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EXPERIMENTAL STUDY ON FOAM CONCRETE TO ENHANCE ITS PROPERTIES

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Abstract: Foam concrete is a type of aerated lightweight concrete; foam concrete does not contain coarse aggregate and can be observed as an aerated mortar. Foam concrete is produced when pre-formed foam is added to slurry, the purpose of foam is to create an air void in concrete slurry. Foam is made separately by using foam generator; the foaming agent is diluted with water and aerated to create the foam. In this study foam concrete mixtures are produced with and without sand and attempts have been made for selecting the proportions of foam concrete mix for the target plastic density of 1900 kg/m^3. Several cube specimens are prepared and tested for mixtures and then their density and their Compressive Strength properties were examined, Specific Strength and Percentage Strength gain for foamed concrete is compared with normal weight concrete and the results are reported. Foam concrete emerges as an alternative to ordinary concrete, as it lowers dead loads on the structure and foundation, contributes to energy conservation and drops the cost of production and labor cost.

Index Terms **- Foam Concrete, Light Weight Concrete, Density, Strength**

I. INTRODUCTION

Foam concrete is a mixture of cement, fine sand, water and special foam which once hardened results in a strong, lightweight concrete containing millions of distributed, consistently sized air bubbles or cells. The density of Foam Concrete is determined by the amount of foam added to the basic cement and sand mixture. FC is both fire and water resistant. It possesses high sound and thermal insulation properties. It is similar to conventional concrete as it uses the same ingredients. However, it differs from conventional concrete in that the use of aggregates in the former is removed. A foam aeration agent is used to absorb humidity when it is exposed to the atmosphere, allowing the hydration process of the cement to progress till it achieve the strength.

The difference between foam concrete and normal concrete is that aggregate is not used in FC and it has been replaced by the homogeneous cells created by air in the form of small bubble which use a stable air cell structure. It can be classified as cellular material because it contains a higher number of pores. Foam concrete can be easily known as cellular material. The quality of foam concrete is based on the quality of foam so that the foam is very important factor for the foamed concrete.

II. LITERATURE SURVEY

Foam concrete is not particular new material, its first patent was recorded in 1920s. According to sach and seifert (1999), limited scale production commences in 1923 and, according to Arasteh (1988), In 1924 Linde described its production, properties and applications. The application of foamed concrete for construction works was not accepted until late 1970s, when it begins to use in Netherlands for filling voids and for ground improvement applications. Noteworthy improvement in productions method and quality of foaming agent over the last two decade leads to bigger production and increase in its applications.

Dhanalakshmi A, and Shahul Hameed M, discussed that the utilization of alternative materials, such as quarry dust, and Marble Sludge power (MSP) for HSSCC applications the results of this research provide a strong support for the use of MSP as filler in SCC manufacturing. A maximum of 8% of lime stone powder with silica fume, 30% of quarry dust and 14 % of clinkers was able to be used as a mineral admixture without affecting the self-compact ability. However, a number of clear conclusions have been obtained about the behavior of HSSCC.

Maheshkumar H. Tharkrele, revealed conducted experimental study on foam concrete study two foam concrete mixtures are produced with and without sand and efforts have been made for selecting the proportions of foam concrete mix for the target plastic density of 1850 kg/m^3. Cube specimens were prepared and tested for mixtures, then their physical (Density) as well as specific structural (Compressive Strength) properties were investigated, Specific Strength and Percentage Strength gain for foamed concrete was compared with normal weight concrete and the results are reported.

Aswathy .M, revealed Smouldered Brick is one of the vital development materials. The nation is presently more on looking for natural answers for greener environment. Froth or foam has great warm and acoustical properties. Foamed cement is the most well-known of all low-thickness cements in creating nations. The utilization o Light-weight Concrete squares gives an appropriate answer for development industry alongside natural conservation. It is created by at first making slurry of Cement + Fly Ash + Water, which is further blended with the expansion of pre-frothed stable froth in a customary solid blender under surrounding conditions. In this paper attempt to made configuration blend are readied for 4", 6", and 8" of solid piece. This paper establishes the outcome on development of concrete.

III. OBJECTIVE OF STUDY AND METHODOLOGY

The objective of this study is to:

- Determine the influence of the density and compressive strength of foamed concrete w/o sand.
- Compare the density and compressive strength of Foam Concrete with Normal Concrete.
- Compare the Percentage Strength Gain of Foam Concrete over Normal Concrete.
- Compare the Specific Strength (Strength-to-Density Ratio) of Foam Concrete and Normal Concrete.

Foam concrete mixture with different ingredients of the materials is used in this investigation. The physical properties and a specific structural property of foam concrete mixtures were obtained first, before the relationship between these properties were determined. Foam Concrete cubes are prepared and the tests are performed in laboratory.

IV. MIX CONSTITUENT PROPORTIONS AND FOAM CONCRETE PRODUCTION

Although there are no standard methods for proportioning foamed concrete, the general rules regarding w/c ratio, free water content and maintaining a unit volume apply, but it is a specified target plastic density that becomes a prime design criterion. It should be noted that it is difficult to design for a specific dry density. Assuming a given target plastic density (D, kg/m^3), water/cement ratio (w/c) and cement content (c, kg/m^3), the total mix water (W, kg/m^3) and fine aggregate content (f, kg/m^3) are calculated from equations (i) and (ii) as follows.

Target plastic density, $D = c + W + f$ …(i)

where $c = PC + FA$ (fine),

$f = FA$ coarse + sand

Free water content,

$W = (w/c) \times (PC + FA \text{ fine} + FA \text{ coarse})$ …(ii)

Foamed concrete was produced in the laboratory using a standard inclined rotating drum mixer by the addition of pre-formed foam to a mortar (i.e., mix with sand fine aggregate) or paste (i.e., mix with no sand, just FA coarse fine aggregate) 'base' mix and mixing until uniform consistency was attained. The specimens were cast in steel moulds lined with domestic plastic 'cling' film, as foamed concrete was found to adhere to the mould surface. After 24hr de-moulding, the specimens were cured and stored at 20^{0}C until testing was done. It is recognized that sealed-curing may result in specimens having different degrees of pore saturation. This effect was considered to be minor for the range of constituent materials studied and certainly more representative of the actual properties of the material than would be the case if standard curing was applied.

4.1 Composition of Foam Concrete

This study is confined with aerated foam concrete which is produce by adding air voids into the cement-based slurry. The cement slurry consists of cement, sand, fly ash and water. Depending on the prerequisite properties, it can be formed with or without lightweight aggregate such as sand, fly ash etc. The introduction of air voids is achieved by adding pre-formed foam to the mixture. A foaming agent is diluted with water and aerated to form the foam.

The foamed concrete has been produced by using the following constituents' viz. cementitious material (i.e., cement & fly ash), sand, water and foaming agent.

Cementitious Material: Portland cement is preferred over other cements, such as pozzolan. For early stripping and optimum mechanical properties, high-grade cement is recommended. Thick walls and when using battery-moulds, excess heat is developing within and might therefore ask for a lesser grade of cement. The slower, hardening and better the final quality of concrete. To make it more economical, fly ash may be added to the mix to substitute some of the cement. Fly ash normally will retard hardening though. In this study, 53 grade Ordinary Portland cement and Fine Fly ash has been used.

Sand: Optimum properties are achieved when selecting the most suitable raw material. The sand is mostly preferred from river, which is washed and should be with minimum 20% fines. Dust in sand increases the demand for water, without adding to the properties, it also increases shrinkage. A certain, small number of fines contributes toward strength. As in conventional concrete, the sand should be free from organic impurities. Crushed sand may destroy the foam mechanically. In this investigation, locally available river bed sand has been used.

Water: Mixing water for concrete should be clean and free from injurious amounts of oils, acids, alkalis, salts, organic matter or other potentially deleterious substances. When water is used to produce foam, it has to be potable and for best performance. Under no circumstances must the foaming agent be brought in contact with an oil, fat, chemical or other material that might harm its function. The oil/wax used in moulds will not harm, since the foam by then will embedded in mortar. Water to prepare the mix has to conform to general requirements for concrete.

Foam & Foaming Agent: Foam is a dispersion of a gas in liquid or in solid. Foam is produced by distribution of gas in a liquid under the influence of a foaming medium, such as soap, oil, acid or a wetting agent. During the production small bubbles are formed and are separated from liquid by a membrane. Clearly, there are many different types of foams with various applications. Therefore, there are many different industries, which use foam-like products.

The density of the foamed concrete is a function of the volume of foam that is added to the cement paste. To ensure that the desired percentage air is entrained in the mixture, pre-foaming; where the foaming agent is aerated being added to the mixture is used. The aerated foaming agent, on mixing with the cement-based slurry entrains a controlled quality of air in uniformly dispersed discreet cavities.

Depending on an application using foam produced from a surfactant usually is not an environmental issue. However, in some countries this can be a religious concern/significance. This would be the case when using hydrolyzed protein-based surfactants that contain keratin or casein derivatives.

Surfactants are surface-active substance or agent [detergents, emulsifiers] that when added to water lowers surface tension and increases the "wetting" capabilities of the water, thus improving the process of wetting and penetrating that surface or material. When agitated forms a large mass of micro/macroscopic bubbles. With this device or process a surfactant or foam concentrate is diluted with water to form a foam solution. This solution is then injected with compressed air through a blending device or foam generator and the foam is produced from foam generator.

V. Mix Design

There is no standard method for proportioning foamed concrete (i.e., mix design), but it is a specified target plastic density that becomes a prime design criterion. On the basis of target plastic density, a theoretical mix design has to be formulated and site trials are undertaken and the results from the site trials are used as mix design for the foamed concrete. A tolerance on plastic density was considered about 100 kg/m^3 of the target plastic density. Assuming a target plastic density of 1850 kg/m^3

Since the foam concrete is in slurry form, higher water-cement ratio is required so assuming w/c is 0.60

Site Trials: Table 1: For Foam Concrete Mix – 1 (Containing Cement & Fly Ash)

Considering cement: fly ash in 1:1 proportion

Sr. No.	Cement (Kg)	Fly ash (Kg)	Water (lit)	Foam (Kg)	Foam (lit)	Density (Kg/m^3)
1	690	690	420	8	109	1808
2	700	700	420	8	109	1827
3	710	710	430	7.5	102	1857

Site Trials: Table 2: For Foam Concrete Mix – 2 (Containing Cement, Fly Ash & Sand)

Considering cement: fly ash in 1:0.5 proportion and cementitious material: sand in 1:1 proportion

Sr. No.	Cement (Kg)	Fly ash (Kg)	Water (lit)	Foam (Kg)	Foam (lit)	Density (Kg/m^3)
1	600	300	900	360	95	2167
2	550	275	825	330	102	1988

From the Site Trials following Proportions are Obtained and Will be used as Mixed Design of Foam Concrete:

As been discussed before, trial and error method were used in determining the most suitable mixture in preparing research samples, five trial mixes have been prepared during the research and from the site trials, the mixture with the lowest density is used for further investigation.

Table 3: Mixed Proportions for Foam Concrete

Sr. No.	Cement (Kg)	Fly ash (Kg)	Water (lit)	Foam (Kg)	Foam (lit)	Density (Kg/m^3)
1	710	710	-	430	102	1875
2	550	275	825	330	102	1988

VI. EXPERIMENTAL PROCEDURE

Foamed concrete mixtures with and without sand for same target plastic density are therefore used in this investigation and the method used to determine the physical (Density) as well as a specific structural property (compressive strength) of the foamed concrete mixtures.

6.1 Composition of Foam Concrete Mixture

The foamed concrete used in this research is produced under controlled conditions from cement, fly ash, sand, water and pre-formed foam. The cement used is 53 grade Ordinary Portland cement, locally available sand, fine fly ash IS certified having density 960 kg/m^3, foaming agent for produce the foam and water has been used for producing foam concrete.

Foam is a very important factor for the foam concrete. Foam was generated by using foam generator the output of generator is around 30 lit/min. for producing the foam foaming agent has been used, foaming agent is diluted with water in a ratio of 1:40 and then aerated to a density of 75 kg/m^3.

6.2 Curing

Lightweight Construction Methods requires a curing means and period identical to that of conventional concrete. It is essential that cement-based elements have moisture for hydration at an early age. This is particularly true in the presence of direct sunlight that is known to cause rapid dehydration of concrete surfaces; curing compound can be applied as an alternative barrier. Full time continuous curing has been done in the laboratory.

6.3 Compressive Strength

The 150 mm test cubes were cast in steel mould and de-moulded after ± 24 hours. It was, then, kept for curing in constant room temperature up to the day of testing. The cubes were crushed on a more sensitive Compression Testing Machine the usually used for normal concrete. Three cubes from the same mixture of foamed concrete were crushed and the average of the three results is used to define the strength of the mixture (According to IS: 516). Compressive strength of foamed concrete was recorded for 3, 7 and 28 days.

6.4 Density

The test specimens for this study have a dimension of 150mm x 150mm x 150mm. The initial density of the specimens as measured during manufacturing is casting density and it can be compared with designer density or in other words the target density. Test specimens are de-mounded within 24 hours of casting and after de-molding, each specimen is cured in constant temperature room for 3, 7 and 28 days. The density was again measure at the time of determination of compressive strength this density is known as test density.

VII. RESULTS AND DISCUSSION

In this heading, discussion will be focused on the performance of foamed lightweight concrete. The results presented are regarding the compressive strength test and density for both mixtures of the foamed lightweight concrete.

7.1 Experimental Result for Compressive Strength and Density

It can be seen that the compressive strength of foamed concrete is increases with age and it can be seen that the compressive strength of foamed concrete is low for lower density mixtures and increase with increase in density. The increment of voids throughout the sample caused by the foam in the mixture will lower the density. As a result, compressive strength will also decrease with the increment of those voids. It is observed that the compressive strength and density increases with age. The criteria for structural lightweight concrete are minimum 28-day compressive strength of 17 MPa and Dry density of 1850 kg/m^3. The compressive strength for both mixtures are less than 17 MPa, as a result reported in this investigation, it can be concluded that both the prepared foam concrete mixtures cannot be used for structural purpose, but can be used for making partition wall in buildings which will result in decrease in the self-weight of structure because the density is very low as compared to bricked masonry work. The density is directly related with compressive strength of foam concrete. This relationship between density and compressive strength is exponential, the value of the exponent varying with the size and distribution of the voids.

Table 4: (Test Result) F.C. Mix - 1

Sr. No.	Age (Days)	Compressive Strength (N/mm^2) / Density (Kg/m^3)			Average Result
1	3	3.49	3.05	3.05	3.20
		1466.67	1407.41	1422.22	1432.10
2	7	3.92	3.49	3.49	3.63
		1540.74	1466.67	1451.82	1486.42
3	28	8.28	7.85	8.72	8.28
		1674.07	1659.26	1688.89	1674.08

Table 5: (Test Result) F.C. Mix – 2

Sr. No.	Age (Days)	Compressive Strength (N/mm^2) / Density (Kg/m^3)			Average Result
1	3	5.23	4.80	6.10	5.38
		1762.96	1674.07	1718.51	1718.51
2	7	7.41	8.28	7.85	7.85
		1688.89	1822.22	1763.74	1738.27
3	28	13.52	12.64	12.21	12.79
		1881.48	1822.22	1748.15	1817.28

Results for Normal Weight Concrete (Conventional Concrete) Density of NWC = 2400 Kg/m^3

Table 6: Compressive strength with age

Age	Compressive strength (N/mm^2)
3	3.9
7	7.3
28	13.8

7.2 Specific Strength

The specific strength is a material's strength divided by its density. It is also known as the strength to weight ratio or strength to density ratio. Structural lightweight concrete is becoming more and more important in building practice as such material can provide mechanical and durability performance like normal weight concrete with higher strength-density ratio. In overall construction practices, lightweight concrete is used to reduce the dead load of a structure. Lightweight concrete can achieve similar strengths as standard concrete, and it produces a more efficient strength-to-weight ratio in structural elements

Table 7: Strength Density Ratio

Age	F.C.-1			F.C.-2			N.W.C.		
	Strength N/m^2	Density kg/m^3	Ratio N-m/kg	Strength N/m^2	Density kg/m^3	Ratio N-m/kg	Strength N/m^2	Density kg/m^3	Ratio N-m/kg
3	3200000	1432.1	2234.48	5380000	1718.51	3130.62	3930000	2300	1708.70
7	3630000	1486.4	2442.11	7850000	1738.27	4515.98	7390000	2300	3213.04
28	8280000	1674.1	4946	12790000	1817.28	7037.99	13800000	2300	6000

The density of foam concrete (300 to 1850 kg/m^3) is very low when compared to conventional concrete (2200 to 2600 kg/m^3), therefore, the self-weight of a structure built with foamed concrete would undoubtedly be reduced significantly, leading to tremendous savings in the use of reinforcement steel in the foundations and structural members. It is observed that the de-mounding of high-density foamed concrete is possible after 24 hours but for low density foamed concrete could not be possible, it required minimum 3 days for de-mounding period because their strength is very low and the cube shape can be change. The result recorded for Compressive Strength at 28 days for both mix samples are not more than 17 MPa, so these mixing proportions cannot be considered for making structural elements.

VIII. CONCLUSIONS

The density of Foamed Concrete is inversely proportional to the percentage of foam that is added to the slurry/mortar. The Compressive Strength and Density of Foam Concrete increases with age. The Compressive Strength of Foamed Concrete increases with increase in the Density. Fine aggregate had a beneficial effect on significantly increase in Compressive Strength of Foamed Concrete. The starting of Strength gain for foamed concrete is on higher side than that of normal weight concrete and Strength gain beyond 28 days is faster than normal weight concrete. The addition of fly ash of equal amount of cement makes it possible to gain the target strength with Age. This study has shown that the use of flay ash in Foam Concrete, can be greatly improves its properties. The mixed proportion for foamed concrete used in this research report cannot be used for structural purpose because there 28 days Compressive Strength is less than 17 MPa. Improved structural efficiency in terms of strength to density ratio resulting load reduction on the structure and substructure. Strength to Density ratio is much higher for foam concrete mix – 2 compared to conventional concrete.

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