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CIVIL & ENVIRONMENTAL ENGINEERING | RESEARCH ARTICLE

Study of aggregate dormancy and its effects on the properties of aggregates and concrete

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Abstract: In our society today most of the aggregates that were used for concrete work were usually abandoned on site for some times with minimum of 6 month or more due to different factors as it may apply. Some which might be due to lack of fund by the client and tussles. This abandonment led to a situation where construction materials are piled onsite over a range of periods of time. These materials are left dormant and exposed to harsh weathering conditions before utilization. This study accessed the effects of aggregates dormancy on its properties quality when use. The study was carried out in three calendar years (2015, 2016 and 2017) to check weathering activities on dormant aggregates. Experimental procedures such as Sieve analysis, silt content, specific gravity, water absorption and compressive strength test were carried out on these aggregates to determine its quality of performance on the product (building). Based on the duration of aggregate on site, it was observed that the strength of concrete produced from the aggregates increased and the aggregates were coarser when exposed to the weather. The study concluded that due to slight changes in compressive strength over the years, dormant aggregate has no negative effect on concrete strength and quality of structural components but it is advised that any procured aggregates meant for construction should be totally free from clay and silt contents. This will enhance the concrete strength and also accelerate its setting time.

Subjects: Construction Materials; Engineering & Technology, Physical Sciences; Materials Processing



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PUBLIC INTEREST STATEMENT

Aggregate is widely adopted and essential element of concrete production. Most times in the developing countries, aggregates were abandoned on site for some period of time due to shortage of fund and other factors. The study showed that the strength of concrete produced from the aggregates increased and aggregates were coarser when left dormant and exposed to harsh weathering condition before utilization. It further revealed that fine aggregate become coarser because the amount of the silt present in the fine aggregate reduced gradually due to the effect of weather on the aggregate material on site.

| **Keywords: aggregate; aggregate dormancy; building; concrete; compressive strength**

1. Introduction

According to the American English Dictionary (AED), dormancy is defined as a state of quietness or inactivity, hence, aggregate dormancy is defined in this study as a period of inactivity of aggregates before utilization in construction works. According to Braimah and Lawson (2014), housing is globally acknowledged as the second most basic essential need of man after food and is a major economic asset in every nation. Housing for residential purposes is the most and major need for the average citizenry. The provision of affordable and decent housing is a major challenge faced by most developing nations and the rural-urban migration has worsened the situation resulting in the widening the gap of housing deficit in a nation (Kabir & Bustani, 2009).

According to World Bank (2013), the housing deficit in Nigeria is estimated around sixteen (16) million housing units requiring over fifty six trillion naira (₦56 trillion) to fund and these estimates exclude the cost of land. This implies that about three million, five hundred thousand naira (₦3,500,000) is needed to provide an average housing unit. The Nigerian government has partnered with the private sector through various affordable housing schemes to combat the housing deficits in the nation but these schemes result in meeting just an insignificant fraction of the deficit and most of them result in the provision of housing beyond the reach of the ordinary citizenry (Braimah and Lawson 2014) and despite this problem, the housing deficit is still growing at an alarming rate. The World Bank (2013) concluded that about seventy-five percent (75%) of the Nigerian housing deficit is needed by families earning less than three times the minimum wage which is still within the poverty range. Ogunbayo, Ajao, Ogunbayo, and Amusan (2015) emphasised that high demands for collateral, unstable increase in interest rate, inaccessibility to fund, limited time for payback period of credit facilities and fear of long time commitment to the banks are some of the factors limiting low-income earners to finance building projects. Ogunbayo, Alagbe, Ajao, and Ogunbayo (2016) argued that some of the factors limiting availability of affordable housing in Nigeria are prices and rents of homes, which have grown ahead of general inflation rate of 12.8%.

In meeting these housing needs, most citizens are looking beyond the Government, private and other formal housing schemes that have not adequately addressed their housing deficit to the informal institutions like thrift, credit societies and money lenders, cooperative societies, voluntary housing movements, personal or family saving for gentle financial plans to provide a decent accommodation for themselves (Agbola, 1986; Omirin, 1998). The access to small funds per time by these informal institutions has given rise to incremental building development where a building is gradually built over a long period of time. Ogunbayo et al. (2018) maintained that good housing project needs a standard design, good planning, which would be constructed and managed based on standards and specifications established by governments, professionals and experts who have adequate knowledge of users' needs and expectations.

These practices resort to a situation where construction materials are stock-piled on site over a range of periods of time where these materials are left dormant and exposed to harsh weathering conditions before utilization. This led to material dormancy which could have deleterious effects on these materials that could compromise their service life in the building structure. For example, warped timber deteriorates in moist conditions, cement hardens and even expires over time, PVCs and other plastics become brittle and losses hardenability, rain and water run-offs tends to wash away finer particles in aggregate heaps and many others.

In any building production, some of the components that are important are aggregates and water (Bamigboye et al., 2017). Fowler and Quiroga (2003) opined that good aggregate is

characterized by shape, toughness, grain sizes, bleeding, pumpability, and segregation of fresh concrete, stiffness, shrinkage, creep, density, permeability and they determine the durability of hardened concrete. Olajumoke and Lasisi (2014); Ode and Eluozo (2016); Sulymon et al. (2017) maintained that the quality of concrete is affected by the choice of coarse aggregate used in its production. Hudson (1999); Aginam, Chidolue, and Nwakire (2013); Bamigboye et al., (2016) opined that aggregates account for about 60–75% of the total volume of concrete mix and 70–85% of weight with coarse aggregate contributing to about 45–55% of the total mass.

Consequently, Li (2011); Ede and Agbede (2015) concluded that concrete has a very good compressive strength but poor tensile strength. As there has not been a better alternative over the years, modern structures in developed and developing nations are mostly built in concrete. It is a composite material of aggregates (fine and coarse) embedded in a Portland cement matrix (Bamigboye et al., 2015). Concrete is a mixture of fine and coarse aggregates (sand and granite or gravel) and a controlled amount of entrained air, held together by a binding material such as Portland cement (Ede, Olofinnade, Bamigboye, Shittu, & Ugwu, 2017). The study further stressed concrete is commonly used worldwide because of the availability of its strength, economy related to availability and sustainability of its constituent materials. The availability of both fine and coarse material required for the production of concrete makes it an important method of production. In Nigeria, over ninety percent (90%) of building structural components that is responsible for the strength and stability of the building is made from reinforced concrete (Joshua et al., 2014). Ajao et al. (2018) maintained that compressive strength being the maximum stress sustained by concrete, is the maximum load registered on the testing machine divided by the cross sectional area of the concrete cube.

From the established background, there seemed to be several studies on engineering properties of aggregate, concrete production and usage. However, there exists dearth of study on aggregate dormancy and the effects on properties of fresh and hardened concrete. Dormancy is related to number of time aggregate are stock-piled before usage and the effects on shape, texture, and grading. This happened to be means of comparing aggregate characteristics to concrete behavior and effect of these characteristics on the performance of concrete. It is on this note the study aimed to investigate the effects of dormancy of fine aggregates (sharp sand) and coarse aggregates (granite) on its evolving physical properties over time and its effect(s) on concrete.

2. Materials and methods

2.1. Materials

Grade 42.5R of Ordinary Portland Cement (OPC) Dangote Cement brand was obtained at their cement depot in Ota, Ado-Odo, area of Ogun State which was in conformity to the physical properties of Type I Portland cement as stated in BS EN 1997-1 and also stated by Standard Organisation of Nigeria (SON, 2003).

Fine aggregate and coarse aggregate were obtained from site at Iju-Ota, Ogun State in compliance with BS EN 933-1, 1997. Clean water, free from impurities and good for consumption as specified in BS EN 1008 (17) was used for the mixing. The equipment used for the experimental process include: Sieves of different diameter, thermostatically oven, weighing balance, moisture content can and lid, compression testing machine and tools such as shovel, hand trowel, head pan, wheel barrow, bucket, e.t.c.

Coarse aggregate sample



Fine aggregate sample



Compression testing machine
Model YES-2000, Max.Capacity:
2000KN
Production No: W1010, Produc
tion Date: July 2010



2.2. Method

This is an experimental research carried out in the laboratory of Department of Building Technology, Covenant University, Ota. The materials used in this study were fine aggregate which is a burrow pit excavated sharp sand and quarry-sourced coarse aggregate that were made dormant and observed annually within the period of three-years (2015, 2016 and 2017). The cement used in this study was the 42.5N strength class, 19 mm coarse aggregate size and the fine aggregates being investigated. The laboratory tests performed were gradation size distribution (sieve analysis) of the coarse aggregate and the fine aggregate being investigated for silt content, specific gravity, water absorption and compressive strength test on concrete made with fine and coarse aggregate.

3. Result and discussion

The experimental results are discussed as follows:

3.1. Sieve analysis

The Coefficient of Uniformity (C_u) for 2015, 2016 and 2017 fine aggregates are 4.2, 4.1 and 10.5 respectively and the Coefficient of Curvature (C_c) are 1.42, 1.59 and 1.60 respectively. As observed in Figure 1, since C_u is greater than four (>4) and C_c lies between 1–3 the soil can be classified as a uniformly graded soil according to the unified soil classification system (USCS). The sand in the year 2017 is more uniformly graded than the 2015 and 2016 soil sample. This could be attributed to more rainfall within the years 2015 and 2016, as a result, finer particles were washed off the sand heap and hence, reducing the finer aggregate particles in the 2017 gradation as observed in Table 1 and Figure 1. However, for all the soil samples tested, it can be said to be well graded (Since $C_u > 4$), it must be noted that a well-graded soil can be more compacted than a poorly graded soil.

3.2. Analysis of the coarse aggregates base on year of testing

From Table 2 and Figure 2, coefficient of uniformity (C_u) and Coefficient of curvature (C_c) in accordance to BSEN933-1:2012, for all the coarse aggregate specimens are all the same and are 2.0 and 1.13, respectively, across all samples. The coarse aggregate is poorly graded but more of uniformly graded because the coefficient of curvature lies between 1 and 3. This confirms that the coarse aggregates possess little or no fine sized aggregate because rain or water run-off within the study years have negligible impact on the coarse aggregate over the study years. This study is similar to results obtained in Ajamu and Ige (2015); Nduka, Fagbenle, Joshua, Ogunde, and Omuh (2018).

3.3. Silt content

The silt content of the fine aggregate was determined with water and the testing sand was thoroughly mixed in a graduated cylinder and allowed to settle for about 12 h. The result is

Figure 1. Gradation analysis of the fine aggregates base on year of procurement.

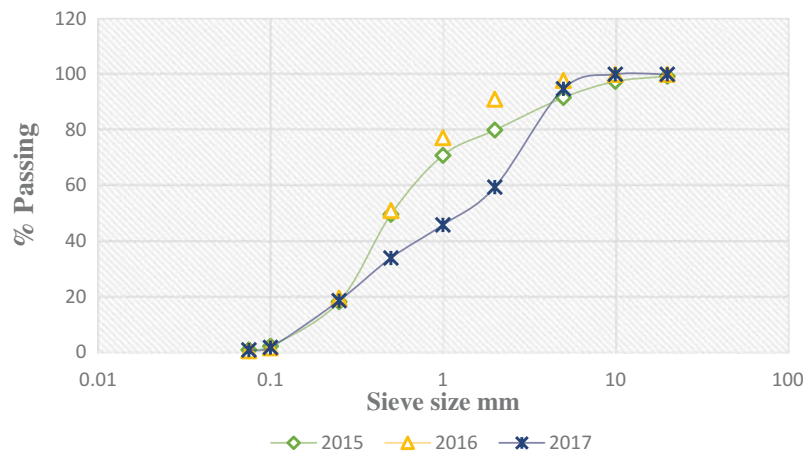


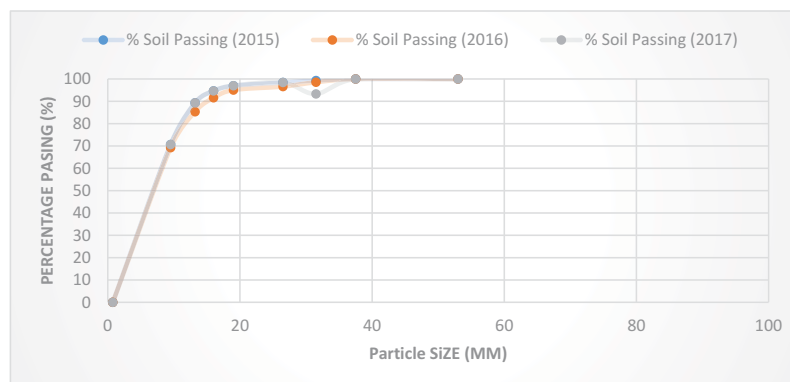
Table 1. Fine aggregate sieve analysis table

S/N	Sieve sizes(mm)	% soil passing through the sieve(2015)	% soil passing through the sieve(2016)	% soil passing through the sieve(2017)
1	20	99.3	100	100
2	10	97.4	99.92	100
3	5.0	91.6	97.75	94.75
4	2.0	79.9	91.00	59.375
5	1.0	70.8	77.17	45.75
6	0.5	49.6	50.92	33.875
7	0.25	18.1	19.42	18.5
8	0.1	2.1	1.5	1.625
9	0.075	0.8	0.42	0.75
10	Pan	0	0	0

Table 2. Coarse aggregate sieve analysis table

S/N	Sieve sizes(mm)	% soil passing through the sieve (2015)	% soil passing through the sieve (2016)	% soil passing through the sieves(2017)
1	53	100	100	100
2	37.50	100	100	100
3	31.50	99.33	98.56	99.33
4	26.50	98.44	96.62	98.44
5	19.00	97.00	95.06	97.00
6	16.00	94.67	91.56	94.67
7	13.20	89.34	85.34	89.34
8	9.50	70.67	69.23	70.67
9	Pan	0.00	0.01	0.00

Figure 2. Gradation analysis of the coarse aggregates base on year of procurement.



shown in Table 3. Though, the sieve analysis of the fine aggregate indicated negligible silt content, this test indicated the presence of silt. The silt content of the fine aggregate gradually reduced over the study periods. This was expected as the rains and water run-off would tend to wash away

Table 3. Analysis of silt content for the fine aggregate

Sample	2015			2016			2017		
	A	B	C	A	B	C	A	B	C
Soil quantity(ml)	100	100	100	100	100	100	100	100	100
Water quantity(ml)	200	200	200	200	200	200	200	200	200
Volume of aggregate retained(ml)	93	95	94	96	95	97	97	98	96
Volume of salt	1tea spoon	1tea spoon	1tea spoon	1tea spoon	1tea spoon	1tea spoon	1tea spoon	1tea spoon	1tea spoon
Volume of organic material present (ml)	1	1	1	1	1	1	1	1	1
Silt content (%)	6	4	5	3	4	2	2	1	3
Average silt content (%)		5			3			2	

or leach the finer particles over time. The most reduced silt content was observed between 2016 and 2017 period. This aggregate required less amount of paste to coat its surface and thereby left more paste for lubrication so that an interaction between aggregate particles during mixing is minimized (Mindess, Young, & Darwin, 2003).

3.4. Specific gravity

There was no significant difference in the specific gravity in both aggregates over the study period. They all maintained a specific gravity between 2.65 to 2.66 over the two (2) year period as shown in Tables 4 and 5. These values are within the ranges for the specific gravity of aggregates from rock fragments, the result is in line with the study of Abdullahi (2012), where specific gravity for fine aggregate is 2.66 and granite aggregate is 2.70, it further buttressed the result of (Neville, 1995; Olanipekun, Olusola, & Ata, 2006).

3.5. Water absorption

As shown in Tables 6 and 7, the change in water absorption was relatively insignificant over the study period in the coarse aggregate but it was observed that there was a significant change in the water absorption in the fine aggregate within the study period. The water absorption gradually decreased within the study years, this could be attributed to the gradual decrease in the in the silt content over the study period. Silt tends to retain more water than the higher aggregate-sized aggregates.

$$W_r = \frac{(W_w - W_D)}{W_D} \times 100\%$$

Table 4. Specific gravity of fine aggregate sampled

S/N	DESCRIPTION	Year 2015	Year 2016	Year 2017
A	Weight of vessel + aggregate + water, (A) (g)	1746.7	1746.2	1747.1
B	Weight of vessel + aggregate + water, (A) (g)	1433.7	1433.7	1433.7
C	Weight of vessel + aggregate + water, (A) (g)	500	500	500
D	Weight of vessel + aggregate + water, (A) (g)	495.6	496	496.1
E	Specific gravity = D/C-(A-B)	2.65	2.66	2.66

Table 5. specific gravity of coarse aggregate sampled

S/N	DESCRIPTION	Year 2015	Year 2016	Year 2017
A	Weight of vessel + aggregate + water, (A) (g)	3372	3370	3374
B	Weight of vessel + aggregate + water, (A) (g)	2754	2754	2754
C	Weight of vessel + aggregate + water, (A) (g)	990	983	990
D	Weight of vessel + aggregate + water, (A) (g)	982	975	982
E	Specific gravity = D/C-(A-B)	2.64	2.66	2.65

Table 6. Water absorption of coarse aggregate

S/N	DESCRIPTION	Year 2015	Year 2016	Year 2017
A	Weight of vessel + aggregate+ water, (A) (g)	3372	3370	3374
B	Weight of vessel + aggregate+ water, (A) (g)	2754	2754	2754
C	Weight of vessel + aggregate+ water, (A) (g)	990	983	990
D	Weight of vessel + aggregate+ water, (A) (g)	982	975	982
E	Specific gravity = D/C-(A-B)	2.64	2.66	2.65
F	Water absorption, percentage dry Weight $\frac{(W_w - W_D)}{W_D} \times 100\%$	0.82	0.82	0.82

Table 7. Water absorption of fine aggregate s

S/N	DESCRIPTION	Year 2015	Year 2016	Year 2017
A	Weight of vessel + aggregate + water, (A) (g)	1746.7	1746.2	1747.1
B	Weight of vessel + aggregate + water, (A) (g)	1433.7	1433.7	1433.7
C	Weight of vessel + aggregate + water, (A) (g)	500	500	500
D	Weight of vessel + aggregate + water, (A) (g)	495.6	496	496.1
E	Specific gravity = D/C-(A-B)	2.65	2.66	2.66
F	Water absorption, percentage dry Weight $\frac{(W_w - W_D)}{W_D} \times 100\%$	0.89	0.81	0.79

Where:

W_D is the weight of dry block.

W_w is the weight of the block after 24 h in water

W_r is the water absorption capacity

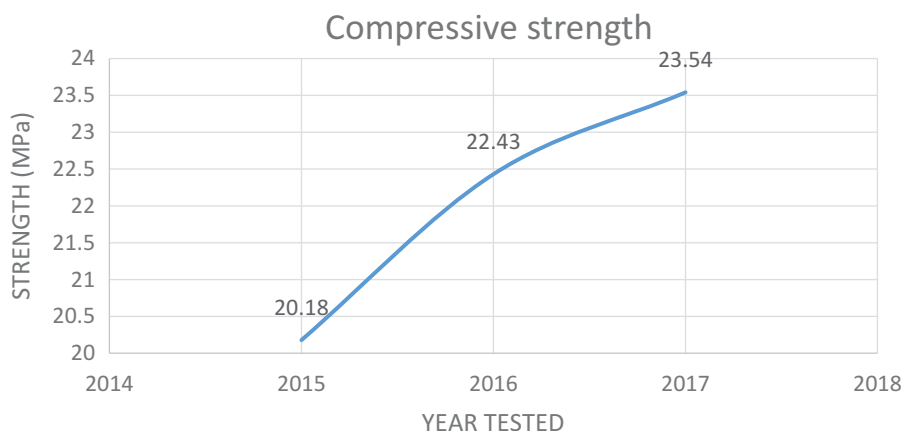
3.6. Compressive strength

A standardized prescribed concrete ST-4 to BS 8500-2:2002 was batched, mixed and cast into 150 mm cube mould and the compressive strength was determined in Table 8. The expected cube

Table 8. Compressive strength test on concrete using sampled material (fine and coarse aggregate) together with water and cement

S/n	Specimen	Specimen size(mm)	Year of Test	Age of concrete cube (days)	Crushing value Cube1(N/mm ²)	Crushing value Cube 2(N/mm ²)	Crushing value Cube 3 (N/mm ²)	Crushing value Mean (N/mm ²)
1	Concrete	150x150x150	2015	28	21.26	20.39	18.88	20.18
2	Concrete	150x150x150	2016	28	21.58	23.07	22.63	22.43
3	Concrete	150x150x150	2017	28	22.54	23.99	24.08	23.54

Figure 3. Compressive strength analysis of concrete.



strength is 20MPa (BS 8500–1:2002). The compressive values were as shown in Figure 3, the result showed that in the year 2015 the crushing value mean of the concrete cube was 20.18 N/mm², it increased to 22.43 N/mm² in the year 2016, while in the year 2017 it further increased to 23.54 N/mm². There was an increase in strength at growing curing age. The difference in strength growth could be partially due to the absence of silt, clay and humus materials which are constraints to improvement of mortar and concrete strength.

4. Conclusion

The study accessed the effect of aggregate dormancy and its physical properties on concrete quality. The study discovered that, dormancy of aggregate on site has no effect on its property quality during usage for building production. It further found that fine aggregate becomes more coarser because the amount of the silt present in the fine aggregate reduces gradually due to dormancy of the aggregate material on site which was caused through weathering effect especially rain water during the dormancy period. The study concluded that there is improvement in concrete strength and its workability while there is also reduction in clay and silt contents over the years.

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