Experimental Investigation of Coarse Aggregates Used for Concrete Production in the Construction of Higher Educational Institution (HEI) Buildings

B F Ogunbayo¹,² and C O Aigbavboa¹

¹SARChl in Sustainable Construction Management and Leadership in the Built Environment, University of Johannesburg, South Africa.
²Department of Building Technology, Covenant University, Ota Ogun state, Nigeria
Corresponding author: babatunde.ogunbayo@covenantuniversity.edu.ng

Abstract. In the construction industry, an aggregate is an important material used in the production of concrete. The strength of any building component, constructed using concrete will depend on the type and texture of aggregates used. It is on this base that this study analysed two different types of coarse aggregate (crushed granite and washed gravel) used in the production of concrete for higher educational institution (HEI) buildings. The following experimental procedures such as silt content, water absorption, specific gravity, sieve analysis, were conducted on the aggregates sampled to determine the property quality of the aggregates when used with other adhesive. Concrete of ratio 1:2:4 were produced using crushed granite and the washed gravel sampled and its strength was tested with the compressive strength testing machine. The 28 days average compressive test of concrete produced with crushed granite and washed gravel are 23.36 N/mm² and 20.44N/mm² respectively. The study suggests that locally sourced gravel should be washed before use to reduce silt content and impurities in the coarse aggregate. The study concludes that based on the compressive strength result of the study both crushed granite and washed gravel can be used for concrete work in construction work or project, but their selection for usage should be based on expected imposed load.

Keywords: Coarse aggregate; Crushed granite; Washed gravel; Compressive strength test.

1. Introduction
Concrete is a major material used for construction work in Nigeria, over a considerable percentage of high rise building in its construction industry are constructed using reinforced concrete [1]. This is because there are have not been a better option in the development of modern structures both in the developed and the developing countries [2]. This is because of sustainability of its material constituent, strength availability, and economy related to its availability [3]. Concrete as one the component of construction is produced through homogenous mixing of aggregates (fine and coarse), cement and a symmetrical portion of water [4]. A concrete produced using this material should be of desired quality strength that should be able to withstand any stresses that it might be subjected [5]. Ogunbayo [6] in there study maintained that concrete required for building project should be produced based on specifications and standards. Recent studies of [7] and [8] shows that in concrete production aggregate type affects the quality of concrete produced. Bamigboye [9] and [5] opined that aggregates account for 45-55% of total mass of concrete mix. Alexander and Mindess [10] noted that aggregates have a good character in improving the workability of freshly mixed concrete. In Portland, cement concrete production coarse aggregates provide a major property role of thermal properties, strength, weight resistance to destructive environment, and volume stability. Aginam [5] opined that coarse aggregates are obtained artificially or naturally.
In concrete production coarse aggregates used are mainly from rock fractions with high strength characteristic. Gravels are formed from natural disintegration of parent rocks and eventual transportation
of the weathered products by erosion and wind and they could also be obtained through dredging from seabed, river, and lake [11]. They are of 2mm in diameter and are commonly round shape with its larger sizes called boulders, cobble, pebble, and gravel [12]. Crushed granite undergoes a mechanical of rock blasting before it can be used for concrete production unlike gravel which does not involve any process because it can be used at the source that is why granite economically is more expensive than washed or unwashed gravel [13] and [14]. The study of [5] shows that the structural performance of concrete and durability is grossly affected by shape, size, shape, and surface conditions of coarse aggregates and further states that the property of aggregates will improve as the strength of concrete increases. To achieve a better standard and quality in concrete production, strength test is usually performed for the purpose of quality measurement of the produced concrete [15]. The study of [16] shows that concrete produced with crushed granite showed highest compressive strength, while that of washed gravel was the lowest after 28 days. The result of [17] study shows that concrete containing crushed quartzite produced the highest compressive strength, followed by concrete produced with washed river gravel, while concrete with the least strength is the one produced using crushed granite. Jimoh [18] research test results showed that using crushed granite of 20mm for concrete production will improve the concrete strength by 34% as against using producing concrete with 28mm washed gravel. However, the differences in concrete strengths could be linked to factor such as: cleanliness and internal structure of the type of aggregate used in the process and production of concrete [5]. Therefore, it is on this parameter that this study investigates coarse aggregates (crushed granite and washed gravel) used for concrete production in an ongoing construction of higher educational Institution (HEI) building in order to compare strength perform of using either type of aggregates for concrete production.

2. Materials and Method

Fine and coarse aggregate (crushed granite and gravel) were obtained from ongoing construction site of Ogun State Polytechnic Ipokia Ogun state Nigeria, in accordance with [19]. Ordinary Portland cement (Elephant brand) of 42.5R grade, Type 1 of current supply, contamination free was obtained and used for this research work in accordance with [20]. Concrete mixing, curing, and strength test were in compliance with [21]. The concrete was mix using clean water, good for consumption devoid of impurities as stated in [22]. The research makes use of the following equipment, apparatus and tools: compressive strength testing machine, sieve shaker with different sieve sizes, digital oven, digital weighing balance, moisture content can with led, conical measuring cylinder, wheelbarrow, hand trowel, steel shovel e.t.c., In carrying out its experiment procedure. Concrete produced using both crushed granite and washed granite was cured for 28 days inside a curing tank and later dries in the open. The cubes were crushed using the compressive testing machine after weighing, in the Building Technology laboratory of Covenant University Technology, Ota in accordance with [23] and [24]. In order to have a good basis for the results of this stud, tests such as water absorptions, grain size distribution, silt content and Specific gravity were carried out on both aggregates which was in conformity with the stipulated standards as stated by [19]. The safety procedure for the research was in line with the finding of [25].

3. Result and discussion

3.1 Grain size Analysis of fine aggregate (river sand) obtained from HEI construction site.

Figure 1 table 1 delineate the grain size analysis of fine aggregate (river sand) carried out in accordance to [26]. The result shows that the coefficient of uniformity (Cu) is 4.3 and its coefficient of curvature (Cc) is 1.54. From this result, it can be deduced that the fine aggregate is well graded since Cu is greater than 4 and its Cc is within 1-3. The aggregate is, however, suitable for construction work. The result of the study is similar to [11] and [2].
Figure 1: Sieve analysis table for dormant fine aggregate

Table 1. Coefficient of uniformity and Coefficient of Curvature

| Fine aggregate sampled | Coefficient of Uniformity (Cu) | Coefficient of Curvature (Cc) |
|------------------------|-------------------------------|-------------------------------|
| River sand             | 4.3                           | 1.54                          |

3.2 Grains size Analysis of coarse aggregate (crushed granite and washed gravel) obtained from the HEI construction site

Figure 2 and table 2 delineate the grain size analysis of the coarse aggregate (crushed granite and washed gravel) carried out in accordance with [26]. The result shows that the coefficient of uniformity (Cu) for crushed granite and washed gravel are 2.05 and 3.52 while there coefficient of curvature (Cc) are 1.15 and 1.69 respectively. From the result it can be deduced that the crushed granite is poorly graded but more of uniformly graded, but it shows that washed gravel is well and uniformly graded, therefore both aggregates are suitable for construction work. The result of the study is similar to the result obtained from the study of [27].

Figure 2: Grain size analysis table for coarse aggregates sampled

Table 2. Coefficient of uniformity and Coefficient of Curvature

| Coarse aggregate sampled | Coefficient of Uniformity (Cu) | Coefficient of Curvature (Cc) |
|--------------------------|-------------------------------|-------------------------------|
| Crushed granite          | 2.05                          | 1.15                          |
| Washed Gravel            | 3.52                          | 1.69                          |
3.3 Analysis of Silt content for aggregates sampled (river sand, crushed granite, and washed gravel)

Result from Figure 3 shows that the average silt content gotten from the study for sampled aggregates are river sand (3.58%), crushed granite (3.07%) and washed gravel (3.71%). The silt content value of all the aggregates sampled base on the result are still within the expected silt percentage of an aggregate required for construction work. This study result is similar to the result of [28].

![Figure 3: Grain size analysis for aggregates sampled](image)

3.4 Analysis of specific gravity for aggregates sampled (river sand, crushed granite, and washed gravel)

Result from Figure 4, shows that the average specific gravity gotten from the study for sampled aggregates are river sand (2.65), crushed granite (2.72) and washed gravel (2.67). The values of the aggregates sampled are within range of aggregates from rock fragments. This result buttressed the result of [29] and [17].

![Figure 4: Analysis of specific Gravity for aggregates sampled](image)
3.5 Analysis of water absorption for aggregates sampled (river sand, crushed granite, and washed gravel)

Result from Figure 5, shows that the water absorption of aggregates sampled are river sand (1.99%), crushed granite (0.92) and washed gravel (1.54%). The result of the study is similar to [5] and [30].

![Figure 5: Analysis of water Absorption for aggregates sampled](image)

3.6 Compressive strength

The result from figure 6 shows that there are differences in the strength of concrete produced with two coarse aggregates sampled after curing for 28 days. The result showed the average compressive strength of concrete cast with crushed granite is 23.36N/mm² while that of washed gravel is 20.44N/mm². Therefore the concrete sample produces with crushed granite (23.36N/mm²) as the highest strength. The result of the study is similar to [2], [11] and [5].

![Figure 6: compressive analysis of concrete produced from sampled aggregates](image)

4.0 Conclusion
This study analyses the coarse aggregate (crushed granite and washed gravel) quality on the property of concrete produced and its strength in the construction of HEI buildings. The study shows that the coarse aggregates sampled were both uniformly graded and suitable for the construction work. It also shows that the average silt content for river sand (3.58%), crushed granite (3.07%), and washed gravel (3.71%) are still within the expected silt percentage of an aggregate required for construction work. The study also shows that the average specific gravity value for river sand (2.65) crushed granite (2.72) and washed granite (2.67) is within the range of aggregates from rock fragments suitable for construction work. The study further shows the water absorption percentage for river sand (1.99%), crushed granite (0.92%) and washed gravel (1.54%) this shows that aggregates sampled absorbed less water which is attributed to its silt percentage and uniformly graded of its grain size particle. From the study concrete samples produce from the coarse aggregates, showed average compressive strength after 28 day of curing between 20.44N/mm² (washed granite) and 23.36N/mm² (crushed granite) this is due to less silt content in the aggregates, the crushed granite is from rock fragment free of impurities while the gravel used is washed gravel containing fewer impurities with high specific gravity and well-graded grain size particle. Base on the finding of the study, it is suggested that locally sourced gravel should be washed before use to reduced silt content and impurities. The study therefore, concludes that both crushed granite and washed gravel can be used for concrete in construction work but their selection for usage should be based on expected imposed load, due to suitability of the aggregates as shown in the strength parameter of the study.

References
[1]. Joshua, O., Amusan, L. M., Olusola, K. O., Ogunde, A., Ede, A. N., & Tunji-Olayeni, P. F. (2017). Assessment of the utilization of different strength classes of cement in building constructions in Lagos, Nigeria. International Journal of Civil Engineering and Technology (IJCIET), 8(9), 1221-1233.
[2]. Ogunbayo, B. F., Ajao, A. M., Ogundipe, K. E., Joshua, O., Durotuye, T. O., & Bamigboye, G. O. (2018). Study of aggregate dormancy and its effects on the properties of aggregates and concrete. Cogent Engineering, 5(1), 1519944.
[3]. Ede, A. N., Olufinmode, O. M., Bamigboye, G., Shittu, K. K., & Ugwu, E. I. (2017). Prediction of fresh and hardened properties of normal concrete via choice of aggregate sizes, concrete mix-ratios and cement. International Journal of Civil Engineering and Technology, 8(10), 288-301.
[4]. Ajao A M , Ogunbayo B F, Ogundipe, K E, Bamigboye, G Ogunde A & Tunji-Olayeni P F 2018. Assessment of sandcrete blocks manufacturers ‘compliance to minimum standard requirements by standard organisation of Nigeria in Southwest, Nigeria. International Journal of Applied Engineering Research, 13(6), 4162-4172.
[5]. Aginam, C. H., Chidolue, C. A., & Nwakire, C. (2013). Investigating the effects of coarse aggregate types on the compressive strength of concrete. International Journal of Engineering Research and Applications, 3(4), 1140-1144.
[6]. Ogunbayo, B. F., Ajao, A. M., Alagbe, O. T., Ogundipe, K. E., Tunji-Olayeni, P. F., & Ogunde, A. (2018). Residents’ facilities satisfaction in housing project delivery by public private partnership (PPP) in Ogun state, Nigeria. International Journal of Civil Engineering and Technology (IJCIET), 9(1), 562-577.
[7]. Sulymon, N., Ofuyatan, O., Adeoye, O., Olawale, S., Busari, A., Bamigboye, G., & Jolayemi, J. (2017). Engineering properties of concrete made from gravels obtained in Southwestern Nigeria. Cogent Engineering, 4(1), 1295793.
[8]. Ode, T., & Eluoze, S. N. (2016). Compressive strength calibration of washed and unwashed locally occurring 3/8 gravel from various water cement ratio and curing age. International Journal of Engineering Research and General Science, 4(1), 462-483.
[9]. Bamigboye, G., Ede, A. N., & Umana, U. E. (2016). Assessment of strength characteristics of concrete made from locally sourced gravel aggregate from south-south Nigeria. British Journal of Applied Science & Technology, 12(5), 1-10.
[10]. Alexander, M., & Mindess, S. (2010). Classification of aggregates.
[11]. Nduka, D., Fagbenle, O. I., Joshua, O., Ogunde, A., & Omuh, I. O. (2018). Comparative analysis of concrete strength utilizing quarry-crushed and locally sourced coarse aggregates. *International Journal of Mechanical Engineering and Technology (IJMET)*, 9(1), 609-617.

[12]. Brady, S.C., Clauser, H.R. and Vaccnri J.A. (2002). Material handbook (15th Ed.).Mc Graw-Hill Handbooks, 30(3), pp. 14–20.

[13]. Bamigboye, G., Ede, A. N., Egwuatu, C., Jolayemi, J., Olowu, O. A., & Odewumi, T. (2015). Assessment of compressive strength of concrete produced from different brands of Portland cement. *Civil and Environmental Research*, 7(8), 31-38.

[14]. Ogunbayo, B. F., Alagbe, O. A., Ajao, A. M., & Ogundipe, K. E. (2016). Determining the individual significant contribution of public and private sector in housing delivery in Nigeria, 4(3), 16-26.

[15]. Ajao, A. M., Ogunbayo, B. F., Ogundipe, K. E., Joshua, O., & Olofinnade, O. M. (2018). Experimental datasets on properties of river sand as an aggregate in replacement of crushed rock for interlocking stones production. *Data in brief*, 20, 602-608.

[16]. Özturan, T., & Çeçen, C. (1997). Effect of coarse aggregate type on mechanical properties of concretes with different strengths. *Cement and Concrete Research*, 27(2), 165-170.

[17]. Abdullahi, M. (2012). Effect of aggregate type on compressive strength of concrete. *International Journal of Civil and structural engineering*, 2(3), 782.

[18]. Jimoh, A. A., & Awe, S. S. (2007). A study on the influence of aggregate size and type on the compressive strength of concrete. *Journal of Research Information in Civil Engineering*, 4(2), 157-168.

[19]. Standard B 1997 Tests for Geometrical Properties of Aggregates-Determination of Particle Size Distribution British Standard Institution, London, UK BS EN 933-1: 1999.

[20]. BS EN 197-1: (2011). Cement part 1: Composition, Specifications and Conformity Criteria for Common Cements. British Standard Institute, London.

[21]. British Standard Institution BSI, *Testing Hardened Concrete: Making and Curing Specimens for Strength Tests* BSEN 12390-2:2009 BSI London 2009.

[22]. BS EN 1008: 2002 (1980). Mixing Water for Concrete: Specification for Sampling, Testing and Assessing the Suitability of Water, including Water Recovered from Processes in the Concrete Industry as Mixing Water for Concrete. British Standard Institute, London.

[23]. British Standard Institution BSI, *Testing Hardened Concrete: Making and Curing Specimen for Strength Tests* BSEN 12390-2:2000 BSI London 2000.

[24]. British Standard Institution BSI, *Testing Hardened Concrete: Making and Curing Specimen for Strength Tests* BSEN 12390-2:2009 BSI London 2009.

[25]. Ogundipe, K. E., Ogunde, A., Olaniran, H. F., Ajao, A. M., Ogunbayo, B. F., & Ogundipe, J. A. (2018). Missing gaps in safety education and practices: academia perspectives. *International Journal of Civil Engineering and Technology (IJCIET)*, 9(1), 273-289.

[26]. BS EN 933-1 (2012). Test for Geometrical Properties of Aggregates. Determination of Particle Distribution. Sieving Method. British Standard Institute, London.

[27]. Ajamu, S. O., & Ige, J. A. (2015). Effect of coarse aggregates size on the compressive strength and the flexural strength of concrete beam. *International Journal of Engineering Research and Application*, 5(1), 67-75.

[28]. Ojerinde, A.M., Ajao, A. M., Ogunbayo, B F., Stevenson, V., Latif, E., *PLEA* (2018) Hong Kong.

[29]. Olanipekun, E. A., Olusola, K. O., & Ata, O. (2006). A comparative study of concrete properties using coconut shell and palm kernel shell as coarse aggregates. *Building and environment*, 41(3), 297-301.

[30]. Oritola, S., Saleh, A. L., & Sam, A. R. M. (2014). Comparison of different forms of gravel as aggregate in concrete. *Leonardo Electronic Journal of Practices and Technologies*, 6(2), 135-144.