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Strength Characteristics of Palm Kernel Shell and Expanded Polystyrene Composite Coarse Aggregate Concrete with Bamboo Leaf Ash (BLA) as a Partial Cement Replacement

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Abstract

With slump heights of 8.5, 2.0, 0.0, and 0.0 mm, the composite aggregate concrete is very hard to work with, even though its density is within the range given. Weak concrete is indicated by a maximum compressive strength of 5.8 MPa after 28 days as against a 17.0 MPa specification for structural lightweight concrete. The concrete's water absorption percentage isn't high enough to compromise its longevity. The concrete's extremely low workability and low compressive strengths at 28 days make it unsuitable for use in reinforced concrete structures, even if its bulk density is within the usual code criteria for structural lightweight concrete. The ability of concrete to resist water absorption determines how long it will last. The concrete's poor compressive strength and low workability make it suitable for usage in unreinforced concrete units, vibrated concrete in roads, and other heavy sections. Even though the concrete quality here may not be up to par,

Bamboo leaf ash (BLA), Expended Polystyrene (EPS), and Palm Kernel Shell (PKS) are still suggested as exceptional materials that might save building costs, improve the green and safe environment, and improve the attributes of concrete.

Keywords: Palm kernel shell, Polystyrene, Bamboo leaf ash, Lightweight concrete, compressive strength

Introduction

Stakeholders in the building business have long been plagued by nightmares due to the devastation of ecosystems caused by natural or conventional aggregate mining for regular concrete manufacturing. Aside from being a threat to the environment, the extraction of these aggregates has affected and added to the weight and density of structural concrete.

Normal concrete is defined as conventional concrete composed of cement, water, and conventional aggregates such fine aggregate from rivers, coarse aggregate from quarries and natural sources, and cement. Professionals and other interested parties in the building sector have been working hard to minimize the self-weight, density, and other undesirable characteristics of typical concrete structural elements while maintaining the structure's intended function. Concrete is made by recycling other lighter materials, like naturally existing lightweight materials and waste from industry and agriculture, in order to achieve these goals. Reducing the self-weight, density, stress, thermal conductivity, and other properties of structural concrete is one benefit of using waste materials like bamboo leave ash, palm kernel shell, and polystyrene in concrete; which also helps to preserve the environment.

Lightweight concrete is a mixture in which the coarse aggregate (granite or regular gravel) is replaced entirely or in part. In certain instances, the fine aggregates may also be lightweight products. The main purpose of structural lightweight concrete is to lower a concrete structure's dead load, which enables the structural designer to minimize the size of columns, footings, and other load-bearing components. The strength-to-weight ratio of structural parts is more effectively achieved using structural lightweight concrete. In comparison to conventional weight concrete, which has an in-place density

range of 2240 to 2400 kg/m^3, structural lightweight concrete has a minimum characteristic strength of 17.0 MPa and an in-place density of 1440 to 1840 kg/m^3. (ASTM 330, ACI 318, Dawood and Rami, 2008).

The purpose of this research is to examine the effects of partially substituting bamboo leave ash for cement in a given percentage (%) in palm kernel shells and polystyrene composite coarse aggregate lightweight concrete; while the main objectives are to investigate the Compressive strengths and water absorption capability for durability testing. The study looked at Large amounts of palm kernel shells produced as agricultural waste with associated disposal issues from palm oil-producing regions in Nigeria, including Edo, Kogi, Enugu, Cross River, Akwa-Ibom, Benue, and portions of Osun State. Another aspect considered is the environmental risk of dumping polystyrene electronic packaging material. Reusing these elements in the manufacturing of concrete will support green concrete, a high-quality environment, and more advancements in building materials. By adding lightweight particles to concrete, conventional concrete's self-weight, density, and stress issues can be resolved. In order to address the issues raised above, this work aims to examine the effects of substituting coarse aggregate entirely with composite palm kernel shells and polystyrene, as well as partially with bamboo leave ash in place of cement.

Every test conducted to ascertain or achieve these objectives are carried out in a laboratory.

Environmental pollution has been largely caused by construction industry activities worldwide, including the use of natural aggregates for conventional concrete production and the management of industrial Agro-base waste, particularly through open-air incineration. Nigeria's high demand for palm kernel oil has resulted in the production of almost 1.5 million tons of waste PKS. Because PKS waste is produced in such massive amounts, disposal and environmental concerns arise. There are many researchers working in this topic at the moment. PKS has been tested in research since 1984 as lightweight aggregates (LWAs) to build lightweight concrete (LWC) (Sundalian *et'al* 2021 and Kabir *et'al* 2017). The twenty-four states that comprise the oil palm belt are located in southern Nigeria, which encompasses all of the Niger Delta states. In Nigeria's oil palm belt, scattered smallholders who collect semi-wild plants and use traditional processing methods account for 80% of production. In Nigeria, oil palm plantations span between 169,000 hectares (72,000 ha of estate plantations and 97,000 ha of smallholder plantings) and 360,000 hectares. (PIND 2011). Large

amounts of PKS are created each year as waste products due to the high or rising demand for palm oil. Notwithstanding the several advantages that PKS waste may have, its careless disposal or incineration without energy recovery still poses a threat to the environment and the economy (Uchegbulam *et al.*., 2022). Expanded Polystyrene (EPS) is a hard cellular plastic that is usually white in colour. It is a wise choice in many industrial applications due to its high impact resistance and superior thermal insulation, and is well-known for its remarkable features, which include its strong load-bearing capacity at a low weight, air tightness for controlled conditions, long-lasting, 100% water and vapour-proof capacity, ease of maintenance, speed, and economical design, all of which increase its adaptability in the construction industry. (Ankesh and Sanjeev, 2021). For low-rise and high-rise structures up to 10 stories, EPS materials have proven to be structurally sound. (Hannah *et al.*., 2017). EPS strong heat conductivity, lightweight nature, and sound insulation are considered to make it a great addition to concrete. Wastes made of (EPS) come from both post-consumer goods and businesses. EPS don't biodegrade, but are typically disposed of by burning or landfilling, which pollutes the environment. Fresh and cured concrete have different qualities depending on how much expanded polystyrene is added. (Adeala and Soyemi, 2020; Ubi *et al.*., 2022). The 28-day cube strength—that is, the crushing strength of regular 150mm cubes 28 days after mixing—is the most commonly used metric for evaluating the quality and characteristics of concrete. (Akinpelu et al.. 2019).

A crucial factor in the behaviour of a building is the density of the concrete, which is a measurement of the material's weight. As the density of the concrete increases, so does the dead load on the structure (Shafigh *et al.*. 2010). Ubi *et al.*. (2020) developed new models for predicting the compressive strength and water absorption of polystyrene lightweight concrete on the 7, 14, 21, and 28 days and found that expanded polystyrene lightweight concrete should be encouraged in Nigeria, particularly to reduce the weight of structures resting on the foundation. Asha *et al*. (2014) found that concrete containing bamboo leaf ash should be used for civil engineering projects where durability is more important than high strength. Onikeku *et al.,* (2019) found that the best replacement level for split tensile, compressive, and flexural strength benchmarks is 10% when using BLA, but however be taken into consideration as an excellent Pozzolanic material that might reduce building costs and improve the qualities of concrete. The aim of this research work is to determine the strength

characteristics of concrete made with palm kernel shell and expanded polystyrene as coarse aggregates with cement replacement by bamboo leaf ash.

Materials and Methods

Materials

Materials required for this research which are sourced from different locations within Nigeria are

Cement: The ordinary Portland cement (Dangote brand 3X) grade 42.3R for general purpose construction confirming with standard specifications of BS and ASTM, used as the binder was locally purchased from cement vendors in Kaura Namoda, Zamfara state.

Bamboo Leaf: Bamboo leaves which were burnt to obtain the bamboo leaf ash (BLA) was sourced from Otukpo local government area of Benue state.

Fine Aggregates: This river sharp sand was locally purchased as obtained from river Gagale in Kaura Namoda town of zamfara state.

Palm kernel Shells: Palm kernel Shells an unconventional coarse aggregate in concrete production was purchased from Utonkom in Ado local government area of Benue state. Utonkom is known for palm oil production within Benue state with sizeable palm plantation.

Polystyrene: This non-biodegradable material EPS is bought from electronic sellers in Kaduna, Kaduna state and used as substitute coarse aggregate in this research. The EPS material was broken up into roughly equal pieces of natural coarse aggregate by hand before being used.

Water: The water used for casting and curing of concrete is potable water obtained from a borehole at the civil engineering department of the Federal Polytechnic, Kaura Namoda, and Zamfara state.

Equipment and tools: The required equipment and tools for the experimental work includes digital weigh balance, set of sieve, sieve brush, cube moulds of ($150mm^3$), concrete compaction tapping rod, a set of slump testing apparatus, a precise compression and tensile testing machine, shovel, hand trowel, head-pan and wheelbarrow, all of which are available in the laboratory where the research experiment is performed.

Research Experimental Process

Mechanical/Physical Properties of Materials

Tests conducted on the common properties of materials used in this research based on standard code specifications includes PKS's water absorption, and the particle size distribution of sand and PKS, the specific gravity and bulk densities of cement, sand, palm kernel shell, and EPS, as well as the cement's setting time. The results are shown in table 1 below.

Table 1: Summary of Material properties

Materials	Properties				
	Specific gravity	**Bulk density (Kg/m^3)**	**Water Absorption (%)**	**Particle size distribution (FM)**	**Setting time (min)**
Cement	3.11	1470	-	-	Initial - 48 Final - 237
Sand	2.58	1604	-	2.6	
PKS	1.301	692.4	1hr. - 13.1% 24hrs. - 21.02%	4.16	
EPS	0.103	15	-	-	-

Sample Preparation and Testing

The cement replacement by bamboo leaf ash were at 0%, 5%, 10% and 15% respectively. Concrete mix ratio of 1:2:4 (M15) was adopted at water- cement ratio of 0.55. In order to get an appropriate and cohesive mix density, the components were initially dry mixed before being physically combined in the laboratory, and to create the wet concrete paste that will eventually solidify and harden into a material resembling rock, wet mixing is then carried out with the addition of the water amount determined by the mixture design. For the compressive strength and water absorption, a total of 72 cubes (150x150x150) mm were produced, three cube for each of the specified curing ages. Concrete was completely submerged in water in a curing tank at a standard temperature to cure it after 24 hours of casting and de-molding. To execute the project, laboratory experiments were conducted in accordance with specified standards, to determine the fresh concrete workability based on slump test performed according BS1881-102 (1983); compressive strength test using precise testing machine which was accurate to within $0.05N/mm^2$ according to BS1881-116

(1983) and total water absorption for the durability test at concrete curing ages of 7, 21 and 28 days respectively.

The summary of the materials components mix combination for the experimental test at various percentage addition of bamboo leaf ash (BLA) as determined by the mixture design is presented in table 2

Table 2. Component mix proportion

BLA Content (%)	Water (Kg)	Cement (Kg)	BLA (Kg)	Sand (Kg)	PKS (Kg)	EPS (Kg)
0%	19.25	35	0.0	70	32	0.7
5%	19.25	33.25	1.75	70	32	0.7
10%	19.25	31.5	3.5	70	32	0.7
15%	19.25	29.75	5.25	70	32	0.7

Results and Discussion

Results

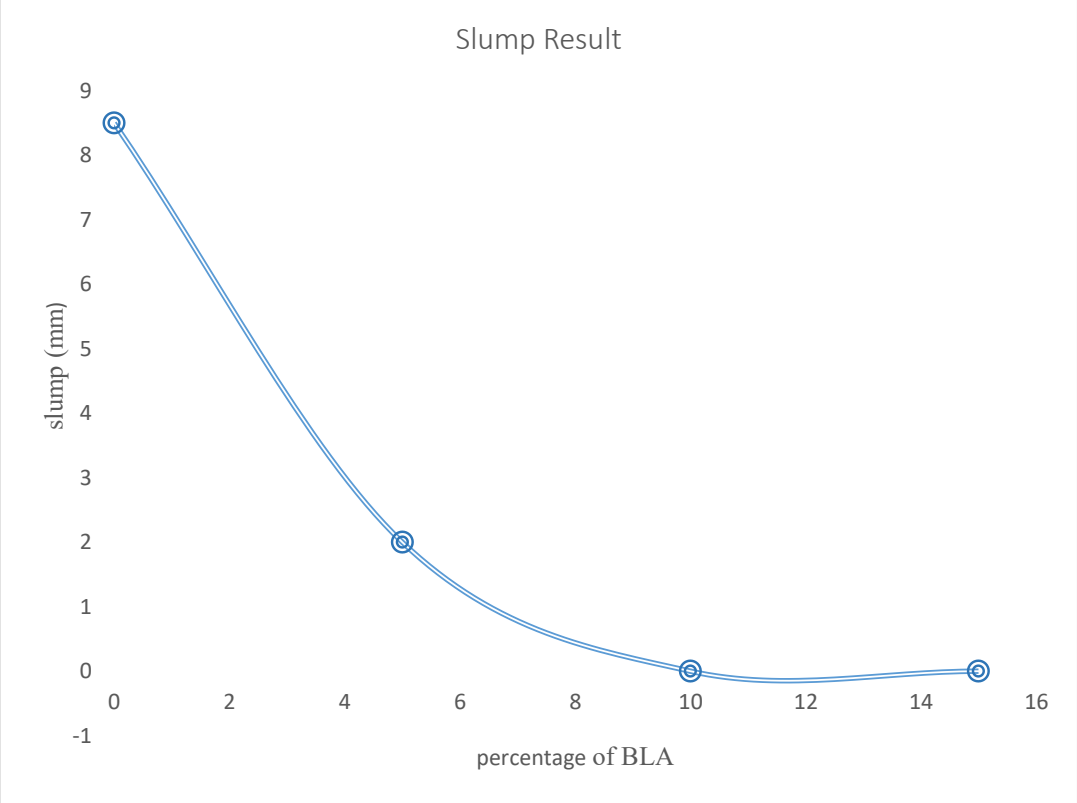


Figure 1: Slump (mm) at percentage of BLA addition in concrete

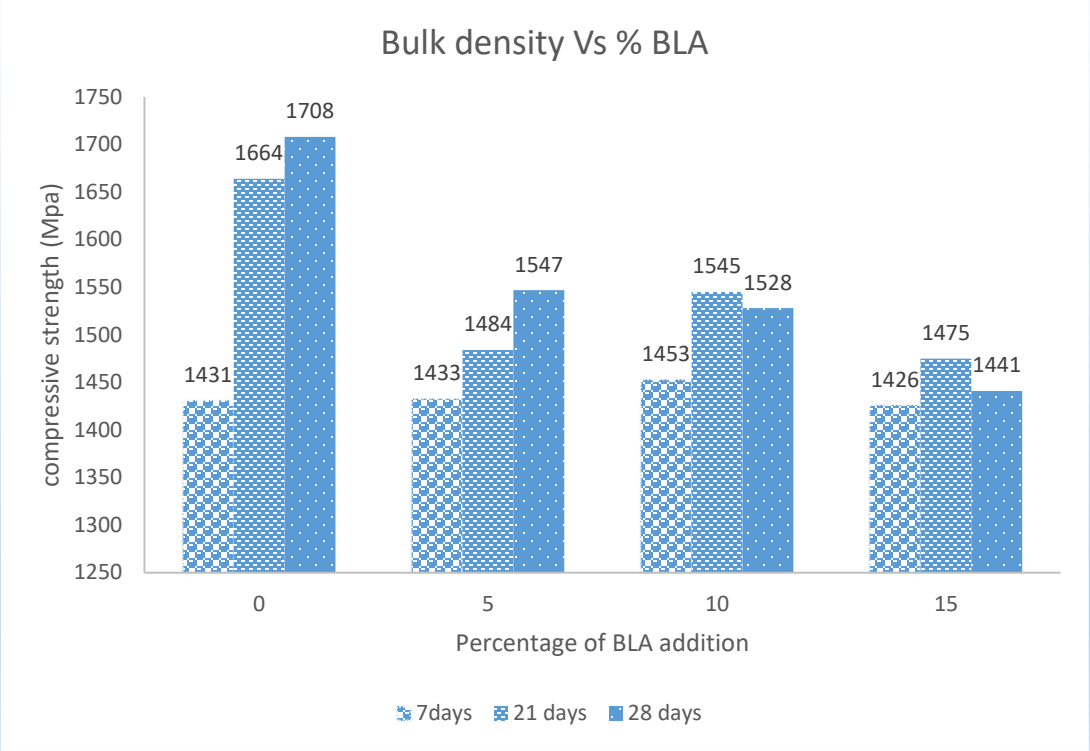


Figure 2: Bulk density at percentage of BLA addition and curing ages

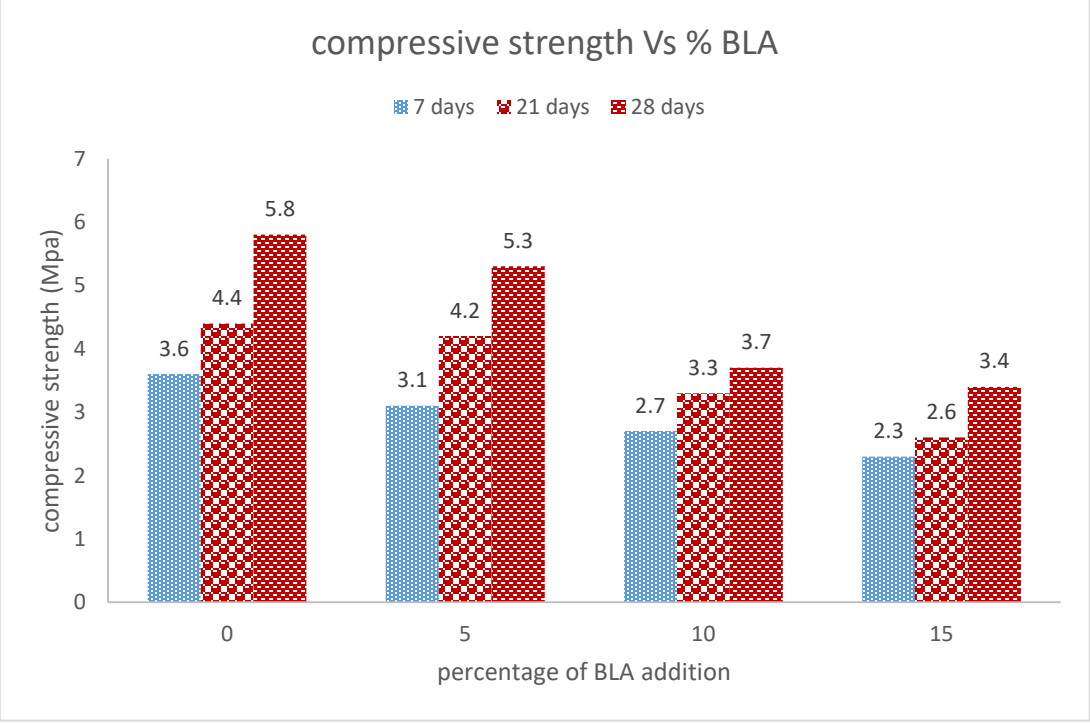


Figure 3: compressive strength at percentage of BLA addition and curing ages

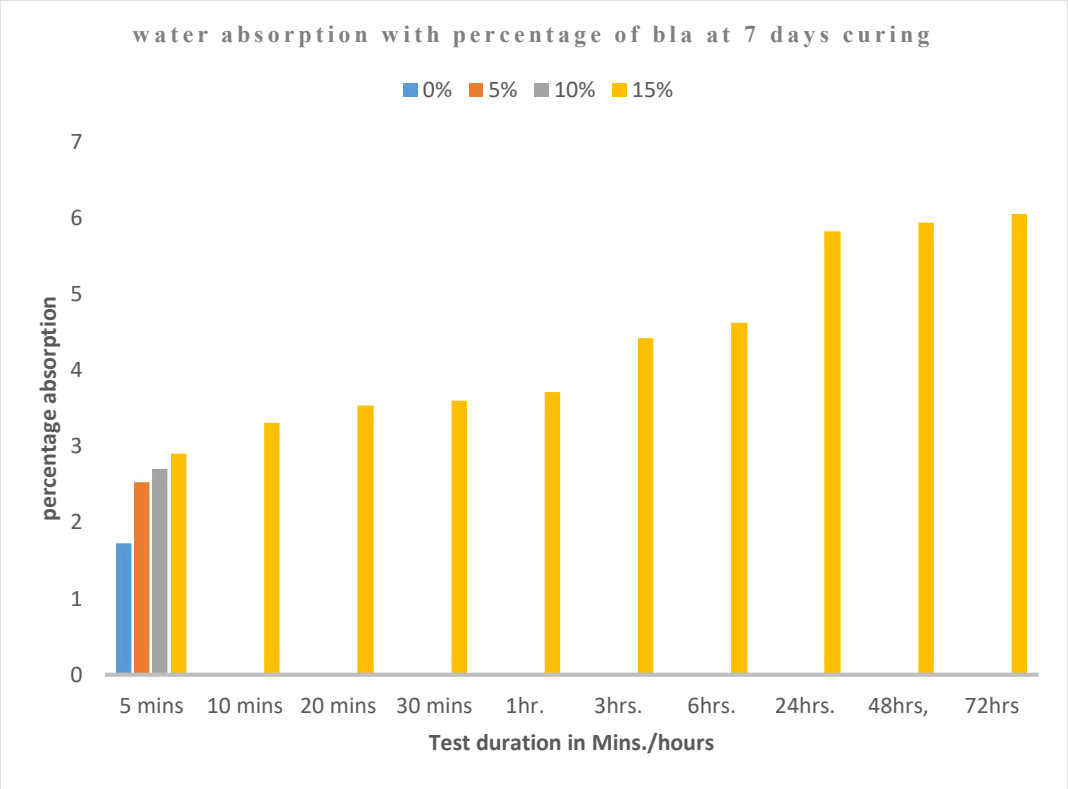


Figure 4: percentage water absorption at % BLA addition and duration in time

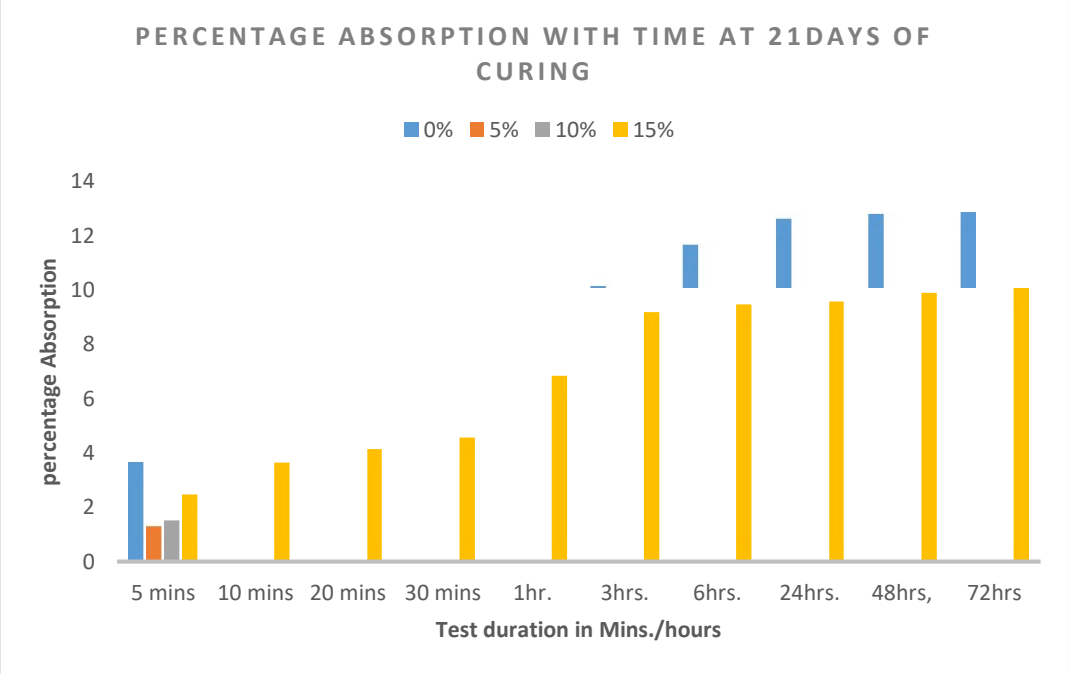


Figure 5: percentage water absorption at % BLA addition and duration in time

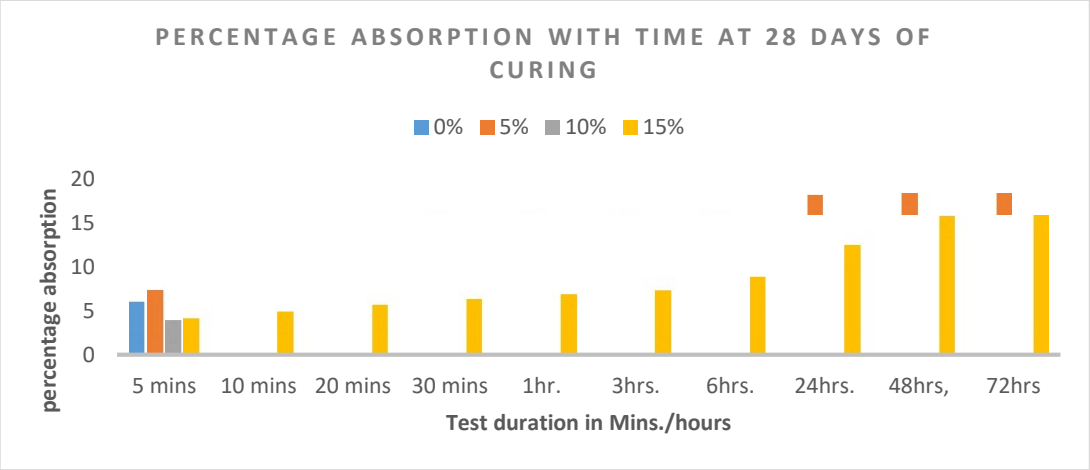


Figure 6: percentage water absorption at % BLA addition and duration in time

Discussion of Results:

Figure 1 illustrates that the slump height of concrete lowers as the percentage of BLA increases. Slump heights for percentages of 0, 5, 10, and 15 mm are 8.5, 2.0, 0.0, and 0.0 mm, respectively. This suggests that the workability of the composite aggregate concrete is extremely low.

High workability (at slump of 100 – 180 mm) is used for sections with crowded reinforcement, whereas very low workability (at slump of 0 – 25 mm) is used for vibrated concrete in roadways and other large sections.

As shown in figure 2, the bulk densities of concrete at varying percentages of BLA replacement for cement at different curing ages all fit within the normal code specification range of 1440 kg/m^3 to 1840 kg/m^3 for structural lightweight concrete. Figure 3.3 shows the composite coarse aggregate concrete's compressive strengths at 7, 21, and 28 days of cure. It demonstrates how the compressive strengths rise with curing age for every percentage of cement replaced with BLA.

However, these strengths fall well short of the 17.0 MPa minimum compressive strength required by norms of practice for structural lightweight concrete. The percentages of total water absorption at various percentages of BLA replacement during 7, 21, and 28 days of curing are shown in Figures 4–6, respectively. The concrete has begun to experience saturation, as indicated by the non-significant change in absorption between hours 24, 48, and 72. Any period after 72 hours may be considered complete saturation. Concrete's ability to withstand water absorption, particularly when it contains dissolved hostile ions and other dangerous compounds, is typically correlated with its durability.

Conclusion and Recommendations

Conclusion

Though the bulk density of the concrete is within standard code specification for structural lightweight concrete; but it's extremely low workability, and low compressive strengths at 28 days makes it unsuitable for application in reinforced concrete structure. The durability of concrete is hinged on its ability to withstand water absorption.

Recommendations

Because of the concrete`s low workability and poor compressive strength, it is recommended for use in vibrated concrete in roadways, unreinforced concrete units and other hefty segments.

Though the quality of concrete here may not be satisfactory but is still however recommended that BLA, EPS and PKS be considered as an outstanding material that might ease building costs, enhance green and safe environment and as well increase concrete qualities.

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Plates



PLATE 1. BLA



PLATE 2. EPS



PLATE 3. CONCRATE CUBES



PLATE 4. CRUSHING OF CONC.

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