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COMPARATIVE ANALYSIS OF CONCRETE STRENGTH UTILIZING QUARRY-CRUSHED AND LOCALLY SOURCED COARSE AGGREGATES

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ABSTRACT

The use of two types of course aggregates for different works is examined in this study. Typical strength concrete is being made from various aggregates and their impact on various characteristics to the subsequent concrete. Compressive strength is the most vital property of a concrete. In this paper, two forms of coarse aggregates, crushed stone(granite) and unwashed gravel were utilized. Sharp sand is the fine aggregate. Initial laboratory examination was carried out to establish the appropriateness of utilizing the aggregates for construction purpose. Particle size distribution (sieve analysis) and slump test were investigated. Mix ratio (1:2:4) was used for this work and mix structures were analyzed by absolute weight technique. A total of 32 cubes (150×150×150mm) were cast to permit the compressive strength to be observed at 7, 14, 21 and 28 days. Test results revealed that concrete produced from unwashed gravel has a better workability than crushed granite. Higher *compressive strength at all period was observed with concrete produced from granite aggregate. Compressive strength patterns were suggested as a result of age at curing.*

Key words: Coarse aggregate, compressive strength, concrete, gravel aggregate, Nigeria

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1. INTRODUCTION

Concrete is a very important material in the Nigerian construction industry as over 90% of her storey buildings are made from reinforced concrete (Joshua et al., 2013a). In the same vein, Tiwari, et al. (2016) posit that the annual global concrete consumption is estimated to be about 25 billion tonnes. Recent studies by Olajumoke and Lasisi (2014), Ode and Eluozo (2016), and Sulymon, et al. (2017) have demonstrated that the quality of concrete is affected by the choice of coarse aggregate used in its production. 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 (Bamigboye, et al. 2016a, Aginam, Chidolue and Nwakire, 2013). The significance of aggregate as noted by Alexander and Mindess (2010) include not only being a filler material but has important physiognomies in improving the workability of a fresh concrete. Additionally, the properties of hardened concrete such as volume stability, unit weight resistance to destructive environment, strength, thermal properties are major roles of coarse aggregate in Portland cement concrete production. Thus, the choice of aggregate in concrete production can significantly affect the performance of a concrete.

The high cost of building materials has led to a clamour for alternative materials. The challenge for the use of locally source materials for the construction of building is as a result of such clamour and has been linked to strategies to reduce the cost of buildings and construction. This could be achieved by the use of materials that are indigenous to the construction location, hence reducing haulage and importation cost of sourcing construction materials from other places. In Joshua *et al.* (2011), Joshua *et al*. (2013b) and Joshua *et al*. (2014), incorporating laterite into sandcrete block production reduced the unit cost of the blocks by about eleven percent (11%). Similarly, incorporating local industrial wastes such as Palm Kernel Nut Waste Ash (PKNWA) as a pozzolan, blended with various classes of cement also produced greener, more durable and more affordable cements (Olusola, et. al., 2012; Joshua, *et. al*. 2017a; and Joshua, *et. al*. 2017b). Other studies have also used construction management tools to optimize housing procurement cost (Amusan *et al.*, 2013; Amusan, *et al*. (2017) and Ogunde, *et al.* 2017). Indigenous materials and principles were also incorporated to achieve green building (Nduka and Sotunbo, 2014; Nduka and Ogunsanmi, 2015; and Nduka and Ogunsanmi, 2016).

In an effort to meet up with the increasing housing deficits, the demand for locally sourced aggregate (gravel) in concrete production continue to rise. The reasons for the choice of gravel as an alternative to quarry-crushed stones are not far-fetched. Sulymon, et al. (2017) attributed this reason to increase in population, personal earnings, state infrastructural needs and state wide economic growth. Furthermore, the high cost of quarry-crushed granite due to high energy consumption during rock blasting and local transportation is also a concern in the built environment. Tiwari, et al. (2016) assert that "about half of coarse aggregates used in Portland cement concrete in North America are gravels". Although studies of Ede, et al. (2016) have shown reservation on the use of gravel for concrete production. This concern is due to gravel composition of varied chemicals and strength inadequacy, local variation in size distribution, degree of sorting and composition of deleterious materials when compared to granite. However, the adoption of locally sourced coarse (gravel) is not prohibitive once their engineering properties are known.

Gravels are formed from natural weathering of parent rocks and eventual transportation of the weathered products by wind and erosion. They are obtained by dredging from pit, lake, river and seabed. Their classification is usually as those having an upper (D) sieve size larger than 4mm wherein the combination of d and D indicates whether the gravel is single sized or graded (BS EN 12620). Bigger sizes can be described as pebbles, cobbles or boulders. Gravels are commonly round in shape which give rise to lower quantity of cement paste to about 4-5 % in concrete production (Brady, Clauser and Vaccnri, 2002).

Empirical studies have been conducted on mechanical properties of concrete made from locally sourced gravel in Nigeria. Aginam, et al. (2013) investigate various coarse aggregate impacts on the compressive strength of concrete in South-East Nigeria. The experimental study revealed that unwashed gravel produced the least compressive strength of $16.9kN/m^2$ compared to $20.0kN/m^2$ of washed gravel. They deduced that there is a positive relationship between concrete strength and internal structure, surface nature and shape of aggregates. In the same vein, Olajumoke and Lasisi (2014) evaluated the strength of concrete made with dug-up gravel available in Ile-Ife area of South-west Nigeria. The study showed that there was significant increase in compressive strength when the gravel used was washed. In determining the compressive strength of washed and unwashed gravel at different mix ratio, Ode and Eluozo (2016), found out that impurities on gravel impacts on the compressive strength of concrete prepared with unwashed gravel. They inferred that there is a positive relationship between strength, stiffness and fracture energy of concrete and type of coarse aggregates.

Bamibgoye, et al. (2016b) undertook particle size distribution analysis, slump test and compressive strength on hardened concrete in exploiting economics of gravel as a substitute to granite in concrete production. They found out that higher composition of gravel significantly improves concretes' consistency property while greater proportions of granite do significantly enhance compressive strength. Also, Sulymon, et al. (2017) reported that sources of gravel greatly influence compressive, flexural and split-tensile strength of concrete. Hence, this paper will draw on the recent studies in investigating the strength properties of concrete produced from locally sourced unwashed gravel with maximum aggregate sizes of 5mm from Ota, Ogun State, Nigeria.

The study area, Ota, Ogun state, Nigeria is well known for its industrial center and population over flow from Lagos State and currently the most industrialized state in Nigeria (Edike and Ayeni 2017). The increasing population growth rate has influenced the rapid construction of buildings in all nooks and crannies of the state. It is a common practice within Ota environs to use unwashed gravel for construction purposes. Hence, it becomes imperative to investigate the integrity of this aggregate to ascertain its performance in the use of structural members. This paper aims at determining the effects of unwashed gravel on the compressive strength of concrete with a view to furthering the knowledge of aggregate choices for construction works. This study also seeks to encourage the use of this indigenous locally sourced gravel in construction works, to maintain the reduced concreting cost within the study area. This is intended to be achieved by researching into ways the gravel could be treated before use to eliminate the possible deleterious effects on concrete durability.

2. MATERIALS AND METHODS

The study adopts purposive sampling method. The aggregates (granites and unwashed gravels and sand) were purchased from an aggregates merchant in Ado-Ota, L.G.A of Ogun state. Aggregates are usually sold in trucks and bags (used cement bags). Two (2) bags of granite and unwashed gravel and four (4) bags of sand were purchased and transported to Building Technology laboratory of Bells University of Technology, Ota for analysis and testing.

Dangote ordinary Portland cement brand was sourced from a local distributor in Ota and of current supply, contamination free was used as the binder. The cement was marked 42.5N to CEM II/A-LL (BS EN 197-1: 2011). The specific gravity and unit weight of cement is 3.15 and 1440 kg/m^3 respectively.

Portable tap water fit for drinking was used in mixing and curing of the concrete as obtained from Building Technology Laboratory, Bells University of Technology Ota. Hence, the water is appropriate for concrete production (BS EN 1008: 2002). Weight batching of normal strength concrete 1:2:4 complying to a standardized prescribed concrete mix ST4 with an expected target strength of 20mPa (BS 8500-1:2002 and BS 8500-2: 2002) and S2 slump was attained with a water cement ratio of 0.6 or 60%. A total of 32 number of 150mm cubes were cast and observed for 7, 14, 21, and 28 curing days. The cubes were weighed and crushed using the Technotest KB 1500kN capacity crushing machine in the Building Technology laboratory of Bells University of Technology, Ota. Each compressive strength is the mean strength of the four (4) cubes. The green concrete was systematically tampered in the steel mould and identification codes were marked on the moulds for ease of recognition of the concretes made with similar coarse aggregate. The concrete cubes were demolded after 24hours and the ponding technique of curing was adopted. In each case, the cubes were submerged in the curing tank in the entire curing period. The thermal stresses that could lead to cracking was avoided by keeping the curing water at a laboratory temperature of about 28^{o}C ((James, et al. 2011).

3. RESULTS AND DESCRIPTION

Figure 1 and Table 1 depict the gradation of the course aggregates and coefficient of uniformity (C_u) and Coefficient of curvature(C_c) in accordance to BS EN 933-1:2012. The granite is poorly graded but more of uniformly graded because the coefficient of uniformity (C_u) is close to one and unwashed gravel is uniformly graded with coefficient of uniformity (C_u) and Coefficient of curvature(C_c) approximately four and two respectively. However, the aggregates are suitable for construction project works. This study is similar to results obtained in Ajamu and Ige (2015).

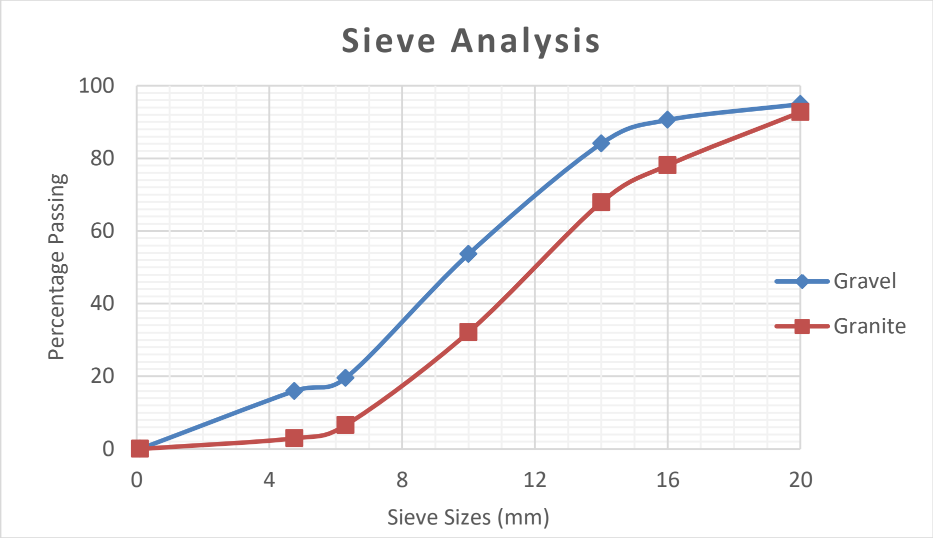

Figure 1 Particle Size Distribution curve for Granite and Unwashed gravel used in Study

Table 1 Coefficient of uniformity (C_u) and Coefficient of curvature(C_c)

Aggregates	Coefficient of uniformity (C_u)	Coefficient of curvature(C_c)
Gravel	3.60	1.74
Granite	1.44	0.70

3.1. Slump Test

The results of the slump test undertaken in Figure 2 revealed a true slump at 25mm value for quarry crushed granite while the locally sourced gravel at the same 60% w/c ratio is also a true slump at 5mm. This could be adduced to the fact that the gravel contains more fines than the granite hence the increased surface area that requires higher water demand to be more workable.

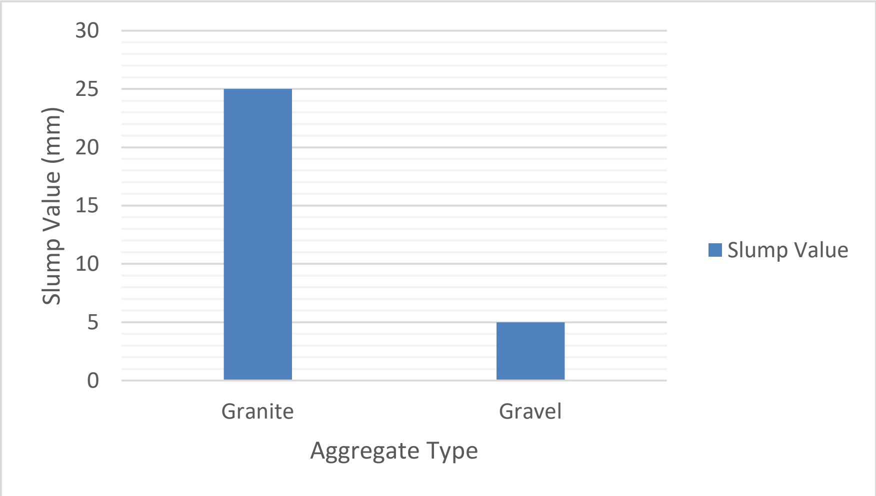

Figure 2 Slump Test Chart

3.2. Compressive Strength

Figures 3 depicts the results of cube crushing at 7, 14, 21, and 28 days respectively. The compressive strength of granite at the 7_{th} day surpassed those of the unwashed gravel with a considerable difference of 5.37 N/m^2 which is 79% variation in strength. The 14-day compressive strength of granite surpassed those of unwashed gravel with a major fringe of 5.08N/m^2 which is 36% variation in strength. At 21days, the compressive strength difference of 8.74 N/m^2 (84%) of granite to unwashed gravel was obtained. The 28-day compressive strength variation of 8.44 N/mm^2 which is 67% variation in strength was achieved. These results can be compared to work carried out by (Aginam, et al., 2013; Olajumoke and lasisi, 2014 and Ode and Oluozo, 2016). Their results indicate an average of 15.93N/mm^2 compressive strength for concrete made with unwashed gravel across southern regions in Nigeria.

There was increase in strength at growing curing ages and in all instances, the compressive strength of the unwashed gravel is the minimum. The difference in strength growth could be due to the presence of silt, clay and humus materials which are constraints to improvement of mortar and concrete strength (Joshua and Lawal, 2011; Olusola and Joshua, 2012; and Joshua et.al., 2014). The views of Bloem and Gaynor (1963) on the need for cleaner aggregates in concrete is further reinforced. Consequently, cleanliness is an essential feature in concrete strength advancement. The finer materials soak up the water that is accessible for the early hydration of cement and subsequently impede on the aggregate-cement bond. The impact of this could be more experienced at higher volume of fines. Based on the findings of this study unwashed gravel will not be specified for use in structural members while granite is suitable for any structural work.

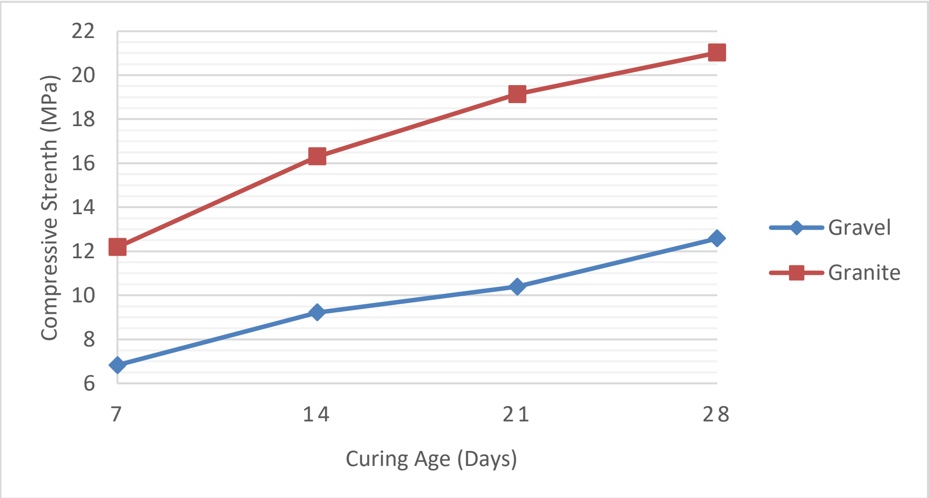

Figure 3 Concrete Compressive Strengths Using Granite And Gravel As Coarse Aggregate

4. CONCLUSIONS

The main goal of the current study was to study the effects of gravel on concrete property and to compare with convectional granite with a view to restricting its use to applications that can accommodate its ill properties. The following conclusions was drawn from this study:

- Gravels will require more water to be workable hence could be adduced for reduced compressive strength. However, unwashed gravel is not suitable for construction of structural members in multi-storey building.

- From the sieve analysis, decomposable materials and other dirts were observed in the gravel that could potentially affect the strength development of the concrete. Also, very fine particles were also observed which could be silt, clay and humus.
- It was observed that concrete prepared with crushed granite achieved better compressive strength than those made with unwashed gravels. This study validates the previous studies ((Aginam, et al., 2013; Olajumoke and Lasisi, 2014 and Ode and Oluozo, 2016).
- The findings in the current study may be of practical importance to stakeholders in the construction industry (i.e. contractors, clients, government, policy makers, and so on) that could adequately adjust their implementation and development plans based on the results of the study.

5. RECOMMENDATIONS

- Notwithstanding the limitations of differences in compressive strength due to variation in compaction, the study suggests that gravel obtained with impurities should be sieved and washed before use in concrete production.
- The utilization of granite is strongly advised in higher strength concrete applications like in high rise buildings where strength compromise cannot be accommodated. Even if gravel is to be used in high higher strength applications, it should be sieved and the coarse content washed before use.
- However, unwashed gravels can be used for concrete production in blinding and mass concrete works. Evaluation of the aggregates for strength capabilities is crucial to the sustainable growth of the construction industry and the economy in general.
- Further studies should investigate on how to improve the utilization of gravel for higher strength applications.

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REFERENCES

[1] Aginam, C.H., Chidolue, C. and 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), pp. 1140-1144.

[2] Ajamu, S.O.and Ige, J.A. (2015). Influence of coarse aggregate types and mixing method of concrete made from natural aggregate. *International Journal of Engineering and Technology,* 5(7), pp. 2049-3444.

[3] Alexander, M. and Mindess, S. (2013). *Aggregates in Concrete: Modern Concrete Technology (e-library).* Taylor & Francis group, London and New York.

[4] Amusan, L., Dosunmu, D., & Joshua, O. (2017). Cost and Time Performance Information of Building Projects in Developing Economy. *International Journal of Mechanical Engineering and Technology (IJMET), 8*(10), 918-927.

[5] Amusan, L., Joshua, O. and Oloke, C. O. (2013). Performance of Build-Operate-Transfer Projects: Risks' Cost Implications from Professionals and Concessionaires Perspective. *European International Journal of Science and Technology. 2(3), 239-250*

[6] Bamigboye, G.O., Ede, A.N., Raheem, A.A., Olafinnade, O.M., & Okorie, U. (2016b). Economics Exploitation of Gravel in Concrete Production. *Material Science Forum,* pp. 866, 73-77.

[7] Bamigboye, G.O., Ede, A.N., Umana, U.E., Odewumi, T.O. and Oluwu, O.A. (2016a). Assessment of Strength Characteristics of Concrete made from Locally Sourced Gravel from South-South Nigeria. *British Journal of Applied Science & Technology,* 12(5), pp. 1-10.

[8] Bloem, D.L. and Gaynor, R.D. (1963). Effects of Aggregate Grading on the Strength of Concrete. *Journal of American Concrete Institute*, 3(6), pp. 1429 – 1455.

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

[10] BS 12620 (2002). Aggregates for Concrete. British Standard Institute, London.

[11] BS 8500-1 and BS 8500-2 (2002). Method of Specifying and Guidance for the Specifier. British Standard Institute, London.

[12] 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.

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

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

[15] Ede, A.N., Adebayo, S.O., Bamigboye, G.O. and Ogundeji, J. (2015) Structural, Economic and Environmental study of Concrete and Timber as structural Members for Residential Buildings in Nigeria. *The International Journal of Engineering and Science (IJES*), 37(1), pp. 43-52.

[16] Edike, U.E., & Babatunde, A. (2017). Crime Management on Construction Site: A Study of Ogun State, Nigeria. *Covenant Journal of Research in the Built Environment (CJRBE)* 5, (1), pp.32-47

[17] James, T., Malachi, A., Gadzama, E.W., & Anametemfiok, V. (2011). Effects of Curing Methods on the Compressive Strength of Concrete. *Nigerian Journal of Technology, 3*(5), pp.14 – 20.

[18] Joshua, O., & Lawal, P. O. (2011). Cost Optimization of Sandcrete Blocks through Partial Replacement of Sand with Lateritic Soil. *Epistemics in Science, Engineering and Technology*, *1*(2), 89-94.

[19] Joshua, O., Amusan, L. M., Fagbenle, O. I., & Kukoyi, P. O. (2014). Effects of Partial Replacement of Sand with Lateritic Soil in Sandcrete Blocks. *Covenant Journal of Research in the Built Environment, 1(2), pp.91-102.*

[20] Joshua, O., Olusola, K. O., Ayegba, C., & Yusuf, A. I. (2013a). Assessment of the Quality Steel Reinforcement Bars Available in Nigerian Market. In *AEI 2013: Building Solutions for Architectural Engineering* pp. 296-305).

[21] Joshua, O., Olusola, K. O., Amusan, L. M., & Omuh, I. O. (2013b). Recycling fine sandcrete block waste (FSBW) as fine Aggregate in the production of sandcrete Block. *IJRRAS 15*, *15*, 359-364.

[22] Joshua, O., Olusola, K. O., Ogunde, A. O., Ede, A. N., Olofinnade, R. M., & Nduka, D. O. (2017a). Investigating for Pozzolanic Activity in Palm Kernel Nut Waste Ash (PKNWA) with Cement towards a Sustainable Construction. *International Journal of Applied Engineering Research*, *12*(23), 13959-13565.

[23] Joshua, O., Olusola, K. O., Ogunde, A., Amusan, L. M., Ede, A. N., & Tunji-Olayeni, P. F. (2017b). 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.

[24] Nduka, D. O. and Sotunbo, A. S. (2014). Stakeholders Perception on the Awareness of Green Building Rating Systems and Accruable Benefits in Construction Projects in Nigeria. *Journal of Sustainable Development in Africa. 16(7), 118-130*

[25] Nduka, D. O., & Ogunsanmi, O. E. (2015). Stakeholders perception of factors determining the adoptability of green building practices in construction projects in Nigeria. *Journal of Environment and Earth Science, 5(2), 188-196.*

[26] Nduka, D. O., & Ogunsanmi, O. E. (2016). Construction Professionals' Perception on Green Building Awareness and Accruable Benefits in Construction Projects in Nigeria. *Covenant Journal of Research in the Built Environment*, *3*(2).

[27] Ode, T., & Eluozo, 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), pp.462-483.

[28] Ogunde, A., Akuete, E., Joshua, O., Bamidele, E., Amusan, L. And Ogunde A. (2017). Project Management a Panacea to Improving the Performance of Construction Projects in Ogun State, Nigeria. *International Journal of Civil Engineering & Technology (IJCIET), 8(9), 1234-1242*

[29] Olajumoke, A.M., & Lasisi, F. (2014). Strength Evaluation of Concrete made with Dug-up Gravel from South-West Nigeria. *Journal of Failure Analysis and Prevention*, 14, pp.384-394.

[30] Olusola, K. O. and Joshua, O. (2012). Effect of Nitric Acid Concentration on the Compressive Strength of Laterized Concrete. *Civil and Environmental Research, 2(10), pp.48-58.*

[31] Sulymon, N., Ofuyatan, O., Adeoye, O., Olawale, S., Busari, A., Bamigboye, G., & Jolayemi, J. (2017). Engineering Properties of Concrete Made from Gravel obtained in South-West Nigeria. *Cogent Engineering,* 4: 1295793.

[32] Tiwari, A., Singh, S., & Naga, N. (2016). Feasibility Assessment of Partial Replacement of Fine Aggregate to Attain Clear Production Perspective in Concrete: A Review. *Journal of Cleaner Production,* 135, pp.490-507.

[33] B.V. Bahoria, D.K. Parbat and P.B. Nagarnaik, Characterization Study of Natural Sand, Quarry Dust, Waste Plastic (LDPE) to be used as a Fine Aggregate in Concrete . International Journal of Civil Engineering and Technology , 8(3), 2017, pp. 391 –401

[34] R. S. Deotale and Dr. A. M.Pande, Durability Studies On M30 Grade Concrete Containing Quarry Sand and Fly Ash. International Journal of Civil Engineering and Technology, 8(4), 2017, pp. 1695–1704.

[35] B.V. Bahoria, D.K. Parbat, P.B. Nagarnaik and U.P. Waghe, Effect of Characterization Properties On Compressive Strength of Concrete Containing Quarry Dust and Waste Plastic as Fine Aggregate. International Journal of Civil Engineering and Technology, 8(3), 2017, pp. 699–707.

[36] Sidharth Sen and K. Balakrishna Rao, Effect of Water Cement Ratio on the Workability and Strength of Low Strength Quarry Dust Concrete. International Journal of Civil Engineering and Technology, 8(10), 2017, pp. 144 8 – 1455

[37] Vetriselvan M and Senthamilkumar S, Study on High Performance Concrete Beam Under Cyclic Loading Conditions by Partial Replacement of Fly Ash and Quarry Dust. International Journal of Civil Engineering and Technology, 8(12), 2017, pp. 1098 - 1106

[38] Far hat Hussain and Amanullah Khan. Sustainability of using Crumb Rubber and Quarry Dust for Stabilization of Expansive Soils in Road Subgrade: A Review. International Journal of Civil Engineering and Technology, 8(12), 2017 , pp. 837 - 842