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An Experimental Study on the Mechanical Properties of Steel Fibered Sand Replaced Foamed Concrete

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Abstract – *Light Weight Foamed concrete(LFC) has become most commercial material in construction industry for non-structural applications owing to its lesser density, stability and high thermal insulation properties. This research aims to develop an alternative for conventional concrete blocks for non-structural applications of masonry. The mechanical properties can be enhanced by the addition of steel fiber to foamed concrete and by replacing the sand with readily available waste product i.e., fly ash. Specifically, the mechanical behavior of foamed lightweight cubes and blocks under pure compression were investigated. Test results showed that the replacement of sand with fly ash almost doubled the compressive strength; addition of steel fiber further enhanced the compressive strength by about 4%. Foamed concrete blocks showed a reduction in density by10% to 15% with enhanced compressive strength.*

***Key Words*: Lightweight Foamed concrete; foam agent; steel fiber; fly ash; compressive strength**

1. INTRODUCTION

Light Weight Concrete (LWC) can be used for reducing the self-weight which represents a very large proportion of the total load on the structure. This can be achieved by the use of smaller sections and the corresponding reduction in the size of foundations. Light weight Foamed concrete (LFC) is one such light weight concrete. Furthermore, with foamed concrete the form work needs to withstand a lower pressure than would be the case with ordinary concrete, and also the total weight of materials to be handled is reduced with a consequent increase in productivity, it also gives better thermal insulation than ordinary concrete, the practical range of densities of lightweight concrete is between 300 and 1850kg/m ^{3}, the weight reduction of a concrete structure would require less structural steel reinforcement. It also reduces the cost of production and transportation of building components compared to normal concrete. The foamed concrete is considered as an economical solution in fabrication of large scale lightweight construction materials and components such as structural members, partitions, filling grades, and road embankment infills due to easy production process from manufacturing plants to final position of the applications [1].

In this study, the influence of steel fiber at a low volume fraction on strength of foamed concrete was investigated. A fiber concrete is a composite which consists of ordinary concrete and other materials such as fiber. Fiber addition into the lightweight concrete mixture will also increase the compressive strength. Addition of steel fibers can overcome the brittle properties of concrete. The mechanical properties of foamed concrete also differ according to a different type of mixture and its composition. Therefore, this research also investigates the physical and mechanical properties of partially/fully sand replaced foamed concrete with fly ash. Fly ash was used as fine aggregate. Fly ash is a residual material of energy production using coal, which has been found to have numerous advantages for use in the concrete by reducing permeability, increasing ultimate strength, reducing bleeding, better surface finish and reducing heat of hydration. Significance of this study is to analyse the properties of sand replaced fly ash foamed concrete in the fresh and hardened states.

2. EXPERIMENTALPROGRAM

2.1. Materials

Cement used for project work is Ordinary Portland Cement of 53 grade. Table 1 shows the properties of cement and fine aggregate used. M-Sand is used as the fine aggregate which is replaced with class F fly ash. Foam agent is a concentrated solution of surfactants, which if to be used, should be diluted with water. Foam agent added is sodium lauryl sulphate. Steel fiber with an aspect ratio of 60 is used.

Table 1: Material Properties

PROPERTIES	VALUES	CODAL VALUES
Specific gravity of cement	3.125	3.12 – 3.14
Standard consistency	30%	26 – 33 %
Initial and final setting time	65 min and >3hours	> 30 min < 600 min
Specific gravity of fine aggregate	2.66	2.6-2.8
Fineness modulus	3.553	
Water absorption	10.2%	<12%
Specific gravity of fly ash	2.5	<2.8

2.2 Methodology

The present experiment is to make LFC without coarse aggregate with a mix of 1:1 by weight of cement and sand and with a water cement ratio of 0.45 is used throughout the

tests of mortar mix. Four variations of foam (5%, 10%, 15% and 20%) were added and fiber content of 0%, 0.25%, 0.5% and 1% of volume of concrete were added. Varying proportions of fly ash (0%, 25%, 50%, 75% and 100%) was replaced with sand. Concrete blocks were made with constituents as cement, sand and fly ash with varying proportions with and without steel fibers.

2.3 Test setup

Typical mortar cubes of size 70.7 x 70.7 x 70.7 mm and 150 x 150 x 150 mm were used. Blocks for foamed concrete are made by 300 x 200 x 150 mm specimens. All the cubes and blocks were subjected to compressive test and density check at every 7day, 28day and 56 day were done. A total of 3 specimens for each variation were casted.

3. TEST RESULTS

With foam addition, the foamed concrete shows reduction in compressive strength. With increase in foam addition, both the density and compressive strength gets decreased. Compressive strength is very low when foam addition is about 20%. Thus considering density and compressive strength, the optimum dosage is adopted as 5%. Table 1 presents the density and chart 1 shows the variation of 3, 7 and 28 day compressive strength of mortar cubes with different percentages of foam.

Table -1: density with various percentage of foam

Foam % by weight of cement	Dry Density (kg/m^3)		
	3days	7days	28days
5%	1712	1706	1699
8%	1680	1676	1664
10%	1601	1597	1586
15%	1568	1561	1556
20%	1540	1536	1530

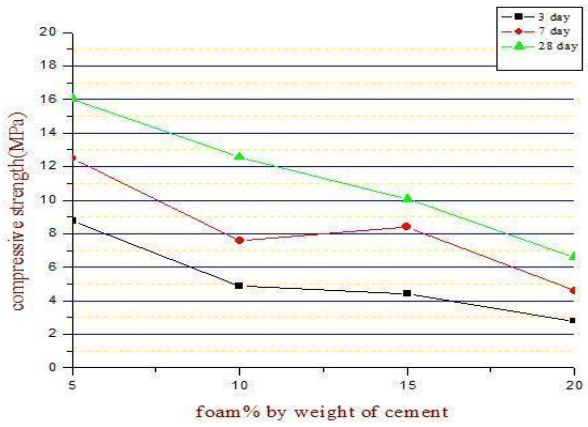

Chart-1: Compressive Strength with Various Percentages of Foam

3.1 Density and Compressive Strength

Table 2 shows the density and compressive strength of foamed concrete with fiber addition. With the addition of steel fiber, there is a slight increase of around 4% in density. Added fiber can still spread randomly as the fiber serves as reinforcement. Steel fiber is also tightly glued with concrete mix forming a compact and solid mass. The inclusion of fiber into LFC is one approach to enhance its durability properties. Compressive strength goes on increasing upto 0.5% of steel fiber by percentage volume of specimen beyond which it decreases. The inclusion of low volumetric fractions of short fiber will reduce the impact of early age shrinkage on concrete durability. It acts as the concrete reinforcement when the concrete cracks.

Table 2: Results of density and compression test with addition of steel fiber

Steel fibre by % volume of specimen	Density(kg/m^3)	Compressive strength(MPa)
0%	1699	16.04
0.25%	1727	17
0.5%	1731	18.2
0.75%	1741	14.4
1%	1752	12

Table 3 shows the results for density and compressive strength of foamed concrete with sand replacement by fly ash. Density of concrete decreases with increase in sand replacement. It achieves minimum density when the sand is replaced 100% with fly ash. Density of concrete decreases marginally though higher volume of material is packed in same volume by partial replacement of sand with fly ash. This may be because of fly ash being lighter material than sand. But since sand with lower volume was replaced by weight by fly ash with higher volume, better packing is achieved to accommodate higher volume in one cubic meter of concrete. Compressive strength of foamed concrete increases with replacement of sand with fly ash, it gives around same values for complete replacement of sand with fly ash and 75% replacement of sand.

Table 3: Results of density and compression test for density and compressive strength of foamed concrete with sand replacement

Sand replacement % by wt.of sand	Density(kg/m^3)	Compressive strength(MPa)
0%	1901	16.04
25%	1728	15.4
50%	1714	28.2
75%	1690	36.8
100%	1603	36

Table 4 shows the results for density and compressive strength of fiber added sand replaced foamed concrete. With addition of steel fiber there is increase in compressive strength upto 0.75% beyond which it decreases. Therefore, 0.75% of steel fiber addition is considered as optimum. This increase in strength upto a limit is because of the

confinement of fiber reinforcement, beyond which it have a detrimental effect. This high dosage of steel fiber will reduce the workability and hence it reduces the compressive strength.

Table 4: Results of fibre added sand replaced foamed concrete

Steel fibre by % volume of specimen	density(kg/m^3)	Compressive strength(MPa)
0%	1690	36.8
0.25%	1698	30.8
0.5%	1706	32.4
0.75%	1720	38.2
1%	1731	24.4

Foamed concrete blocks were made with cement, fly ash and sand proportion of 1:0.75:0.25 with/without steel fibers. Also, blocks without sand were made in cement to fly ash proportions of 1:1 and 1:2. Comparison with commercially available blocks was also carried out. Table 5 and Table 6 give the density and compressive strength of foamed concrete blocks with varying proportions.

Table 5: Density and compressive strength of foamed light weight blocks

Cement : fly ash : Sand ratio = 1 : 0.75 : 0.25		
Steel fiber by % volume of specimen	**density(kg/m^3)**	**Compressive strength(MPa)**
0%	1555	20
0.75%	1612	21

Table 6: Density and compressive strength of foamed light weight blocks

Cement : fly ash		
mix	**density(kg/m^3)**	**Compressive strength(MPa)**
1:1	1000	20
1:2	888	19

From the table it can be concluded that the density of light weight fly ash foamed concrete is much lesser compared with locally available solid blocks, which brings down the dead load of structure resulting in reducing the size of beams and columns for high rise buildings. The overall expense of foamed light weight block with and without steel fiber was calculated and compared with the locally available blocks which is tabulated in Table 7.

Table 7 : Cost evaluation of a single foamed concrete blocks and locally available blocks

Mix	Ratio	Cost (in Rs.)
Cement: fly ash: sand	1: 0.75: 0.25	Rs.35
Cement: fly ash	1:1	Rs.32
Cement: fly ash: sand:0.75% steel fiber	1: 0.75: 0.25	Rs.130
Cement: fly ash	1:2	Rs.21

4.CONCLUSIONS

Based on the results, the following conclusions are derived:

- Foamed concrete which is made with the help of foam where the dosage is optimized as 5% of weight of cement makes the concrete more porous and light weight.
- Addition of steel fibre to the mix increases the compressive strength. It is useful when the cost of laying does not get considered such as in shallow foundations in dwelling houses in the form of reinforced concrete slabs or strip foundation grids.
- Fly ash which is a waste product from coal industry replaces sand which makes the foamed concrete much less denser and stronger. 0.75% replacement and complete replacement of sand gives much larger comparable strength.
- Fly ash which is freely and readily available can make foamed concrete cost effective.
- Addition of steel fibre to fly ash foamed concrete increases the compressive strength which is applicable in road sub base in bridges where the loads impose on bridges can be reduced.
- Foamed light weight blocks can be used for wall panels, insulating panels over the wall to make it more thermal insulating.
- Fly ash used enables the large utilization of waste product which brings down the exploitation of natural resources and reduces the emission of green house gases.

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