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COMPRESSIVE STRENGTH OF CONCRETE MADE WITH MASHED PERIWINKLE SHELL AS FINE AGGREGATE FOR DISASTER MITIGATION

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ABSTRACT

This study presents the suitability of mashed periwinkle shell (MPS) as fine aggregate on concrete compressive strength for disaster mitigation. The effect of mashed periwinkle shell (MPS) at 0%, 10%, 20%, 50% and 100% replacement as fine aggregate was investigated for its concrete compressive strength. Laboratory and non-linear regression mathematical model methods were adopted in this study. Preliminary tests like sieve analysis, specific gravity etc. were performed on the aggregate materials from which a mix ratio of 1:2:4 was obtained. A total of 60 concrete cubes of 150 mm x 150 mm x 150 mm sizes were cast, properly cured and checked for the 7, 14, 21, 28 days compressive strength. The results obtained showed optimum improvement on concrete compressive strength at 10% and 20% MPS replacement as fine aggregate for both the experimental and model methods. The 100% MPS replacement gave a poor strength gain showing that MPS full replacement as sand in concrete might cause failure of the structure. The mathematical model gave a better representation of the concrete strength and the accuracy of the model determined from results of the coefficient of determination gotten as; 0.980, 0.97, 0.986 and 0.989 respectively. Hence this study tends to mitigate against using sub-standard materials in construction and also solves environmental problems that might arise from dumping periwinkle shells.

Keywords: Aggregates, disaster mitigation, environment, mashed periwinkle shell, waste recycling

INTRODUCTION

Disaster mitigation helps to put things in place in order to protect people or properties from hazards because hazards when they occur can take a society backwards with many losses. Disaster mitigation involves development, improvement and application of practices that will minimize disaster in an environment socially and economically (Wahlstrom, 2015). A clean and disaster free environment is of paramount importance for human wellbeing which will in turn increase man's general creative output for a better society and things are allowed in their natural order. The case of Covid-19 as an example, that started at one corner of the world and then later spread globally should not be allowed to happen again. Covid-19 and its associated effects are still felt in the world today therefore, disasters are better prevented and mitigated against than to be controlled. Disaster prevention from waste product like periwinkle shells was studied to have an environment that is free and clean from hazards for man's wellbeing. In a similar manner, Chiwetalu et al., (2021) studied soil alkalinity control using three different bio-materials (wastes) for soil sustainability and productivity. Their study was geared towards disaster prevention and sustainability of the environment.

Nonetheless, the failure of any structure as a result of using sub-standard materials always questions the processes of engineering activities involved. These failures pose great risks and hazards to the environment especially loss of human lives, loss of material resources, time wasted and most times, the structure will be lying waste as it cannot fulfil its intended purpose. In Nigeria for example, cost of concrete materials has always been continually increasing and being a country still developing, more constructions are still going on despite the fact that majority of the population continues to fall below poverty line and cannot afford such price increase. Concrete being a construction material is widely used for various types of structures due to its durability (Neville and Brooks, 2010). The increasing cost of construction and the need to be rid of environmental pollution and make construction reasonable has required exploration into utilization of alternative materials or waste products (agricultural or industrial) to partially or fully replace the costly conventional materials thereby preventing depletion of materials, reducing construction cost, drive infrastructural development, enhance employment opportunities and make engineering construction sustainable (Ettu et al, 2013).Continuous generation of waste from man's activities, create acute environmental problems both in terms of their treatment and disposal (Yang et al, 2005). Recently, researchers are focused on waste that can completely or partially replace the conventional concrete materials (sand, gravel, cement) without compromising the quality of concrete produced. Aggregates, the primary component material in concrete production accounts for about 70% of its volume (Devi and Gnanavel, 2014). The aggregates consist of coarse and fine aggregate. Fine aggregate (sand) is an important component in the composition of concrete or mortar. Sand can fill in voids in concrete and contributes to concrete strength. The extensive use of mortar and concrete in construction has resulted into great demand for sand to keep up with infrastructural development in developing nations. However, increase in demand for sand in construction has led into scarcity and depleting of quality sand. Hence, recycling of waste is thought to be the most environmental friendly approach in dealing with problem of waste disposal (Ettu et al, 2013) and substitute or partial replacement in the case of periwinkle shell as coarse aggregate. Due to the fact that not every waste is suitable for mortar and concrete production, selection of locally available waste materials is based on the following considerations; strength, cost, compatibility and availability (Ede et al, 2014) for construction. Example of such waste is the periwinkle shell.

Periwinkles shells (PS) are waste products obtained from Periwinkles. Periwinkles are small greenish-blue marine snails with spiral conical shell and round aperture that are common in the riverine areas and coastal regions of Nigeria where they are used for food (Umo and Olusola, 2012). Mashed periwinkle shell (MPS) is a product gotten from grinding periwinkle shell. The hard shells, which are regarded as wastes ordinarily posed environmental nuisance in terms of its unpleasant odour and unsightly appearance in open-dump sites located at strategic places. The reasons favouring extensive usage of periwinkle shells as concrete materials are; the shells are hard, apart from being hard, they are generally light materials, readily available in sizeable quantity. Over the years, large quantities of periwinkle shells have accumulated in many parts of the country such as Bori, Western Ijaw, Burutu, Agoro, Ogalaga and Lotugbene in Nigeria (Dahunsi and Bamisaye, 2002). The use of periwinkle shell as concrete material might be good because of its hard nature, good bonding properties with cement and sand. They are readily available and less expensive than sand and gravel. Efforts are being made on their usefulness as aggregate materials in concrete as the construction industry has been identified as one of the areas where wastes can be absorbed, with the majority of such waste materials identified as fillers useful in concrete. The utilisation of periwinkle shell as alternative of coarse aggregate in concrete works (Soneye et al, 2016; Oyedepo, 2016; Dahiru et al, 2018), showed that the strength depends on the mix, water cement ratio, the type of aggregate replaced and can be suitable as concrete materials. Also, Adewuyi and Adegoke (2008) in their work showed the benefit on the use of periwinkle shells as coarse aggregate in concrete works. Yang et al, (2005) investigated the properties of concrete made up of crushed oyster shells as substitute for fine aggregate and found improvement on the compressive strength of concrete.

Due to increase in construction activities, concrete materials are increasingly depleted leading to scarcity, increase in cost and use of any available material, then the need for local and recyclable wastes (MPS) materials as alternatives for constructing functional structures. Periwinkle shell waste was evaluated in this work for its suitability as fine aggregate in concrete works for disaster mitigation. Nevertheless, the use of periwinkle shell might help in solving associated environmental problem caused by dumping periwinkle shell and as well its importance in economic development. There would be some substantial amount of money saved when MPS is partially or wholly used as fine aggregate in concrete thereby making houses affordable to the populace. A non-linear regression model that can predict the effects of MPS percentage replacement on concrete compressive strength will be developed in this study to reduce especially tedious laboratory processes involved (Ibearugbulam et al, 2013) and also for situations when time is of essence for future use and reference in solving such problems.

MATERIALS AND METHODS

The concrete materials used include

1. Ordinary Portland cement of Unicem brand bought from Orie Emene, a local market in Enugu state.
2. Aggregates;
   a. Fine Aggregate;
   Two fine aggregate materials were used:
   - Sand; gotten from Mmiri-ocha river at Iva valley in Aguabor, Enugu State, Fig.1a shows washed sand.
   - Mashed periwinkle shell (MPS); this was obtained from periwinkle shells crushed into sand size. The periwinkle shells were collected from a dump site near a market called New market in Enugu state. It was washed to remove impurities and dirt. Then further hand picking was done on the periwinkle shells to remove large impurities. The periwinkle shells were sundried for days under no special condition to dry up water in it. Then it was ground into sand size using a machine called harmer meal machine. There was no particular adjustment on the machine during grinding process. 5mm sieve size was used to sieve the ground periwinkle materials and materials passing through the 5mm sieve size were used and all materials that retained on it were removed, hence the mashed periwinkle shells (MPS) in Figures 1b &1c.

   b. Coarse Aggregate;
   The coarse aggregate used for this study was crushed aggregate obtained from Isiagu in Abakaliki, Ebonyi state. The coarse aggregate sizes used were 5mm and 13mm. This was done to have a well graded aggregate.
3. Water: water used was clean, odourless and free from visible impurities, sourced from good water supply.

Laboratory Method

The following tests were carried out on the materials listed above; particle size distribution for the aggregates (sand, MPS, coarse), specific gravity (sand, MPS, coarse), slump test, compressive strength test. The target concrete strength is 25 N/mm^2 Mix design was done using results from the preliminary tests of the aggregates giving a mix of 1:2:4.Using this mix ratio, casting of the concrete cubes (150 mm x 150 mm x 150 mm) was done. Five types of concrete samples were made which include; 0% (control sample), 10%, 20%, 50% and 100% MPS replacement for 7 days, 14 days, 21 days, 28 days concrete strength. This percentage replacement presented was for effective data representation. A total of 60 concrete cubes were cast using 150 mm x 150 mm cube mould. The workability of the fresh concrete for all MPS percentage replacements were determined using slump test. The concrete was allowed to set for 24hrs.After 24 hrs of casting, the concrete cube samples were de-moulded, put in curing tank and were properly cured in water. For each of the MPS percentage replacement, three cube samples each were crushed for the concrete compressive strengths at 7, 14, 21, 28 days. All experimental results obtained were presented in tables and graphs below.

Figure.1a: washed MPS & sand

Figure.1b: MPS material

Figure.1c: MPS material

Model Method for the Concrete Compressive Strength
The mathematical modeling of the compressive strength of concretes in which MPS was used as fine aggregate at various percentage replacements was considered.
The compressive strength properties of concretes were modelled using two variables, namely, the various strengths and percentage content of MPS as fine aggregate in concrete. A polynomial function model of the form in Equation (1) was adopted for predicting the strength properties of concretes at various percentage replacements;

$$F_t = A + B\varphi - C\varphi^2 \quad (1)$$

Where F_t isconcrete compressive strength in (N/mm^2), φ is percentage replacement (%), A, B and C are constants.
Let $F_t = Y, \varphi = x$ so that

$$Y = A + Bx - Cx^2 \quad (2)$$

By applying regression approach, constants A, B and C can be determined. The accuracy and reliability of the models developed was determined using suitable statistical evaluation criteria namely Coefficient of Determination R^2. The compressive strengths at various ages of curing of 7, 14, 21 and 28 days were predicted using the models developed as shown in Equations 3 to 6.

$$F_7 = 18.21 - 0.006 - 0.001\varphi^2 \quad (3)$$

$$F_{14} = 21.51 - 0.022\varphi - 0.001\varphi^2 \quad (4)$$

$$F_{21} = 21.50 - 0.018\varphi - 0.001\varphi^2 \quad (5)$$

$$F_{28} = 22.92 - 0.002\varphi - 0.001\varphi^2 \quad (6)$$

RESULTS AND DISCUSSIONS

The model and experimental results of the compressive strength of concrete with MPS percentage replacement and its correlation are presented in Fig.2 to Fig.9. The concrete compressive strength model results were gotten from Eq.3 to Eq.6 by using percentage content of MPS as fine aggregate and the concrete strength. Table 1 shows the slump values from the various MPS percentage replacement.

Model Verification for MPS Percentage Replacement as Fine Aggregate in Concrete

Nonlinear models developed to predict strength properties of concretes at various MPS contents were verified using the strength data obtained from the laboratory procedure. Also the accuracy of the models was determined by using statistical tools such as coefficient of determination R^2. The model predicted compressive strengths were compared graphically with that observed through the laboratory experiments as shown in Figures 2 to 5. The model compressive strength values exhibited a high correlation at all ages of curing which was determined by using the coefficient of determination R^2, with values of 0.980, 0.97, 0.986 and 0.989 at the respective curing ages of 7, 14, 21 and 28 days as shown in Figures 6 to 9.

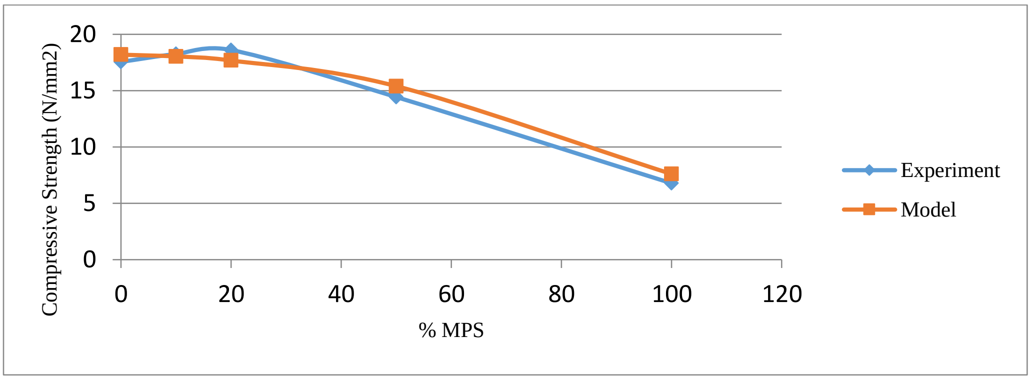

Figure 2: 7 days compressive strength for Experimental and Model

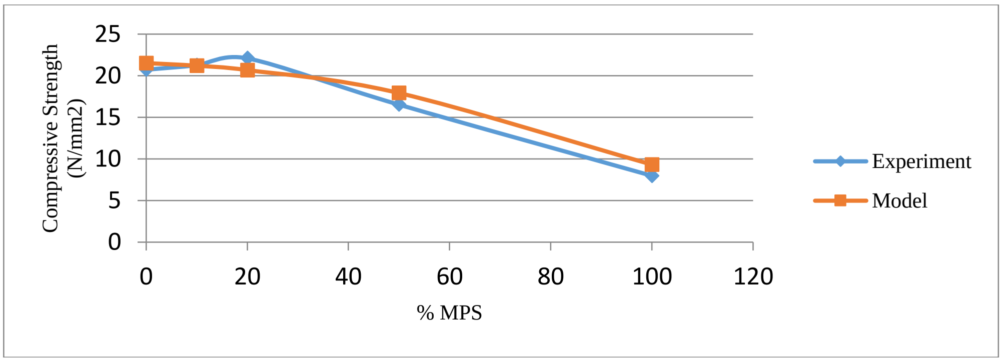

Figure 3: 14 days compressive strength for Experimental and Model

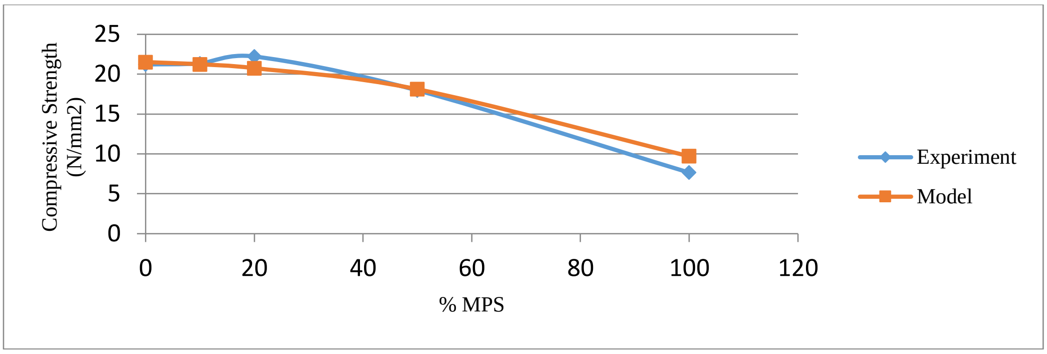

Figure 4: 21 days compressive strength for Experimental and Model

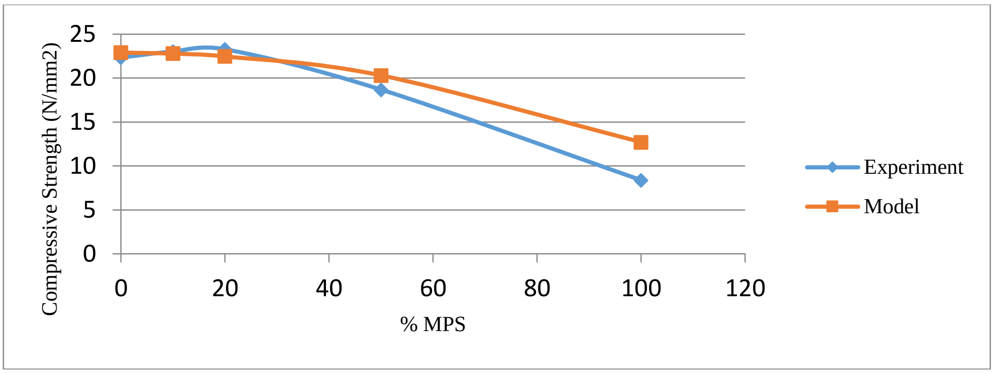

Figure 5: 28 days compressive strength for Experimental and Model

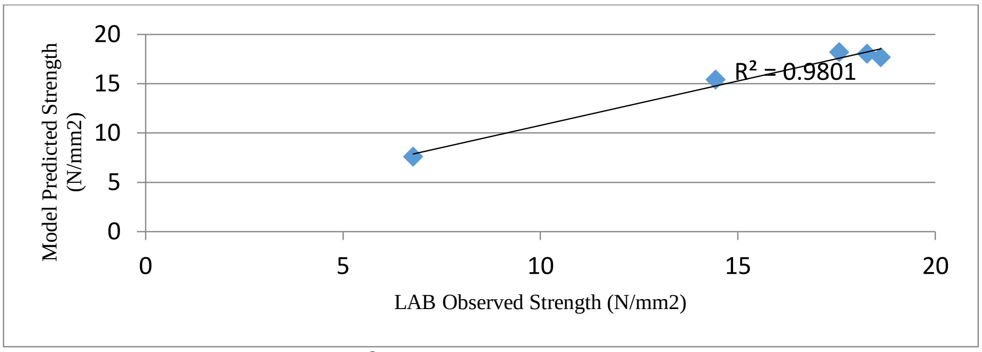

Figure 6: coefficient of determination R^2 at 7 days compressive strength

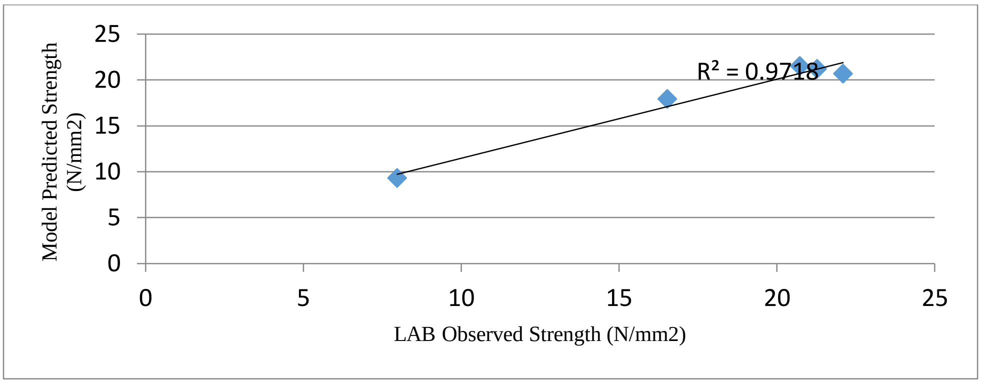

Figure 7: coefficient of determination R^2 at 14 days compressive strength

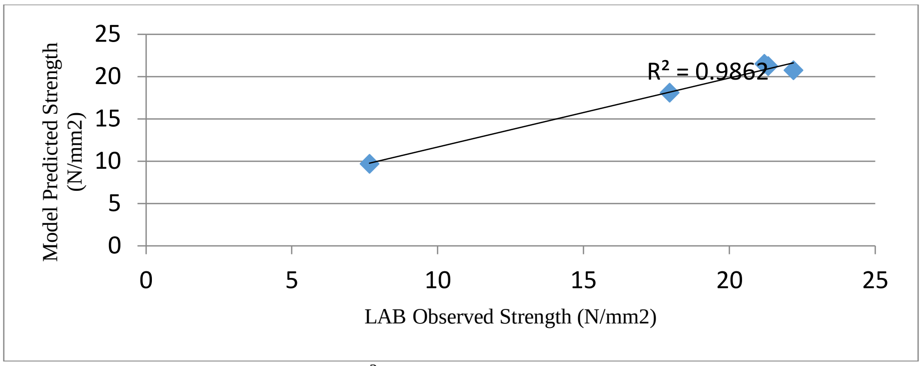

Figure 8: coefficient of determination R^2 at 21 days compressive strength

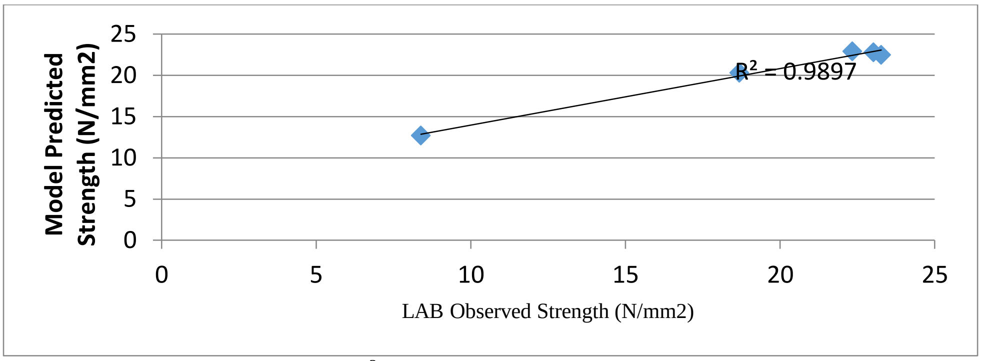

Figure 9: coefficient of determination R^2 at 28 days compressive strength

The slump test in Table.1, decreased with increase in percentage replacement of MPS in concrete. This can be attributed to more intake of water as MPS percentage replacement increases.

Table.1: Slump test at various %MPS

% MPS	0%	10%	20%	50%	100%
Slump (mm)	50	43	42	38	32

Specific gravity of fine aggregate is the ratio of weight of given volume of aggregate to the weight of equal volume of water. From the result of this study, both of the fine aggregate materials have almost the same values of specific gravity with the specific gravity of sand aggregate as 2.51 and that of MPS aggregate is 2.50.
The investigation showed that fine aggregate material (sand) used has a fineness modulus of 1.83 with about 91.54% passing 600µm fine aggregate sieve size as in Fig.10. This shows that the sand aggregate is in zone four grade classified for use as plaster sand and it is not good for concrete works. As a result of this, it might have contributed to the target concrete strength of 25N/mm^2 not attained at 28 days.

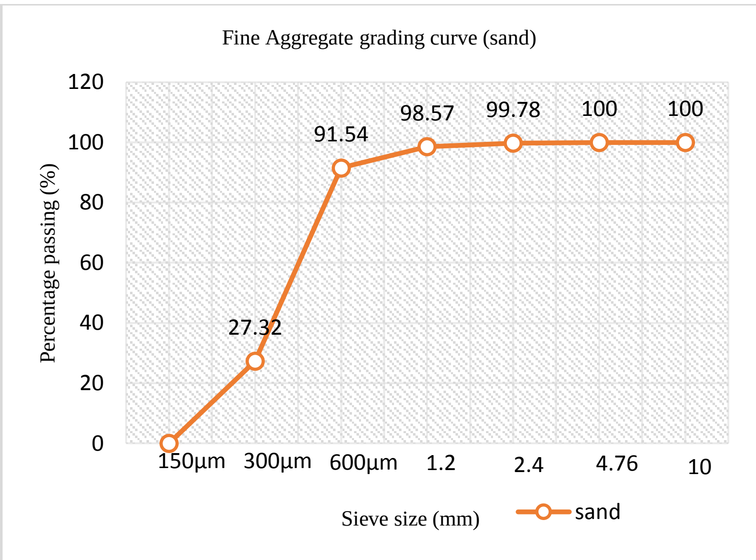

Figure 10: Fine Aggregate grading curve (Sand).

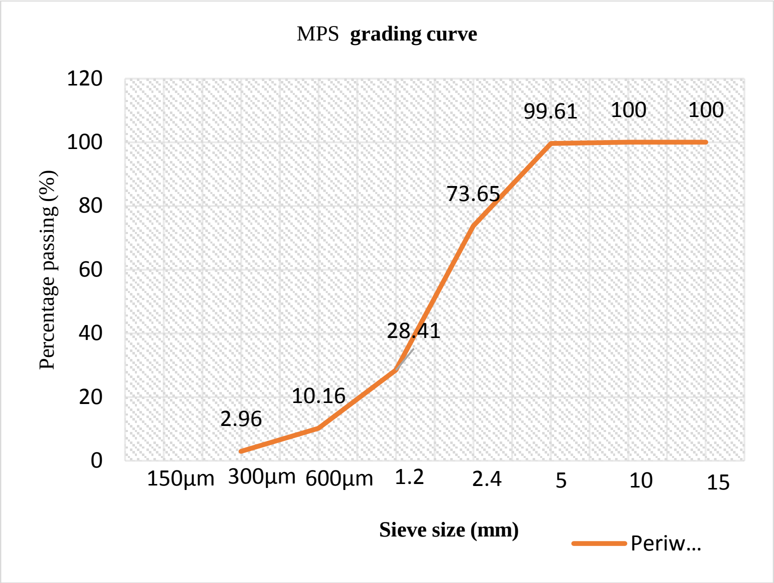

Figure 11: MPS Fine Aggregate grading curve.

The MPS fine aggregate has a fineness modulus of 3.85 with about 10.16% passing through 600µm fine aggregate sieve size as in Fig.11. This MPS aggregate did not fit into the conventional grading limit for fine aggregate, however, from this obtained result, MPS can be said to be in zone one fine aggregate grading. Though MPS being a lighter aggregate than sand and with no known grading limit, it can still be used in concrete production as seen from the result of this study. Moreover, some aggregates that failed to enter grading envelope still proved their 7 and 28 days' cubes strength to be good. (Soneye et al, 2016). This was shown in the improvement of 10% and 20% MPS replacement in Fig.2 - Fig.5 of this study.

The target concrete strength of 25N/mm^2 was not realized in the study. This can be from the fact that sand aggregate used was zone four grading. This zone four sand grade is not good for concrete works. However, there was significant improvement on the concrete strength when MPS aggregate as partial replacements was used. This can be attributed to the rough texture of periwinkle shells which might have aided in good bonding of MPS with other concrete materials. Results from this study showed that 10% and 20% MPS replacement gave 23.02N/mm^2 and 23.27N/mm^2 respectively at 28 days age with the control having 22.34N/mm^2 at 28 days strength. From Fig.2 to Fig.5, the effect of MPS partial replacement of sand can be seen from the 7 days age to the 28 days age strength for both the laboratory and model methods showing improved concrete compressive strength. 10% and 20% MPS partial replacement gave the optimum concrete strength and can be recommended for use in construction especially for low cost buildings.

Because of the improvement on the concrete compressive strength from this study, MPS when used with a zone one sand fine aggregate at 10% and 20% replacement is expected to give a concrete strength that can reach or even exceed the target strength. The result also showed that MPS fine aggregate at 50% and 100% replacement for sand aggregate cannot be recommended for concrete works because the strength might be affected. There was poor gain in concrete strength from Fig.2 to Fig.5 above for the 7 days to 28 days age. This poor strength gain was so significant when compared to the target strength of the concrete. Concrete produced with 50% and 100% MPS replacements were lighter in weight when compared to the control concrete samples. This might be because MPS is a light weight material and sand is denser. The more the percentage replacements of MPS fine aggregate, the lighter the weight of concrete sample and the more reduced the concrete strength, hence high percentage MPS replacements in concrete is recommended when beauty is of essence and not strength.

Results from the mathematical model gave a better representation of MPS fine aggregate percentage replacement on the concrete compressive strength and this was verified using the coefficient of determination as was shown in Fig.6 to Fig.9 for the different concrete ages.

CONCLUSION

The study showcased the effect of fine aggregate zone in concrete works. The sand fine aggregate used in this study was in zone four which might have contributed to the target concrete strength not being achieved. This type of sand zone is not encouraged for use in structural works because the strength can be compromised. The use of 10% and 20% MPS fine aggregate replacement in concrete showed an improved compressive strength more than the control sample (0%) from the experimental and model works respectively. The model work gave a better representation of the result as verified using coefficient of determination from Fig.5 to Fig.8 with their values as: 0.980, 0.97, 0.986 and 0.989 respectively. MPS fine aggregate at 10% and 20% is recommended for use in concrete works because of the improved concrete strength obtained. The use of MPS in concrete can reduce the cost of construction and as well minimize environmental problems like unpleasant odour contaminating surrounding air, unsightly appearances and any impending disaster resulting from periwinkle shells dump-sites. Hence sustainable affordable infrastructure is achieved for future need. The use of MPS fine aggregate as replacements at 100% and 50% for sand in concrete works is not advised from this study because of the poor strength gain but can be suitable for low strength lightweight concrete for aesthetic use. The mathematical model analysis can reduce error occurrences and also the tedious tasks of laboratory processes involved, therefore can be recommended for use.

DECLARATION OF CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this work

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