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An Experimental Study on the Durability Properties of Foam Concrete with Addition of Natural Fibers

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ABSTRACT

Fibers are usually used in concrete to control cracking due to plastic shrinkage and due to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion, and shatter resistance in concrete. Generally fibers do not increase the flexural strength of concrete, and so cannot replace moment–resisting or structural steel reinforcement. Indeed, some fibers actually reduce the strength of concrete. The amount of fibers added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibers), termed "volume fraction" (V_f). V_f typically ranges from 0.1 to 3%. The aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). Fibers with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the fiber's modulus of elasticity is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increasing the aspect ratio of the fiber usually segments the flexural strength and toughness of the matrix. However, fibers that are too long tend to "ball" in the mix and create workability problems. The inclusion of fiber reinforcement in concrete, mortar and cement paste can enhance many of the engineering properties of the basic materials, Such as fracture toughness, flexural toughness, flexural strength and resistance to fatigue, impact, thermal shock and spalling. Foamed concrete has become most commercial material in construction industry. People in industries came out with the new mix design of foamed concrete to meet the specification and the requirement needed, this is because foamed concrete has the possibility as alternative of lightweight concrete for producing intermediate strength capabilities with excellent thermal insulation, freeze-thaw resistance, high impact resistance and good shock absorption. It is known to employ foam in concrete to improve its use characteristics; however, it is difficult to provide and maintain correct ratios of foam producing agent in water supplied to the dry concrete mix, and correct ratios of foam to concrete, particularly at the job site, and it is found that such ratios can and do vary greatly at different job sites whereby the quality, pumpability, extrudability, and finishing characteristics of the concrete vary and suffer. There is need for simple, low-cost, and effective apparatus and method to provide required quality control of the ratios referred to and enable production of high quality concrete, in terms of pumpability, extrudability weight control, insulative and fire proofing capability, as well as other desirable qualities.

Keywords: Aspect Ratio, Extrudability, Foam, Permeabilit, Pumpability, Reinforcement, Spalling,

I. INTRODUCTION

1.1 Foam Concret:

Foamed concrete is cement-based slurry into which stable and homogeneous foam is mechanically blended, either by mixing or by injecting. When compared with normal concrete, coarse aggregate is replaced with foam in producing foamed concrete. In the late 1980's significant research and development was conducted in the Netherlands. This helped establish foamed concrete as an accepted building material. In the UK, British Cement Association (BCA) initiated research on foamed concrete in 1990. In addition to the BCA research, the recommendations for use of foamed concrete in highway reinstatement works in the Horne report and the Highways Authorities and Utilities Committee (HAUC) Specification for the Reinstatement of Openings in Highways helped increase production and broaden the scope of applications of foamed concrete in the UK in the last 20 years. Foamed concrete is now being used in wide range of construction applications. However, in India no major project applications were found may be due to lack of awareness and confidence on the material and availability of technology. Foamed concrete is a material suitable for a wide range of purposes and applications such as roofing insulation, trench reinstatement, void filling, road sub-base, floor construction, sewer infilling, storm drain infilling, culvert abandonment's filling, culvert's or bridge approach, subway abandonment's filling, bridge strengthening, bridge decks, large diameter shaft and tunnel abandonment's bridge abutments, slope protection, basement infill, vault infill, pipeline infill, tank infill, fuel tank infill, swimming pool infill, raising the levels of flooring, under floor infilling, train platform infilling/re-profiling, floor and roof screeds, panels and blocks production, wall casting, complete house casting, sound barrier walls, subsurface for sport arenas, aircraft arresting beds, road crash barriers, floating barge, jetties platform, floating homes, soil stabilisation and as a semi structural material . Figure 1 illustrates few construction applications of foamed concrete.

In this project we have mixed foam concrete with sisal fibre. In this project the aim is to study the strength characteristics of the foam concrete with sisal fibre.

1.2 Sisal Fibre:

Sisal, with the botanical name ***Agave sisalana***, is a species of *Agave* native to southern Mexico but widely cultivated and naturalized in many other countries. It yields a stiff fibre used in making various products. The term sisal may refer either to the plant's common name or the fibre, depending on the context. It is sometimes incorrectly referred to as "sisal hemp", because for centuries hemp was a major source for fibre, and others were named after it. The sisal fibre is traditionally used for rope and twine, and has many other uses, including: paper, cloth, wall coverings, carpets, and dartboards. Sisal fibre is one of the most widely used natural fibres and is very easily cultivated. Though native to tropical and sub-tropical North and South America, sisal plant is now widely grown in tropical countries of Africa, the West Indies and the Far East. A sketch of a sisal plant is shown in fig.1 and sisal fibres are extracted from the leaves. The chemical composition of sisal fibres have been reported by several groups of researchers. For example, Wilson indicated that sisal fibre contains 78% cellulose,8% lignin,10% hemi-celluloses,2% waxes and about 1% ash by weight; but Rowell found that sisal contains 43-56% cellulose,7-9% lignin,21-24% pentosan and 0.6-1.1% ash. More recently, Joseph et al reported that sisal contains 85-88% cellulose. These large variations in chemical compositions of sisal fibre are a result of its different source, age, measurement methods, etc. Indeed, Chand and Hashmi showed that the cellulose and lignin contents of sisal vary from 49.62-60.95 and 3.75-4.40%, respectively, depending on the age of the plant.

II. HISTORICAL REVIEW

The concept of using fibers as reinforcement is not new. Fibers have been used as reinforcement since ancient times. Historically, horsehair was used in mortar and straw in mud bricks. In the early 1900s, asbestos fibers were used in concrete. In the 1950s, the concept of composite materials came into being and fiber-reinforced concrete was one of the topics of interest. Once the health associated with asbestos were discovered, there was a need to find a replacement for the substance in concrete and other building materials. By the 1960s, steel, glass (GFRC), and synthetic fibers such as polypropylene fibers were used in concrete. Research into new fiber-reinforced concretes continues today.

2.1 Materials, Mix Proportioning and Production:

2.1.1 Cement:

Ordinary Portland cement is a major cementations material in foamed concrete. High-early-strength cements, pozzolana cement, rapid hardening cement, high alumina calcium sulfo aluminate cement were also successfully used in producing foamed concrete. In general, cement varies from 250-500kg/m^3.

2.1.2 Fine Aggregate:

The maximum size of aggregate particles for satisfactory preparation of foamed concrete is usually smaller than 2.5mm. However, if the size of the sand is decreased, compressive strength of foamed concrete increases. For densities 1000kg/m^3 or above fine aggregate is preferred. At lower densities fine aggregate can either fully or partially be replaced with pozzolanic materials such as fly ash. Light-weight coarse aggregates such as shale, slate, sintered fly ash, perlite and vermiculite as well as natural light-weight aggregates such as pumice, scoria or tuff can be used in foamed concrete.

2.1.3 Foam:

Foaming agents or surfactants are diluted in water to produce surfactant solution and thereby foam. Protein based or synthetic foaming agents are used to produce foam. Depending on the surfactant type and quality, dilution ratios from 1:5 to 1:50 were adopted to produce surfactant solution. Normally, protein based surfactants gives smaller bubble size and stronger bubble structure. These surfactants give higher strength than synthetic surfactant. Depending on ionic charges, there exists three types of surfactants which are anionic (negatively charged molecules), cationic (positively charged molecules) and amphoteric (both negative and positive molecules). Of the three kinds, anionic surfactants are used in majority of the cases. The importance of the electric charges of pre-foamed foam molecules in cement mortar is still unclear. However, it was believed that amphoteric surfactants are more stable in concrete environment because of its dual charge nature.

III. INITIAL TESTS ON MATERIALS

For sands: following are some test procedures for sand

- ✓ Specific gravity
- ✓ Sieve analysis
- ✓ Fineness modulus of sand
- ✓ Bulking of sand

Specific Gravity:

Specific gravity of the soil solids is useful in the determination of void-ratio, degree of saturation, etc., besides the 'Critical Hydraulic gradient', and 'Zero-air-voids' in compaction. It is useful in computing the unit weight of the soil under different conditions and also in the determination of particle size by wet analysis. Hence, the specific gravity of soil solids should be determined with great precision. The standardised detailed procedure for the determination of the specific gravity of soil solids is contained in the Indian Standard Specification – "IS: 2720 (Part-III)-1980, First Revision-Method of Test for Soils, Part III, Determination of specific gravity". First, the weight of the empty pycnometer is determined ($W1$) in the dry condition. Then the sample of oven-dried soil, cooled in the desiccators, is placed in the pycnometer and its weight with the soil is determined ($W2$). The remaining volume of the pycnometer is thengradually filled with distilled water or kerosene. The entrapped air should be removed eitherby gentle heating and vigorous shaking or by applying vacuum. The weight of the pycnometer, soil and water is obtained ($W3$) carefully. Lastly, the bottle is emptied, thoroughly cleaned and filled with distilled water or kerosene, and its weight taken ($W4$).

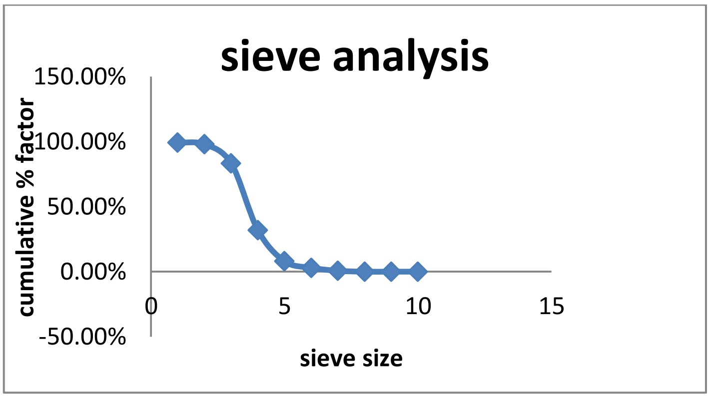
Sieve Analysis:

Basically the soils are classified as two types:

- ✓ Fine grained soils
- ✓ Coarse grained soils

The general procedure may be summarised as follows:

A series of sieves having different-size openings are stacked with the larger sizes over the smaller. A receiver is kept at the bottom and a cover is kept at the top of the assembly. The soil sample to be tested is dried, clumps are broken if necessary, and the sample is passed through the series of sieves by shaking. An automatic sieve-shaker, run by an electric motor, may be used; about 10 to 15 minutes of shaking is considered adequate. Larger particles are caught on the upper sieves, while the smaller ones filter through to be caught on one of the smaller underlying sieves. The material retained on any particular sieve should naturally include that retained on the sieves on top of it, since the sieves are arranged with the aperture size decreasing from top to bottom. The weight of material retained on each sieve is converted to a percentage.



Fineness Modulus of Sand:

Fineness modulus for fine aggregate that can be used in concrete, the recommended range of fine aggregate is 2.3-3.1 for coarse aggregate fineness modulus is 7.

Fineness modulus of sand depends on the results of sieve analysis. In this test we consider standard sieve sizes for calculation of fineness modulus of sand, above 150 micron sieve's cumulative percentage retained details are considered.

Basically fineness modulus is the ratio of sum of cumulative percentage retained to hundred

Fineness modulus = sum of cumulative percentage/100

Water Absorption of Sand:

A clean container of non-corrodible material is taken and its empty weight along-with the lid is taken. A small quantity of moist soil is placed in the container, the lid is replaced, and the weight is taken. The lid is taken removed and the container with the soil is placed in a thermostatically controlled oven for 24 hours, the temperature being maintained between 105-110°C. After drying, the container is cooled in desiccators, the lid is replaced and the weight is taken.

IV. MIX PROPORTIONS AND PRODUCTION OF MIX:

4.1 Mix Proportions:

First the density of the mix is fixed to 1200 kg/m³. The mix proportions of the materials are as shown in the table below:

Cement(kg/m³)	Water(kg/m³)	Sand(kg/m³)	Foam(kg/m³)
250	125	825	24

In the above proportions the water-cement ratio is taken as 0.5

4.2 Production of Base Mix:

Separately weight the required quantity of mixing materials (sand, cement and water) separately and keep them aside. First the inner walls of the mixer should be made wet to reduce the water absorption by inner walls of mixer. Add half quantity of cement and sand to the mixer and start the mixer. Slowly add the water along the inner walls of the mixer. After some time add remaining amount of sand and cement to the mixer. Allow the mixer for few minutes to get a equivalent mix. This mix is called base mix.

4.3 Generation of Foam:

It is a major object of the invention to provide method and process apparatus, overcoming the above difficulties and problems, and providing for efficient metering and blending of foam producing chemical with water or other aqueous fluids, and mixing with air under pressure, to produce foam added to concrete mix, as at a batching plant, in correct ratio. The method may be categorized as including the steps:

a. Supplying a synthetic resinous foaming agent, in liquid form,
b. Combining the foaming agent with water, to form a liquid mix, and pressurizing the mix,
c. Sub-dividing the mix into droplets, in a confined flowing stream
d. And reducing the stream confinement,
e. Whereby the droplets expand as foam.

Figure 4.1 Foam generation

4.4 Production of Foam Mix:

After formation of base mix, the readily generated foam is added to the base mix within very short time and switch on the mixer and allow it to run for few minutes for efficient mix. Check the density of the mix it should be very near to 1200 kg/m³.

Figure 4.2. Foam sample

4.5 Mixing of Fibre:

The sisal fibre is mixed by cutting it into small parts of length 2-3 cms. The sisal fibre is added to the foam mix according to the desired percentages of cement weight. Here the fibre is added in the percentages as shown in below table.

Table 4.1. Different mix proportions

MIX	Fibre added (% of cement weight)
MIX1	0
MIX 2	0.67
MIX 3	1.33
MIX 4	1.67
MIX 5	2.00

The fibre is made separated one from the other to avoid clumsiness. That fibre is weighted and taken out the required quantity and added to the foam mix present in the mixer as shown below. The mixer is started and allowed to run for few minutes.

Figure 4.3. Sisal fiber sample

4.6 Filling of Mix Paste into Moulds:

After collecting of desired mix, the cement paste is filled in the moulds. The lubricant should be applied to the inner walls of the moulds to free removal of specimen from the mould after hardening.

Figure 4.4. Concrete moulds

4.7 Curing of Specimens:

Curing means taking steps to keep the concrete under the right temperature and moisture conditions during the first few days of hardening after placement. Proper curing is vital because the concrete will eventually be much harder and stronger if it is cured correctly. The basic idea behind proper curing is to allow this reaction to continue as long as practical by maintaining a suitable curing temperature, usually 50°f to 90°f, and by keeping the concrete wet. If the temperature of the concrete drops below 50°f, hydration begins to slow, and if the water in the mix freezes, the concrete will be ruined. Also, if too much water escapes from the concrete, hydration will stop altogether. The longer favourable conditions are maintained, the longer the concrete will cure, resulting in a better product.

Figure 4.5. Curing specimens

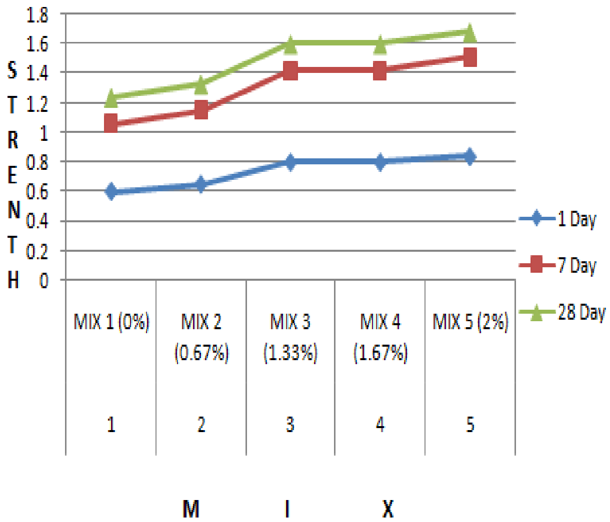
V. TESTS ON CONCRETE

5.1 Compressive Strength:

The compression test shows the compressive strength of hardened concrete. The compression test shows the best possible strength concrete can reach in perfect conditions. The compression test measures concrete strength in the hardened state. Testing should always be done carefully. Wrong test results can be costly. The testing is done in a laboratory off-site. The only work done on-site is to make a concrete cylinder for the compression test. The strength is measured in Mega Pascals (MPa) and is commonly specified as a characteristic strength of concrete measured at 28 days after mixing. The compressive strength is a measure of the concrete's ability to resist loads which tend to crush it. The compressive strength tests on final concretes were carried out in a compressive strength-testing machine which of capacity 2000 kN in which initial mixes were tested. But 100 mm cubes were used for final mixes. The test was performed at 7, 28 and 90 days for these mixes. The specimens were tested immediately after the cubes taken from curing tank in saturated surface dry condition.

Figure 5.2. Compressive testing machine

MIX	Compressive strength in MPa		
	1 day	7 days	28 days
MIX 1	0.6	1.06	1.24
MIX 2	0.65	1.15	1.33
MIX 3	0.8	1.42	1.6
MIX 4	0.8	1.42	1.6
MIX 5	0.84	1.51	1.68

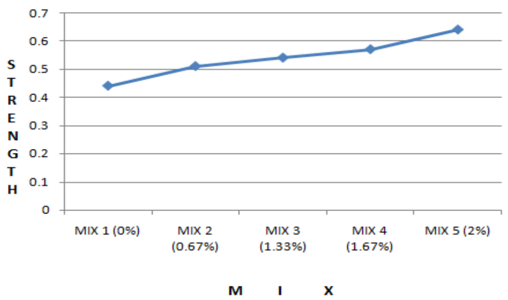


5.2 Split Tensile Strength:

The split tensile strength test was conducted in the same compression-testing machine. Cylinders of 100 mm x 200 mm (diameter x height) were used for the split tensile test. The test specimen was placed between two platens with two pieces of 3mm thick and approximately 25mm wide plywood strip on the top and bottom of the specimen. The split tensile test was conducted at the age of 90 days. Place the sample cylinder horizontal in the U.T.M and continuously apply load on it then the failure of cylinder starts at a certain point of load then this is considered as tensile strength of the specimen. The split tensile strength of the specimens are increases with increase in fibre percentage. It is due to tensile strength of fibre. The following value shows the tensile strength of the normal foam concrete and foam concrete with fibre.

Figure 5.3. Split tensile test

S.NO	MIX	SPLIT TENSILE STRENGTH (28 DAYS) Mpa
1	MIX 1	0.44
2	MIX 2	0.51
3	MIX 3	0.54
4	MIX 4	0.57
5	MIX 5	0.64



5.3 Flexure Test:

The loading arrangement to test the beam specimens for flexure shown in fig 3.6. The test is conducted on universal testing machine. The beam element is simply supported on two rollers of 4.5 cm diameter over a span of 450 mm. The element is checked for its alignment longitudinally and adjusted if necessary. Required packing is provided using rubber material .care was taken to ensure that the two loading points were at same level. The loading was applied on the specimen through hydraulic jacks and was measuredUsing universal testing machine. The load is transmitted to the beam element through the I-section and two 16mm diameter rods spaced at a distance of 150mm. for each increment of loading, the deflections at the center of span are recorded using dial gauges. Continuous observations were made and the cracks were identified with the help of magnifying glass. Well before the ultimate stage, the deflect meters were removed and the process of load application was continued till to continued total failure and at this stage the load is recorded as ultimate load.

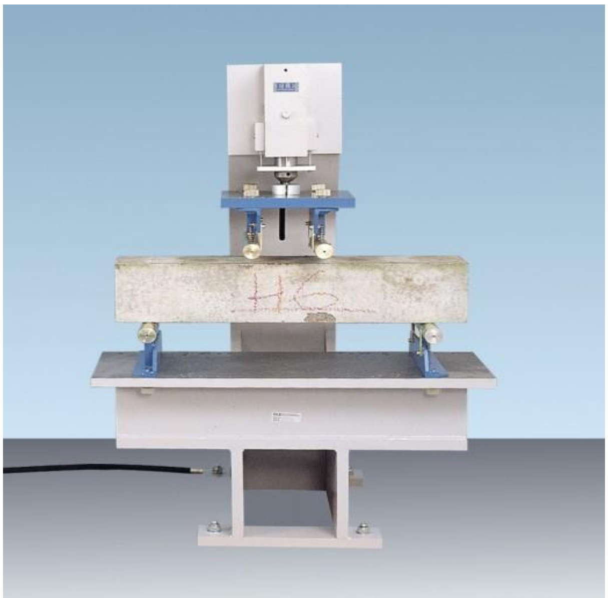


Figure 5.4. Flexural strength setup

S.NO	MIX	FLEXURAL STRENGTH (28 DAYS) Mpa
1	MIX 1	0.49
2	MIX 2	0.56
3	MIX 3	0.58
4	MIX 4	0.64
5	MIX 5	0.68

VI. CONCLUSIONS

From the brief work carried out in this investigation following tentative conclusions can be drawn.

1. From practical observations the density of foam concrete is found to be nearly same with addition of fibre.

2. From the values we got in the previous chapters, it is clear that the strength of the foam concrete is increases with increase in percentage of fibre added.
3. The strength of the foam concrete without fibre is 0.6 MPa and with finre is0.65 MPa this shows the increase in strength by adding fibre.
4. The target mean strength of concrete is obtained at addition of 2% of fibre.
5. Cylinder compressive strength is observed to vary from 1.24MPa to 1.68MPa for 28 days curing.
6. The strength of the specimens is increased by increase in curing time.
7. The strength of the specimens according to curing duration is of following order
   28 days > 7 days > 1 day
8. From the practical observations the sisal fibre gives the tensile strength to the specimen.

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