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INFLUENCE OF BIOMASS AGGREGATE ON STRENGTH OF FOAM CONCRETE

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ABSTRACT

Light weight concrete was initially used for nonstructural purposes but now due to advancement of new materials such as recycled biomass aggregates this concrete can be used for structural purposes as well. In past, different materials have been used in making foam concrete but this work utilized particularly recycled biomass aggregate as a filler. This research is aimed to study the effect of biomass aggregates on strength of concrete. The biomass aggregate was crushed into fine aggregate of size lesser than 2mm. A total of 72 foam concrete cubes of size 100mmx100mmx100mm were cast for this research. The foam concrete cubes were air-cured in outdoor environment and in the concrete curing chamber for 28, 56 and 91 days. The foam concrete achieved highest compressive strength by using biomass aggregate at 91 days of air curing as compared to normal sand at indoor environment. The study is a new step towards utilization of recycled material. The possible utilization of such material would reduce the consumption of natural resources and also reduces the carbon footprint from the industries

Key words: Foam Concrete, Biomass Aggregate, Recycled Materials, Compressive Strength, Density of Concrete, Fillers.

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1. INTRODUCTION

Foam concrete is a type of structural lightweight concrete which is also known as porous concrete. It consists primarily of a cement- based mortar that contains about 20% or more percentage of air volume. Foam concrete possesses minimal consumption of aggregates, high flow ability, controlled low strength and excellent thermal insulation and acoustics properties. Nowadays, foam concrete is extensively utilized in various construction fields due to its inherent excellent properties. Its utilization as low weight concrete opened channel towards a new research. The main raw material of foam concrete is fine aggregate. According to [1], foam concrete can be pleasantly merged with recycled secondary aggregate (RSA) such as demolition fines, fly ash, fine aggregate and recycled aggregate.

This research used recycled biomass aggregate as fillers to produce foam concrete. Usage of recycled biomass aggregate is of utmost importance as it protects the natural resources. It becomes a new source for producing concrete, thus making foam concrete a green construction material.

The study analyzed the performance of recycled biomass aggregate in foam concrete. In comparison, foam concrete retains a slightly lighter density than normal concrete but it also depends on the composition of the mixture and used materials [2]. Normal concrete has a density of 2400 kg/m^3 while foam concrete varies between 400 to 1600 kg/m^3. This shows that recycled aggregate has lower density than normal aggregate, thus making foam concrete much lighter than normal concrete. Furthermore, the porosity of recycled aggregate is obviously higher than the normal aggregate [3]. This high porosity of recycled aggregate affects the water absorption of foam concrete. Moreover, the quality of the materials used in foam concrete also a decisive factor for water absorption. Additions of different fillers has significant impact on properties of foam concrete. Durack and Weiqing, 1998 concluded that a mix with fly ash as fine aggregate in foam concrete has higher strength than normal mix of cement sand [4]. A similar type of research is done by in 2006 [5]. The research includes two different types of filler i.e sand and fly ash in making foam concrete. The study concludes that higher strength can be achieved with fly ash as compared to sand also fineness of the particles increases the strength.

In this study, water absorption of the foam concrete is measured in 24 hours immersion. Since the recycled biomass aggregate foam concrete is a concrete with high proportion of recycled aggregate, hence the workability of foam concrete is low as the water absorption is particularly high. Different studies are available in literature on properties of foam concrete but the utilization of biomass aggregate is one of the new and interesting research. In this study, the density and water absorption properties of recycled biomass aggregate foam concrete are experimentally observed in laboratory and results are analysed.

2. CONSTITUENTS OF FOAM CONCRETE

2.1. Foam

A description of commonly used natural material-based and synthetic foaming agents have been discussed by various researchers such as [6-10]. In this study synthetic foaming agents (surfactant) were used. This synthetic foaming agent is a commercial Sika Pvt brand, commercially known as SikaAER 50/50. SikaAER 50/50 is a synthetic air-entraining agent formulated based on BS 5075 Part 2 and Pr EN 934-2. It is a high concentrated liquid foaming admixture for concrete. The foaming agent to water ratio is 1:20. The foam were produced in the foam generator as shown in Fig. 1.

2.2. Recycled Biomass Aggregate (RBA)

The study utilized recycled biomass aggregates as filler in the concrete. The recycled biomass aggregate were crushed into fine aggregate, passing 2 mm sieve (i.e. sieve #10). Biomass aggregate was produced from the controlled incineration of a mixture of rubber wood bark and palm biomass at elevated temperature of around 650°C. Fig. 2 shows the sample of recycled biomass aggregate.

Figure 2. Foaming Generator

Figure 2. Recycled Biomass Aggregate (RBA)

2.3. Ordinary Portland Cement (OPC)

Portland cement, OPC (BS: 12: 1996) is the most common type of biding material. OPC was used as the binding material in making foam concrete for this research work. This is mixed with recycled biomass aggregate, water and foam to form a mortar paste.

2.4. Water

The water used for the mixing concrete should be potable. The water is used for hydration process to activate the binding of cement through the chemical reaction and contribute to workability. The amount of water used is very important as water-cement ratio will affect the strength of foam concrete. Tap water available in laboratory was used in this work confirming to BS 3148: 1980.

3. PROPERTIES OF RAW MATERIAL

3.1. Density and Specific Gravity

The density and specific gravity of raw materials i.e. sand and biomass aggregate were tested in laboratory. The results of laboratory testing are mentioned in Table 1.

Table 1 Bulk Densities and Specific Gravities of Raw Materials

Materials	Loose bulk density (kg/m^3)	Compacted bulk density (kg/m^3)	Specific gravity
Sand	1250	1320	1.65
Biomass Aggregate	527	566	1.14

Properties of raw materials can be classified based on the bulk density. Biomass aggregates are categorized as lightweight aggregate, which according to BS 3797 should not exceed 1200 kg/m^3 for fine aggregate.

3.2. Mortar Flow and Foam Concrete Density

Workability of mortar is its ease of use, measured by the flow of the mortar. The standard flow tests uses a standard conical frustum shape of mortar with a diameter of four inches. Table 2. describes the slump value of foam concrete used in research.

Table 2 Slump of Foam Concrete Density

Mix	Mortar flow diameter(mm)
Sand	360
Biomass aggregates	600

According to European Standard EN 206-1:2000, the slump class is S5 (>220) for all mixes. This indicates that the mixes are highly workable and can be self-compacting. All mixes produced lightweight concrete having density lesser than 2000kg/m^3.

4. EXPERIMENTAL WORK DETAILS

4.1. Mix Design

Mix design is defined as the process of selecting appropriate ingredients of concrete and determining their relative quantities with the core purpose of producing an economical concrete which has certain properties, notably workability, strength and durability [11].

To achieve a high strength with low density of foam concrete, mix proportion plays a significant role to obtain the required objectives. Water cement ratio and aggregate-cement ratio also influence the strength and density of foam concrete. The recycled biomass aggregate has high porosity which affects the water absorption ability of the foam concrete. In this research, the mix design method used for making foam concrete is according to BS 1881: Part 125: 2013.

4.2. Testing Specimen

For this research purpose, specimen of 100 mm size cube was used in the laboratory (shown in fig. 3 & 4). Total 72 foam concrete cubes were cast in laboratory. Tables 3 describes the mix design and detailing of number of specimen carried out in laboratory for this research work.

Figure 3 Pouring of Foam Concrete Cubes in Moulds

Figure 4 Foam Concrete Cubes After Casting

Table 3 The Composition of the Materials and the Number of Concrete Cube Specimens for Foam Concrete

Mix Design	Density (kg/m3)	Curing Days (Inside & Outside)	No. of samples	
			Biomass Mix	Sand Mix
1:2 (Cement: aggregates), 0.6 w/c ratio, 0.8 Foam/Cement ratio	1200	28	03 03	03 03
		56	03 03	03 03
		91	03 03	03 03
1:2 (Cement: aggregates), 0.6 w/c ratio, 0.9 Foam/cement ratio	1500	28	03 03	03 03
		56	03 03	03 03
		91	03 03	03 03

4.3. Air Curing Process

Curing is the procedure used to develop strength of concrete by promoting the hydration of cement. The curing procedure is control of the temperature and the moisture movement from and to the concrete [11]. In this research, air curing method is chosen instead of water curing. The foam concrete cubes were stored in a curing chamber under room temperature and suitable humidity. The cubes were remained under air curing for 28, 56 and 91 days inside the curing chamber. Fig. 5 shows the curing chamber and fig. 6 shows electronic humidity sensor and Thermometer used for this research purpose. Electronic humidity sensor and thermometer was used to measure the humidity and temperature inside and outside the chamber, mentioned in table 4.

Figure 5 Curing Chamber

Figure 6 Electronic humidity sensor and thermometer

Table 4 Relative Humidity and Temperature at Different Environments

Environment	Relative Humidity	Temperature (^{0}C)
Chamber	76.1	24.8
Indoor	72.0	27.5

Actually, the humidity and temperature readings are similar to room condition. With the use of these electronic instruments, results are more accurate and reduces the interference factor on the results.

5. PROPERTIES OF FOAM CONCRETE

5.1. Density

The typical dry density of foam concrete is ranging from 1000 to 1700 kg/m^3. The wet and dry densities of foam concrete were studied in laboratory. The formula of calculating the density (BS1881: Part 107: 1983) of foam concrete is:

$$\text{Density } (\rho) = \frac{m}{v}\left(\frac{kg}{m^3}\right)$$

5.2. Workability

Workability is the amount of useful internal work necessary to produce compaction, Neville & Brooks (2001). The optimal workability would give maximum density, minimum voids with no segregation. The workability may reduce during mix design where the water loss through absorption and evaporation. Therefore, the measurement of workability of concrete is necessary. The final selection of workability test methods is based on the properties of foam concrete such as filling ability, passing ability and resistance to segregation. The plastic viscosity and yield value is mainly determine the filling ability of foam concrete. Thus, the slump flow with T50 test is used for workability determination.

5.3. Compressive Strength Test

The compressive strength test (BS1881: Part 116:1983) of foam concrete was carried out in the concrete laboratory. The Universal Testing Machine (UTM) was used to test the compressive strength. Total of 72 (100 mm x 100 mm x 100 mm size) of foam concrete each of having curing days of 28, 56 and 91 were tested. The compressive loads applied on the cube were recorded. The compressive strength is determined using following formula:

$$\text{Compressive strength} = \frac{\text{Ultimate Loading}}{\text{Cross sectional arae of foamed concrete cubes}}\ (MPa)$$

6. RESULT AND DISCUSSION

The average compressive strength of specimens tested in Universal Testing Machine (UTM) at 28 days, 56 days and 91 days after keeping at indoor and outdoor environments are illustrated in Tables 5 and 6.

Table 5 Average Strength of Specimens of 1500kg/m^3 over Time after Being Put in Different Environments

Mixes (1500 kg/m^3)	**Strength (MPa)**					
	28th day		**56th day**		**91thday**	
	Indoor	**Outdoor**	**Indoor**	**Outdoor**	**Indoor**	**Outdoor**
Mix 1-Sand	12	11	13.5	12.8	15.7	14.6
Mix 2-Biomass	13.5	13	15.7	15.6	19.01	16.6

Table 6 Average Strength of Specimens of 1200kg/m^3 Density over Time after Being Put on Different Environments

Mixes (1200 kg/m^3)	Strength (MPa)					
	28th day		56th day		91thday	
	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor
Mix 1-Sand	6.8	6	7.9	7	10.2	9.8
Mix2-Biomass	8.2	6.3	9.1	8.3	11.7	10.4

From the obtained result, it is clear that the strength for every specimen has increased with time for both outdoors environment and in inside the chamber among the different types of mixes i.e. biomass aggregate and sand. Moreover the results reveals that the sand mix achieved the highest value of 15.7 MPa at indoor environment on 91th curing day. The same is the case with biomass mix concrete. The highest value achieved by biomass mix is 19.01 MPa at inside the chamber at 91th curing day. Also compressive strength of 1500 kg/m^3 is higher than of 1200 kg/m^3 mix in all specimens. Furthermore the fig.7 and fig.8 illustrate the behavior of compressive strength variation at different curing days with different mixes.

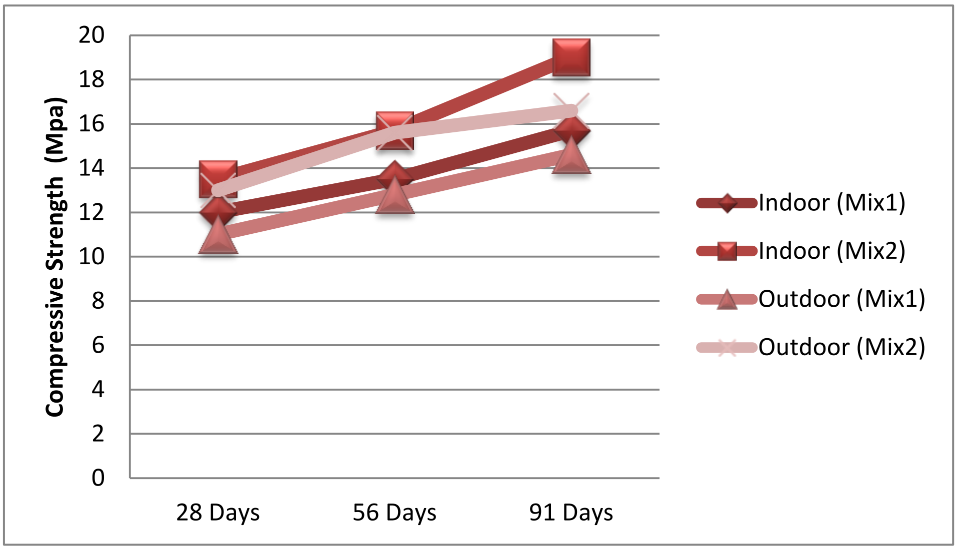

Figure 7 Strength over time for sand indoor and outdoor specimens

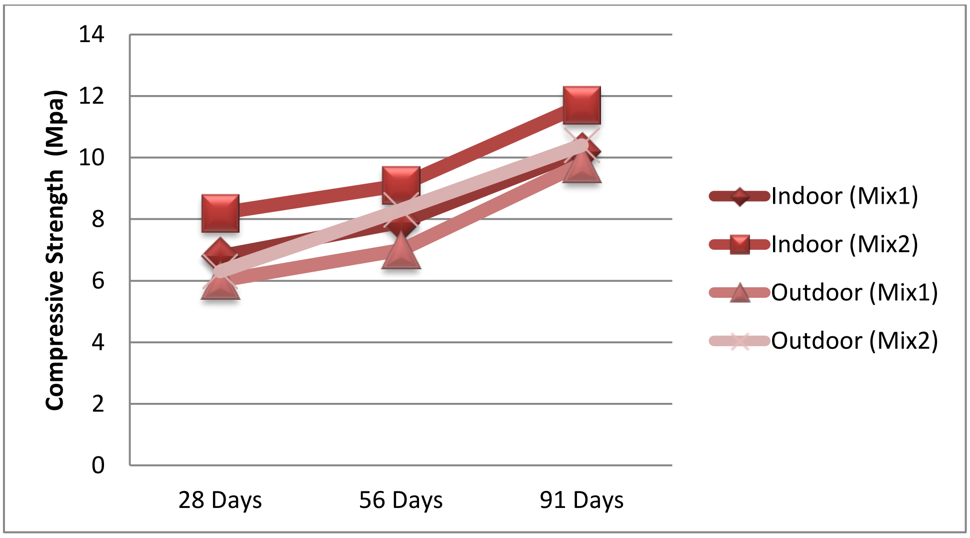

Figure 8 Strength over time for biomass indoor and outdoor specimens

It is clear from the graphs, the strength has increased with time for both environments. Among the different types of mixes i.e. biomass aggregate and sand mixes, the recycled biomass achieved higher compressive strength than the sand mixes.

6. CONCLUSIONS

This study included the preparation of foam concrete mixes containing the same percentage of materials, replacing different fillers in this mix. The evaluation of foam concrete properties including mix workability, compressive strength and density has also been done. According to experimental results, the use of biomass aggregate in foam concrete mixes as an alternative of natural aggregate is possible. The influence of the aggregate alternatives on foam concrete properties had been studied.

Experimental works have proven that biomass aggregates could also produce good quality foam concrete. From the results of this work, following conclusions can be made.

For Biomass, aggregate specimens:

- Indoor environment favors the biomass utilization in foam concrete as compared to outdoor environment.
- As curing days increase the strength of foam concrete also increases.
- Foam concrete achieved highest compressive strength at higher density at indoor environment.
- Biomass aggregates achieved higher strength than control specimen of sand aggregate, hence this can be utilized as substitute for sand in foam concrete.

Sand aggregate specimens:

- Indoor environment also favors the sand as filler in foam concrete as compared to outdoor environment.
- As curing days increase the strength of foam concrete also increases.
- Foam concrete achieved highest compressive strength at indoor environment.
- Sand as a filler in the mixes achieved an acceptable range of strength but it is lower as compared to biomass aggregate specimens.

7. DIRECTION FOR FUTURE WORKCONCLUSION

Only one type of mix design has been used throughout the whole of this study. It is expected that different mix designs would produce specimens with different properties and perform differently. Biomass aggregates are used as fine aggregate alternatives however coarse aggregates were not considered at all. Biomass aggregates can also be converted to coarse aggregates and the use of coarse biomass aggregates in concrete production can be expected. This research is only limited to two different densities of concrete i.e. 1200 kg/m^3 and 1500 kg/m^3 however, the research can further be extend to other different densities to get optimum results.

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