Comparative Analysis of the Strength Characteristics of Reinforced Foamed Aerated Concrete Slab

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ABSTRACT

The growing awareness of the harmful effects that some construction projects could have on the environment coupled with the ever increasing cost of construction have necessitated the search for alternatives to the conventional construction materials. Aerated concrete is considered versatile, durable, easy to use and energy efficient as lightweight concrete and is comparatively homogeneous when related to normal. This research focus on the study of the strength characteristics of foamed aerated concrete slab reinforced with different percentages of reinforcement. The foamed aerated concrete was produced from cement and sand mixed in the ratio 1:3 with water/cement ratio of 0.5. Sieve analysis test was carried out in accordance with BS EN 933-2:2020. The ordinary Portland cement conforming to BS EN 197 and having bulk density ranging from 3050 Kg/m^3 – 3159Kg/m^3 was batched with sand by weight in the ratio 1:3 with w/c of 0.50 to produce the foamed aerated concrete with the foaming agent mix ratio being 1:33. The diameters of steel reinforcement used for the work were 12mm for the main bars and 10mm for distribution bars. The percentages for the reinforcement are 0.5%, 1.0%, 1.5% respectively. Slabs with dimensions 1300mm x 500mm x 100mm were cast and a three-point load deflection test was carried out so as to determine the deflection pattern of the slabs. The mode of failure for slabs without reinforcement was purely by flexural. The stiffness and moment capacity of the slab have been increased as a result of the reinforcement in the tension zone, the failure load for slab without reinforcement was 23.55MPa while for a reinforced aerated concrete, the failure load were 82.63MPa, 95.03MPa and 103.03MPa for percentages 0.5, 1.0 and 1.5 respectively. The compressive strength obtained for the slabs at 28-day age was 16.21MPa which is beyond the limit of 15MPa, an indication of the usefulness of the foamed aerated concrete for roof slab, waffle and ribbed slab construction.

KEYWORDS: Compressive strength, Environment, Foamed aerated concrete, Failure, Reinforcement.

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1. INTRODUCTION

The need to move with technological innovations have geared the construction industries to embrace the agenda for sustainable development in unlocking a vastly improved sustainably built environment that is hinged on goals 9 which focus on building resilient infrastructure and innovation. Coupled with the growing awareness of the harmful effects that some construction projects could have on the environment and the ever-increasing cost of construction have necessitated the search for alternatives to the conventional construction materials that are versatile, durable, easy to use and energy efficient.

The use of environmentally-friendly building materials is the way forward and one of such eco-friendly construction material is foamed aerated concrete, which has low energy consumption when compared to that required in the production of normal weight concrete.

Concrete comprises normal weight concrete, light weight concrete and heavy weight concrete with the basis of classification being their densities. Light weight concrete has density ranging between 300-1950Kg/m^3, normal concrete varies from 2200-2500Kg/m^3 while for heavyweight concrete, it's between 3360-3680 Kg/m^3 (Falade F. 2000)

Aerated concrete also known as Autoclaved aerated concrete is considered as lightweight and is comparatively homogeneous when related to normal concrete being that it does not contain coarse aggregate with its properties dependent on its microstructure and composition. Large voids characterized autoclaved aerated concrete with the voids purposely incorporated in its matrix to lessen the density (Narayanan N & Ramamurthy K. 2000). Its preference is predicated not only on its low density (ranging between 300-800Kg/m^3) but also on the thermal insulation property.

Lightweight concrete has the advantage of reducing the dead load of a concrete structure, which will make possible the design of structural elements with reduced sizes thereby resulting in an economical construction with less pollutants. (Nelson R.L and Barnett R.E 1997).

Aerated Concrete can be either cement or lime mortar in which 75% air void by volume are entrapped in the mortar matrix by means of suitable aerating agent. The categorisation depends on the different calcareous materials used or sand and fly ash based depending on the different siliceous materials used (Qu, X., & Zhao, X. 2017)

The potential of aerated concrete as construction material was investigated by Ikponmwosa E *et al* (2014). The research based on its mechanical properties with the aerated concrete having a density of 1600kg/m^3. The results showed that at that designed density, the material was workable and repeatable. Aerated lightweight concrete put into consideration the frugality in materials and waste materials such as fly ash and this was confirmed by Jones M.R. and McCarthy A. (2005) by partially replacing the cement with fly ash and the coarse fly ash replacing sand. The use of the fly ash in the work led to reduction in the cement use and invariably reducing the greenhouse gases. The significant early age, engineering and durability properties were measured and all pointing to the fact that foamed concrete is undeniably feasible for structural uses.

Pulverised bone has found uses in the production of aerated concrete, basically because of the the need to have eco-friendly construction. Falade F *et al* (2013) used pulverized bone to partially replace cement in foamed aerated concrete and the results of their efforts revealed that foamed aerated concrete with percentage replacement of up to 20% cement with pulverized bone has tolerable strength acceptable to standards for construction purposes.

Thakur, A., & Kumar, S. (2022) did an investigation into the shear and tensile bond strengths of autoclaved aerated concrete (AAC) with various mortar formulations and depths using a three-fold analysis and cross-couples test. Their results premised on the failure mechanism and the strength of the tensile and shear bond of autoclaved aerated concrete mats, made them to recommend a 1:5 ratio cement sand or modified polymer mortar with a thickness of 17 mm for AAC brickwork. The behavior of sandwich blocks fabricated encased in a ferrocement box using aerated concrete was investigated by Memon et al (2006) by considering

the chicken and square wire mesh types and the number of layers in the ferrocement box. The results revealed substantial increases in the compressive strength as a result of the encasement of aerated concrete. This indicated the significance of the ferrocement encasement in the transforming the brittle mode of aerated concrete into a ductile one. Incorporating reinforcement in aerated concrete will further enhances the ductility of this lightweight concrete but the percentage replacement must be specified and must comply with standards. This work aim to determine the percentage replacement that will optimize the potentials of the reinforced aerated concrete.

2. METHODOLOGY

The material for the foamed aerated concrete comprises cement, fine aggregate, foaming agents and clean water**.** The fine aggregate (sharp Sand) with specific gravity of 2.66 was got from an upland source, Ogun river in Ogun State, Nigeria because of it low chloride content. The sample was air-dried before the sieve analysis test was carried out in accordance with BS EN 933-2:2020. The ordinary Portland cement conforming to BS EN 197 and having bulk density ranging from 3050 Kg/m^3 – 3159Kg/m^3 was batched with sand by weight in the ratio 1:3 with w/c of 0.50 to produce the foamed aerated concrete. The foaming agent used was Lithofoam SL 200L, a protein based agent with the foaming agent mix ratio being 1:33. The diameters of the steel reinforcement used for the work were 12mm for the main bars and 10mm for distribution bars. The percentages of reinforcement used were 0.5%, 1.0% and 1.5% of the slab cross section. After mixing has been achieved, the aerated concrete is poured inside a 1300 mm x 500 mm x 100 mm slab mould. The hardened concrete was then removed from the mould totaling twenty-seven samples, cured and tested at 7, 14 and 28 days' age respectively so as to determine the deflection pattern of the slabs in accordance with ASTM C78

3. RESULTS

The results obtained from the laboratory tests carried out to determine the deflection on the steel reinforced foamed aerated concrete slabs and also the compressive strength of the concrete materials using the cubes.

3.1 Deflection test

Table 1: Summary of The Failure Loads and their Deflection Values

Percentage Reinforcement		**0**	**0.5 %**	**1.0 %**	**1.5%**
Failure loads-Deflection Values	**Load KN/m**	**23.55**	**82.63**	**95.03**	**103.03**
	Deflection mm	**0.61**	**7.53**	**8.65**	**9.76**

The deflection and failure loads are succinctly summarized in table 1. The cracks pattern noticed in the samples showed that the cracks emanated from the support and extended to the point of application of the load. The failure mode of the slabs with reinforcement was by shear. It was seen that the while there was crushing of the concrete, the reinforcement was not affected. In slabs with no reinforcement, its failure mode was by flexure and the application of load gave a sudden failure and this occurred where the maximum moment predominant, which invariably at the mid-span.

The stiffness and moment capacity of the slab have been increased as a result of the reinforcement in the tension zone. The failure load for slab without reinforcement was 23.55KN/m while for percentages 0.5, 1.0 and 1.5, we have the failure loads to be 82.63KN/m, 95.03KN/m and 103.03KN/m with corresponding deflection of 7.53mm, 8.65mm and 9.76mm respectively. These showed a marked difference when compared to that of 0% reinforcement.

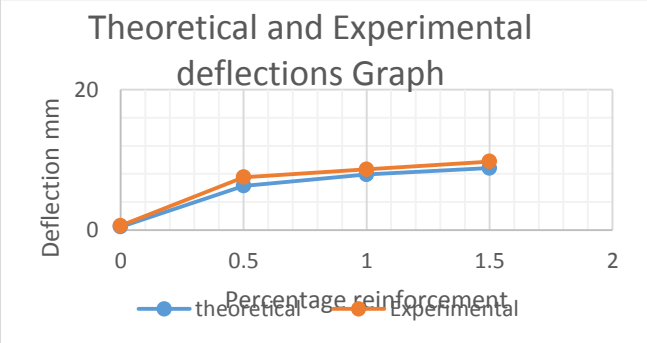

Figure 1: A graph of the theoretical and experimental deflections of the slabs

The figure 1 shows the values of deflection obtained after failure experimentally and theoretically so as to determine the capacity of the slab. It can be seen from the table that the experimental values obtained after failure is almost approximately equal to that obtained theoretically using $y = 5Pl^3/48EI$

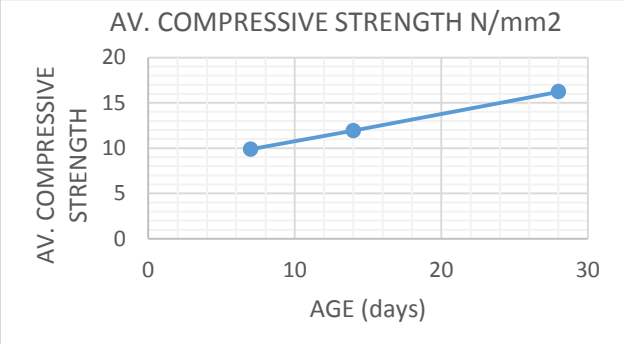

Figure 2: Compressive strength of slab at 7, 14 and 28 days

3.2 Compressive Strength Results

From the graph showed above, the average value of the compressive strength of the aerated concrete after been air cured for 7, 14 and 21 days was 16.21MPa whereas the least target value required was 15MPa of the target.

4. CONCLUSIONS

The foamed aerated concrete was free flowing indicating that the foam/water ratio was adequate. The compressive strength obtained for the cubes at 28 days' age was 16.21MPa which is beyond the limit of 15MPa. Also, it was observed that the aerated concrete with fine sand of about 75% and above passing through 600 micros and free from alkalinity has better curing with good results in terms of strength.

During the test, slab without reinforcement failed by flexure whereas those with reinforcement percentages of 0.5, 1.0 and 1.5 failed by shear as evident in their failure patterns which started from the supports and extended to the point where the loads were applied. Also observed was the cracks shear on one side of the slab this is due to the method of testing adopted producing eccentricity. All the aforementioned showed that the foamed aerated concrete can be used for roof slab but not for wider span aerated concrete has lighter weight and density compared to normal weight concrete its can adequately replace waffle or ribbed slab construction.

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