---|---|
| | | $0^{th}$ | $10^{th}$ | $20^{th}$ | $30^{th}$ | $40^{th}$ | $50^{th}$ | $60^{th}$ | |
| 100% | 7 | 15.78 | 17.47 | 17.64 | 19.02 | 21.07 | 21.38 | 20.44 | 14 |
| granite | 28 | 16.53 | 18.56 | 20.09 | 23.91 | 20.87 | 25.36 | 25.64 | 14 |
| 100% | 7 | 9.76 | 13.02 | 16.31 | 19.42 | 19.31 | 20.93 | 21.20 | 14 |
| pebbles | 28 | 16.49 | 20.49 | 17.64 | 21.02 | 20.64 | 23.60 | 23.33 | 14 |
| Total cube cast | | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 56 |

## 4 Conclusion

In conclusion, the compressive strength of re-vibrated concrete made from pebbles as a full substitute of granite used as coarse aggregate was investigated and presented.

Due to the bulk density of pebbles, with a higher void ratio of 0.59 and an impact value result of 18.45% indicate that pebbles is low resistant to crushing when compared with granites.

The average maximum compressive strength for both concrete, 25.64 $N/mm^2$ for 100% granite, and 23.33$N/mm^2$ for 100% pebbles were attained at $60^{th}$-minute re-vibration time-lag yet higher than the vibrated (non-revibrated) which is sited at $0^{th}$-minute re-vibration time-lag. Re-vibration is thus significantly and positively impactive on the density and compressive strength of the concrete made from granite and pebbles as 100% coarse aggregates respectively. There was also an appreciable increase in the compressive strength of concrete with every increasing age of curing.

Therefore, it can be suggested from this study that pebbles (*Bida gravels*) can fully (100%) substitute granite as coarse aggregate to produce structural concrete that requires strength of about 23$N/mm^2$, but the re-vibration process must be done to achieve the targeted compressive strength.

Further researches can be conducted by varying percentages of pebbles and also extending re-vibration time-lag beyond 1 hour.

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