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Evaluation of Strength and Micro-Structural Properties of Rice Husk Ash (RHA) In Laterised Concrete (LATCON)

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Abstract
This study investigates the use of rice husk ash (RHA) in 0%, 5%, 10%, and 20% bulk replacements of Portland cement in concrete, with optimization of ash by incineration. Compressive strength tests were performed with cement substituted with rice husk ash (RHA) in four grades (0, 5, 10 and 20)% and fine aggregate substituted with laterite in three grades (0, 10 and 20)% and cured was performed at 7, 14 and 28 days of age. Concrete with a mixture of 1:2:4 (cement:fineaggregate:coarse aggregate) was used throughout the experiment with a water-cement ratio of 0.65; the fine aggregate being a mixture of lateritic soil. The proportion of lateritic soil was varied between 0%, 10% and 20%, RHA was varied between 0%, 5%, 10% and 20%, while all other components of the concrete were kept constant. The normal concrete samples served as a control for the test. Dosing was by weight. Compressive strength results were obtained and it was observed that strength increased with increasing age of cure until a point of optimum strength of 14.8 N/mm 2 at 5% RHA and 10% LAT was reached, followed by a subsequent decrease in strength. It was concluded that the RHA/LAT combination is suitable to produce structural concrete mixes at a hardening age of 28 days with a replacement content of 5% RHA and 10% LAT. It may be recommended to use RHA in concrete to improve its strength and other durability factors. A partial replacement of cement with rice husk ash can also be recommended in the construction of lightweight concrete and walls.

Keywords: ***RHA, laterised concrete compressive strength, concrete, micro-structure***

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I. Introduction

The construction industry is one of the leading industries in the world. Nigeria is a developing country where the rate of construction is increasing exponentially. The construction industry uses a lot of energy, depletes limited natural resources and emits large amounts of greenhouse gases. The construction sector plays a central role in economic growth (Jaina*et. al*., 2021). Global carbon emissions are around 23% due to the construction industry (Medina et. al., 2018). The cement industry itself contributes to 8% of anthropogenic CO2 emissions (Hossain *et al.*, 2020). Also, the consumption of natural resources is increasing very fast, which will lead to some environmental problems. Therefore, there is an urgent need to find an alternative solution to this worsening problem in the very rapidly expanding era of the construction sector. Today, many industrial and agricultural wastes are used in the construction sector as an alternative to cement, sand, coarse aggregates and reinforcement materials (Cavalcante*et al*., 2018).

Housing was seen as part of the absolute basic human need and the demand for it is ever increasing. This increasing demand for housing has been a major challenge for individuals and governments in underdeveloped and developing rural areas around the world. The provision of affordable housing is one of Nigeria's main problems. As more Nigerians make their cities and communities their homes, the resulting social, environmental, economic and political challenges urgently need to be addressed (Raji, 2008).

At the same time, house values and rents have risen in the slipstream of headline inflation. The share of rental and departmental houses in the market has moved strongly towards very expensive houses (Nubi, 2008). As can be seen in almost all developing countries, it is almost impossible to meet the enormous requirements for housing neither with conventional construction techniques nor with conventional building materials such as concrete, aluminium, brick, cement and steel, which have high energy consumption in production and negative environmental impact caused. In Nigeria, most buildings are made of sand concrete blocks, fired adobe bricks, wood and concrete, which are affordable for few people due to their high cost (Minke, 2006).

The most commonly used materials for concrete are cement, fine aggregate, coarse aggregate and water. The high cost of these materials results in a large amount of money in the manufacture of concrete, so alternative means of construction had to be adapted. In addition to the high cost of cement, its production produces a large amount of CO_2, which is harmful to human health and also destroys the ecosystem. The need to find alternatives to the use of cement is essential to addressing the problem attributed to it. Unfortunately, some materials classified as waste pose a burden on the environment because they are poorly controlled and disposed of. These agricultural and industrial wastes could serve the purpose of expensive materials such as cement, which is an essential material component of cement, either by partial or complete replacement. When used as substitute materials in the construction industry, the materials would help reduce the burden of searching for imported materials in the construction company, reduce the use of cement, and thus reduce the danger caused by its large production and also reduce the harmful impact of waste on the environment, thereby improving people's living standards (Adetoro& Adam, 2015).

Many researchers have been interested in studying the feasibility of various by-products or waste materials (e.g. fly ash, marble powder, rice husk ash, iron dust, etc.) generated during the manufacture of various products. In particular, the use of such waste in relation to the materials used in construction such as cement, fine aggregate and brick blocks, etc. (Aliabdo*et al.*, 2014). In the last two decades, agricultural waste in sustainable building products has received more scrutiny. Rice Husk Ash (RHA) is the agro-industrial waste produced by burning rice husks at a controlled temperature (Saloni*et al*., 2020, Antonio *et al*., 2018). This research will use rice hull ash (RHA) to partially replace Portland limestone cement and laterite to replace fine aggregates in concrete production.

II. Literature Review

Balogun and Adepegba (1982) discovered that the most suitable mixture of laterized concrete for structural purposes is 1:2:4, metered by weight with a water/cement ratio of 0.65, provided that the laterite content below 50% of the total content is kept aggregated content. The water/cement value used corresponds to the recommendation received and showed a linear relationship between the laterite cement value and the optimal w/c value.

Ghassa and Hilmi (2010) studied the properties of rice hull ash (RHA) produced using an iron-cement kiln. First, the effect of milling on particle size and surface area was studied, then XRD analysis was performed to verify the presence of amorphous silica in the ash. In addition, the effects of average RHA particle size and percentage on concrete workability, bulk density, superplasticizer (SP) content and compressive strength were also studied. Although grinding RHA would reduce its average particle size (APS), it was not the primary factor controlling surface area and thus resulted from RHA's multi-layered, angular and microporous surface. The incorporation of RHA into concrete increases the water requirement. RHA concrete gave an excellent improvement in strength at 10% replacement (30.8% increase over the control mix), and up to 20% of the cement could be replaced with RHA without adversely affecting strength. Increasing the RHA fineness improved the strength of the blended concrete compared to coarser RHA and control OPC blends.

Ogunbode and Akanmu (2012) performed a series of experimental tests on the strength properties of laterite concrete (LATCON) made from cassava husk ash (CPA), an agricultural waste, in varying amounts as a substitute for ordinary Portland cement (OPC) up to 40% . . The best strength performance was obtained at 30% cement substitute, while the laterite performed better at 30% fine aggregate substitute for concrete manufacture, which was comparable to normal concrete (i.e. control concrete). They, therefore, concluded that CPA/OPC LATCON has sufficient strength and adequate density to be accepted as a structural concrete

Kusuma and Devi (2020) used marble powder and rice hull ash to partially replace them with cement. Marble powder and rice husk ash are both materials that are cheaply available in India. Cement production causes environmental problems, and marble powder and rice hull ash cause environmental problems. i.e. marble powder and rice hull ash as a partial replacement with cement in concrete. This study reports the results of the mechanical properties of the concrete with partial replacement of marble powder (0%, 5%, 10%, 15% and 20%). Partial replacement of rice husk ash (0%, 5%, 10%, 15% and 20%) separately and mixed of marble powder and rice husk ash combined Partial replacement (0%, 5%+5%, 10%+10%, 15%+15 % & 20%+20%). The test results show that marble powder and rice hull ash are an effective mineral admixture, with 10% and a combination of both (5% + 5%) being the optimal replacement ratio of cement. Bending strength and tensile strength is maximum at 15% replacement of the two additional materials (marble powder, rice hull ash). Beyond 10% marble powder and rice hull ash, the compressive strength of concrete decreases and is lower than that of control concrete.

Jaina et. al., (2021) studied the effect of RHA on the fresh properties of concrete. Workability means the ease with which the concrete can be placed and compacted without segregation. Therefore, to produce high-quality concrete, its workability is a very important factor. To measure the workability of the concrete, the slump test is the most commonly performed. This test gives a general idea that the mixture produced is rough or flowable. In this study, RHA was added to the concrete in varying proportions as a binder. The results show that RHA can be used as a binder in sustainable construction

III. Experimental Procedures

The study involved the use of standard methods and materials described as follows:

3.1 Materials:

The materials utilized in the cause of the research ranged from cement conforming to the appropriate standards to Rice Husk Ash (RHA) obtained locally from the mill. Other materials used include fine aggregate, coarse aggregate, portable water and lateritic soil. The materials all conform to acceptable standards.

3.2 Methods

Rice hull ash (RHA) was collected, sundried and incinerated to ash using an open combustion system. The fully burned ash was allowed to cool for 72 hours before being collected and finely ground. After milling, the particles were sieved through a 75μm sieve. Chemical analysis was performed on the RHA and lateritic soil samples to determine their oxide composition. The following preliminary tests were carried out on the component concrete to obtain its properties: consistency, sieve analysis and setting time. Four levels of RHA replacement with cement at 0%, 5%, 10%, 20% and three levels of lateritic soil replacement of sand ranging from 0%, 10%, 20% at geometric intervals (i.e. a total of 12 samples prepared in triplicate after 7, 14 and 28 days) with the addition of microstructural samples (12 samples) for a total of 120 cubes. Concrete with a mixture of 1:2:4 (cement:fineaggregate:coarse aggregate) was used throughout the experiment with a water-cement ratio of 0.65; wherein the fine aggregate is a mixture of laterite earth and/or stone dust. The proportion of lateritic soil was varied between 0% and 20%, RHA was varied between 0% and 20%, and all other constituents of the concrete were kept constant. The normal concrete samples served as a control for the test. Dosing was by weight and the concrete was dosed by the recommendations of BS 5328-1,1997. Thereafter, the samples were subjected to a compression test to determine their compressive strength after each cure age. The internal structure of the concrete samples was further examined with the help of Scanning Electron Micrograph (SEM) devices.

IV. Results And Discussion

4.1 Workability tests:

The workability tests involve compacting factor and Slump test described as follows

4.1.1 Compacting factor Results:

The results are shown in Table 4.1 and Figure 1.0 of the Compaction Factor Test show the outcome of the test. In the first three replacements (0, 0), (0, 10), (0, 20), the cylinder with the concrete constituent has the highest values, which are 14.2, 14.1, and 14.0, but later had one decreasing value, the reason being that in the first three replacements there is no replacement of cement by rice husks, but in the other ingredient there is a partial replacement of fine aggregate by laterite earth.

Table 4.1: Table showing compacting factor results

S/N	1	2	3	4	5	6	7	8	9	10	11	12
REPLACEMENT LEVEL (RHA, LAT) %	0,0	0,10	0,20	5,0	5,10	5,20	10,0	10,10	10,20	20,0	20,10	20,10
Compacting Factor	14.2	14.05	14.0	13.9	13.8	13.7	13.6	13.8	13.7	13.9	13.85	13.8

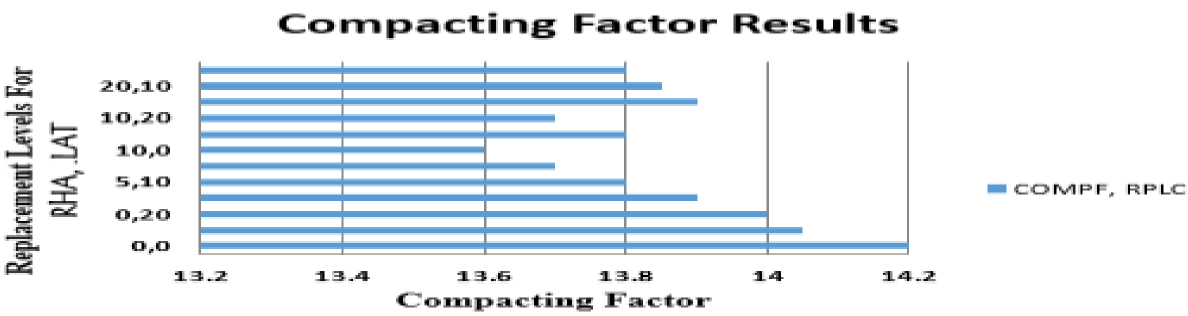

Figure 1.0: Compacting factor results

4.1.2 Slump test results:

The slump results of fresh concrete ranged from 28mm to 30mm as shown in Table 4.2 and Figure 2. There is a decrease in a slump as cement and river sand are replaced with RHA and laterite, respectively. This shows that as more cement and river sand is replaced, more water is needed to improve the workability of the concrete. The decrease in a slump with increasing RHA and laterite content can be attributed to its high surface area and high carbon content of RHA. The use of finer aggregates increases the surface area and thus increases the water requirement. Thus, the poor machinability may be caused by the high water absorption rate of lateritic fine aggregate compared to natural sand. The poor machinability of the lateralized samples is caused by the presence of kaolinite and illite minerals in the laterite, which requires additional water to aid in plasticity.

Table4.2: Table showing slump test results

S/N	1	2	3	4	5	6	7	8	9	10	11	12
REPLACEMENT LEVEL (RHA, LAT) %	0,0	0,10	0,20	5,0	5,10	5,20	10,0	10,10	10,20	20,0	20,10	20,10
Slump Values (mm)	28.5	29.2	28.7	29.3	29.1	28.5	28.3	29.1	28.0	28.3	29.2	29.5

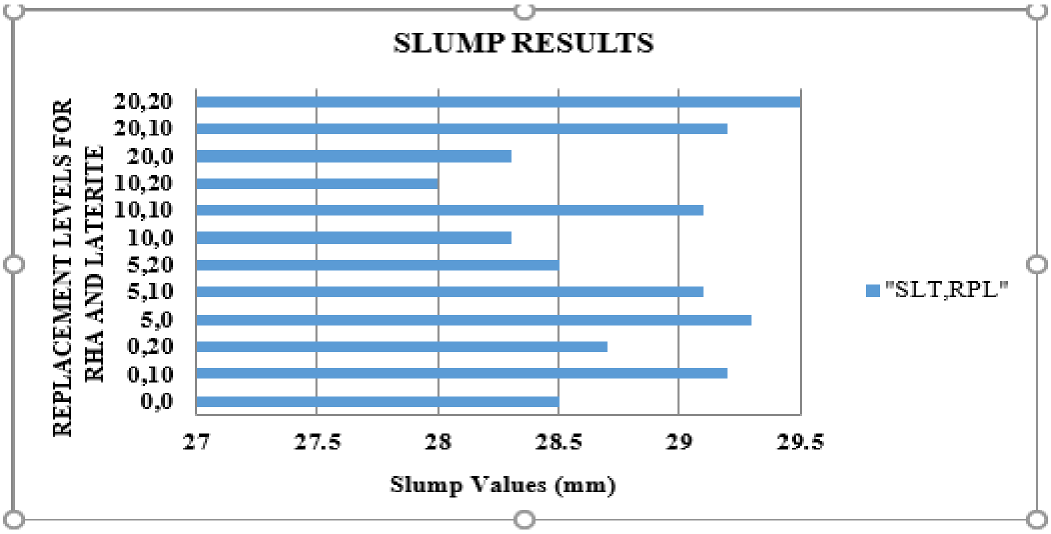

Figure 2.0: Slump test results

4.2 Compressive strength results

Figure 3.0 is a graph showing the compressive strengths of replacement rice hull ash and laterite with their different replacement levels at age of cure, with the age of cure of 7 days, 14 days and 28 days having their optimal value at 5% RHA, 10% LAT for 28days. Careful Observation After observing the compressive strength of 7, 14 and days day curing of concrete mixes composed of 0%, 5%, 10% and 20% RHA laterite substitute, it is found that among all mixes 5% substitute shows good strength comparable to strength without replacement. On the other hand, the reason for the decrease in compressive strength when RHA laterite is added is due to the presence of high clay content in laterite. With a higher laterite content (more than 5%), the workability of the concrete will be affected and the compactness of the samples could also be affected. Also of note is that strength increases with increasing age of set and the highest increase in strength for blends is Day 28 at 5%/10 RHA laterite substitute. It is based on the fact that curing age improves hydration rate, which in turn increases compressive strength.

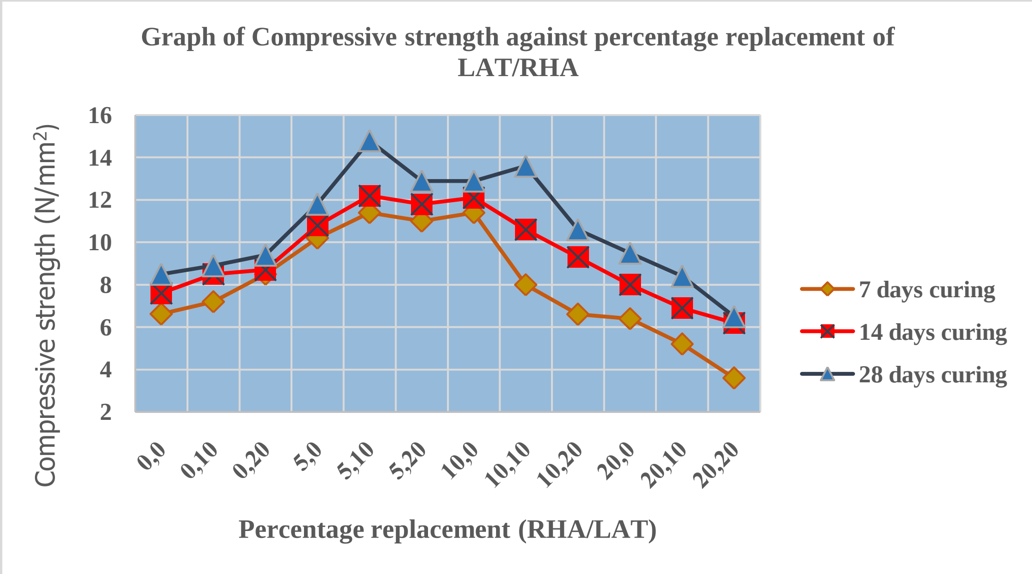

Figure 3.0: Compressive strength of RHA/LAT concrete

4.3 Microstructural properties

The results of the microstructural properties of the RHA laterite concrete are shown in Figure 4.0 (a-d). It is observed that all samples showed somewhat similar greyish microstructural characteristics. However, samples (a-c) have somewhat white jelly-like films well dispersed in their greyish matrix. The greyish matrix obtained can be attributed to calcium aluminate silicate hydrate gel (C-A-S-H), while the white jelly-like film on the surface can be attributed to the formation of calcium silicate hydrate gel (C-S-H). The presence of aluminium leading to the formation of a C-A-S-H structure could be attributed to the significant amount of Al present in the typical composition. It is also observed for (a) that hydration products (CSH) are seen and for (b and c) the soil-cement clusters are well developed, which are attributed to the growth of cementitious products such as CSH and CASH over time can. It can also be observed in (d) with 20% RHA laterite that the pore volume is larger, however as the percentage decreases the pore volume decreases which could be a result of cementitious products sealing the pores (ac). . These cementitious products not only improve the bond strength between clusters but also seal pore spaces. The formation of a better C-S-H phase, which is not well defined in (d), could be due to the amount of laterite added. It can be observed that the microstructural features of (a & b) are in great contrast to those observed for (c-& d) due to the formation of a well-developed and favoured CSH phase throughout the matrix, which is attributed to good pozzolanic may react due to the high content of amorphous silica (Mehta, 1986). (a-c) shows the formation of C-S-H gel in a significant amount, while in (a & c) the presence of an elongated crystalline cluster structure can be observed. This cluster of small fibrous hydration products has been assigned Type I C-S-H, resulting in the formation of a solid Type I C-S-H (cement hydration mature products) structure. Well defined and developed hydration products can be observed throughout the matrix of (a & b). Long and thin fibrous products are observed in (b & c), gel and net-like hydration products are observed in (c). This phenomenon was also noted by Taylor (1997).

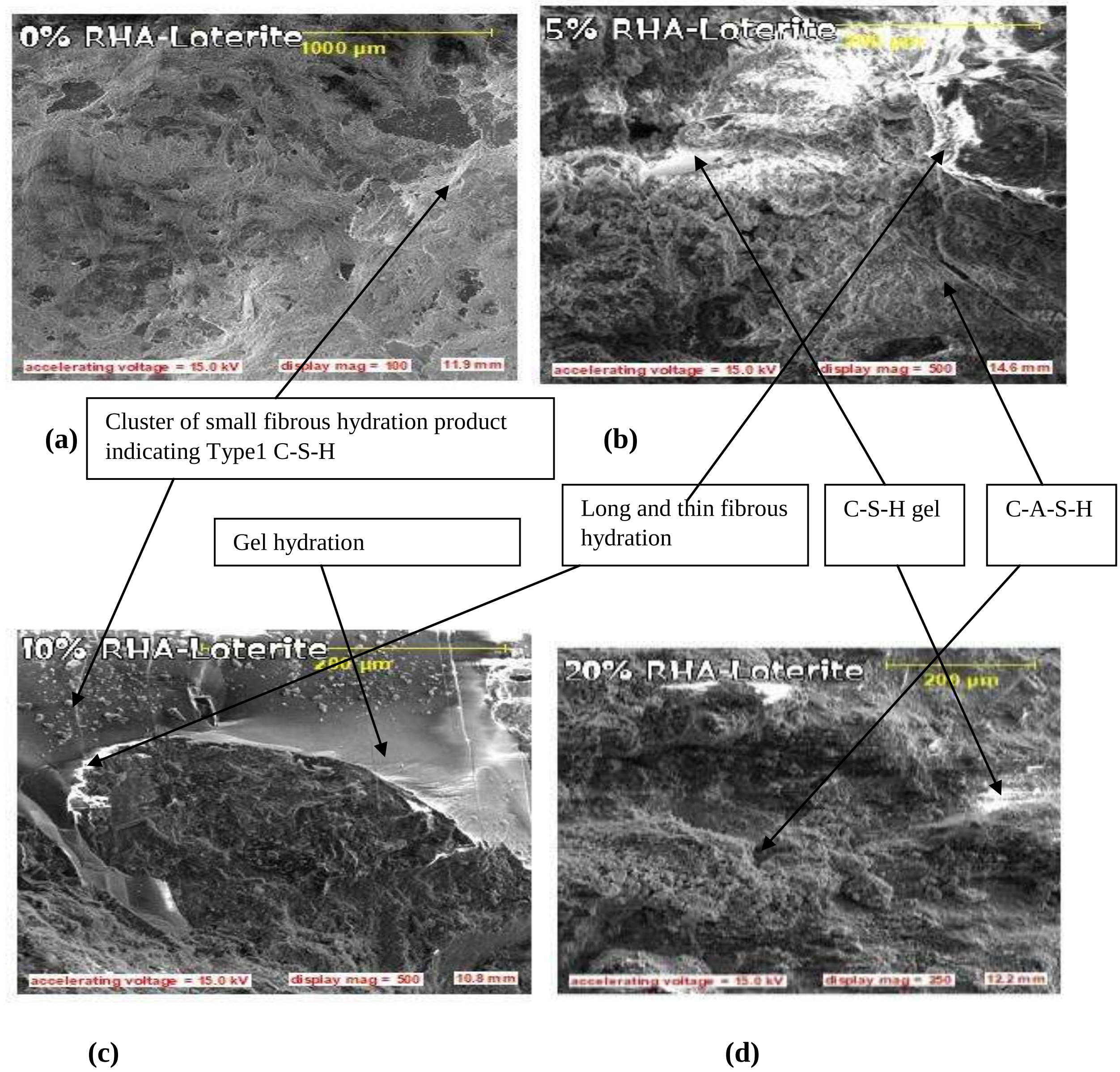

Figure 4.0: SEM image of rice husk ash-Laterite Concrete at (a) 0% (b) 5% (c) 10% (d) 20%

V. Conclusion And Recommendation

In the compressive strength test carried out, the optimum value of the test was found at 5% RHA 10% LAT, which corresponds to 14.8 N/mm2, therefore it is concluded that it is suitable for the construction of lightweight concrete. The workability tests (slump and compaction factor) showed significant positive results at the optimal mix of 5% RHA and 10% LAT, establishing this as the optimal mix recommended in this study for lightweight concrete production

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