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EXPERIMENTAL STUDY ON COMPRESSIVE AND SPLIT TENSILE STRENGTH OF FOAMED CONCRETE USING STONE DUST

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Abstract – *This paper facilitates the use of stone dust in place of coarse sand. Stone dust and coarse sand more or less have same properties. Foam concrete is a lightweight concrete. A study has been undertaken to study the compressive and split tensile strength of foamed concrete replacing coarse sand with stone dust. Foamed concrete of density 1000 kg/m³ was prepared taking cement: sand: water as 1:1.5:0.35. In another set of specimens sand was replaced with stone dust and the ratio was kept same as above. Foam was prepared using protein based foaming agent mixing it with water in ratio 1:40. 12 cubes of size 150*150*150 mm were prepared with coarse sand and 12 cubes were prepared with stone dust. These cubes were tested for 1, 7 and 28 days curing and compressive strength is determined. Similarly, 12 cylinders of size 150*300 mm are prepared with coarse sand and 12 cylinders are prepared with stone dust. These cylinders are also tested for 1, 7 and 28 days curing and split tensile strength is determined. Comparing the compressive and split tensile strength of foamed concrete with stone dust to that of foamed concrete with coarse sand shows that the strength of foamed concrete increases when stone dust is used.*

Key Words: **Foamed concrete, Foaming agent, Stone dust, Protein based, Compressive strength, Split tensile strength.**

1. INTRODUCTION

Foamed concrete also known as foamcrete, CLC or reduced density concrete is a light weight concrete. The light weight of foamed concrete is generally due to the absence of coarse aggregate. It is a cement based slurry with a minimum of 20% (per volume) foam entrained into the plastic mortar. This mixture may also include aggregates or chemicals added to change its physical properties. It is a lightweight material with low density and limited strength in most application. Density of foam concrete usually varies from 400 to 1600 kg/m³. It is typically a self levelling and compacting material thai is resistant to cracking and shrinkage than standard concrete mixes.

History of foamed concrete reckons that study on the properties of foamed concrete started in 1950s and 1960s. Later on new admixtures were added and the properties of foamed concrete were studied in 1970s. Foamed concrete consists of a slurry of cement, sand and water. This slurry is mixed with foam. This foam is created using protein based foaming agent. Foaming agent when mixed with water produces foam. This slurry of cement, sand, water and foam when becomes hardened results in a light weight concrete known as foamed concrete.

The major constituent used in foamed concrete is foam. Foam is produced by mixing protein or synthetic based foaming agent with water and passed in air generator. Protein based foaming agent is prepared with raw material in presence of $Ca(OH)_2$ and a small portion of $NaHSO_3$. Synthetic foaming agent are such chemicals which reduce the surface tension of liquid and commonly used globally to make blocks, bricks, CLC etc.

The use of lightweight foamed concrete offer many benefits and advantageous particularly cost saving, fast completion and easy application compared to other materials such as steel and timber. Lightweight foamed concrete is characterized by its low compressive strength and high insulation against heat and sound. The compressive strength and other functional properties of lightweight foamed concrete are greatly influenced by the amount of air content introduced by foaming agents. The application of lightweight foamed concrete in civil engineering works is very broad as it can be used in almost every parts of building from the superstructure right down to the substructure, including wall panels and roofing. Any conventional panels or masonry units used for load and non-load bearing walls using normal concrete can be replaced directly by foamed concrete panels and units. Very low density lightweight foamed concrete can be used as thermal and sound insulation panels, filtering media and floating blocks for fishery purposes. Lightweight foamed concrete can also be used to cast elements for architectural purposes, pottery, void filling, trench reinstatement, foundation raising and swimming pool. In highway construction, lightweight foamed concrete can be applied as soil filling for sub-base, bridge abutments and bridge embankment. It is worth noting that the use of

lightweight foamed concrete is popular in other countries such as Europe, Japan and United Kingdom.

The main objective of this research work is to facilitate the use of stone dust in place of coarse sand in foamed concrete. Previous research works indicate that stone dust can be successfully used in place of coarse sand in normal concrete. But stone dust has never been used with foamed concrete.

2. MATERIALS

The main constituents of foamed concrete are as follows:

2.1 Cement

Ordinary Portland cement is commonly used, but rapid hardening cement can also be used if necessary. Foam concrete can incorporate a wide range of cement and other combination. The cement that is used should be free from any lumps and fresh.

S. No.	Characteristics	Test Result	Standard Result (Acc. To IS Code)
1.	Specific Gravity	3.159	3.15
2.	Fineness Modulus	6%	Not above 10%
3.	Initial Setting Time	49 minutes	Not less than 30 minutes
4.	Consistency	32%	30%
5.	Compressive Strength	44.7 N/mm^2	Not below 43 N/mm^2

2.2 Sand or Stone Dust

The maximum size of sand used can be 5mm. Use of finer sands up to 2mm with amount passing through 600 micron sieve range from 60 to 95%. Stone dust is a substitute of river bed sand or fine aggregate for construction purposes. The size of stone dust is under 4.7mm. Because of quickly developing of construction industry, the interest for stone dust has expanded enormously, bringing about lack of reasonable river bed sand in most piece of the word. Because of the exhaustion of good quality river sand for the utilization of construction, the utilization of stone dust has been expanded. The cement amount required will be less by using stone dust. Interest for stone dust for making concrete is expanding now-a-days as river sand can't take care of the rising demand of construction activities.

Description	Properties of Stone Dust
Fine Sand (0.425 mm to 0.075 mm)	27.1% by weight of stone dust
Medium Sand (2 mm to 0.425 mm)	44.8% by weight of stone dust
Coarse Sand (4.75 mm to 2 mm)	28.1% by weight of stone dust
Zone of Fine Aggregate	Zone II
Specific Gravity	2.64

2.3 Foam

Foam for foamed concrete is made from a concentrated foaming agent. The foam is made using a foam generator. In the foam generator the foaming agent is diluted in water to make a pre foaming solution and then the pre foaming solution is expanded with air into foam. The bubbles are stable and able to resist the physical and chemical forces imposed during mixing, placing and hardening of the foamed concrete. Between 75 and 85% of the bubbles are of 0.3 to 1.5 mm in diameter.

2.3.1 Foaming Agent

A chemical which facilities the process of forming foam and enables it with the ability to support its integrity by giving strength to each single bubble of foam is known as foaming agent. It may categorize in two parts:

1. Protein based foaming agent
2. Synthetic foaming agent

Protein based is commonly used for the low density and for higher densities synthetic foaming agents were preferred. Foam can create through forcing the chemical, air and water by restriction which results foam formation. Synthetic foam requires less energy while protein foams need more. Energy required during the foam formation decides its quality.

2.3.1.1 Protein based foaming agent:

It made to form light weight concrete and other concrete materials. Foam produce no reaction on concrete but it serves as a layer which is air trapped and forms no fumes or toxic. Protein based foaming agent requires comparatively more energy to make foam. It is prepared with raw material in presence of $Ca(OH)_2$ and a small portion of $NaHSO_3$. For improving the stability of foaming agent it is modified with

the addition of several kinds of gel and surfactants. Few significant improve the workability of foaming agent such as addition of alkyl benzene sulfonate etc.

2.3.1.2 Synthetic Foaming Agent:

CLC concrete has very good potential which helps to structure the cellular lightweight applications. Using right category of foaming agent makes a huge difference in products such as the mechanical properties of concrete and it resistance etc. Synthetic foaming agents are such chemicals which reduce the surface tension of liquid and commonly used globally to make blocks, bricks, CLC concrete etc where the high density is needed and it requires less energy for formation as compared to other foaming agents. It is highly recommended to use in the constructional fields where requirement of light weight concrete is increasing by time.

2.4 Water

Water cement ratio in foam concrete is usually kept between 0.35 to 0.60.

3. PROPERTIES OF FOAM CONCRETE

3.1 Fresh state properties:

As foam concrete cannot be subjected to compaction or vibration the foam concrete should have flow ability and self-compact ability. These properties are evaluated in terms of consistency and stability of foam concrete.

3.1.1 Consistency: Flow time using marsh cone and flow cone spread tests are adopted to assess the consistency of foam concrete. The consistency reduces with an increase in volume of foam in the mix, which may be attributed to the reduced self-weight and greater cohesion resulting from higher air content. Adhesion between the bubbles and solid particles in the mix increases the stiffness of the mix.

3.1.2 Stability: The stability of foam concrete is the consistency at which the density ratio is nearly one (the measured fresh density/design density), without any segregation and bleeding.

3.2 Physical properties

3.2.1 Drying shrinkage

Foam concrete possesses high drying shrinkage due to the absence of aggregates, i.e., up to 10 times greater than those observed on normal weight concrete. Autoclaving is reported to reduce the drying shrinkage significantly by 12–50% of that of moist-cured concrete due to a change in mineralogical compositions. The shrinkage of foam concrete reduces with density which is attributed to the lower paste content affecting the shrinkage in low-density mixes.

3.2.2 Density

Due to its low density, foam concrete imposes little vertical stress on the substructure - a particularly important attribute in areas sensitive to settlement. Heavier density (1000 kg/m^3+) foam concrete is mainly used for applications where water ingress would be an issue - infilling cellars, or in the construction of roof slabs for example.

3.2.3 Well-Bonded Body

Foam concrete forms a rigid, well-bonded body after hydrating. It is effectively a free-standing (monolithic) structure and once hardened, does not impose lateral loads on adjacent structures.

3.3 Mechanical Properties

3.3.1 Compressive strength

The compressive strength decreases exponentially with a reduction in density of foam concrete. The parameters affecting the strength of foam concrete are cement–sand and water–cement ratios, curing regime, type and particle size distribution of sand and type of foaming agent used.

3.3.2 Flexural and tensile strengths

Splitting tensile strengths of foam concrete are lower than those of equivalent normal weight and lightweight aggregate concrete with higher values observed for mixes with sand than those with fly ash. Use of Polypropylene fibers has been reported to enhance the performance with respect to tensile and flexural strength of foam concrete.

4. ADVANTAGES OF FOAM CONCRETE

- Does not settle, hence requires no compaction.
- Lightweight - does not impose large loadings.
- Free flowing - spreads to fill all voids.
- Excellent load spreading characteristics.
- Once placed requires no maintenance.

- Does not impose significant lateral loads.
- Reliable quality control - batches are easy to reproduce.
- Resistant to freeze-thaw cycle (1000 cycles of -180c to+200C).
- Low water absorption over time.
- Non-hazardous either during application or in service.
- Highly cost effective compared with other methods.
- Enables fast work.
- Sufficiently strong and durable for most applications.

5. APPLICATIONS OF FOAM CONCRETE

Lightweight foamed concrete includes in structural elements, non structural partitions and thermal insulating materials. Manufacturers developed lightweight foam concretes of different densities to suit the above requirements. The density of lightweight foamed concrete ranges from 300 kg/m^3 to 1800 kg/m^3 and these products were used in trench reinstatement, bridge abutment, void filling, roof insulation, road sub-base, wall construction, tunneling etc.

Self weight represents a very large proportion of total load on the structure, and there are clearly considerable advantages in reducing the density of concrete in concrete construction. A decreased density of concrete for the same strength level permits a saving in dead load for structural design and foundation. Lightweight foamed concrete can be applied in the field of construction such as in lightweight bricks or blocks for high-rise buildings, in panels and partition walls of various dimensions either pre-cast or poured in place, cast in-place for a unit of low cost terrace houses and bungalows, in all types of insulation works, including cavity walls, in roofing and ceiling panels, in sound proofing application, in pre-cast industrial and domestic building panels, both internal and external, in pre-cast or in place exterior wall facades for all sizes of buildings, in foundations for roads and sidewalks, in sub-surface for sport arenas, e.g. tennis courts, in infill sections between beams of suspended floors, in aircraft arresting beds, in crash barriers, in explosion-resistant structure, in highway sound barriers and in floating barge, jetties, walkways, fish cages and floating homes.

5.1 Building Blocks

Blocks and panels can be made for partition and load bearing walls. They can be made with almost any dimensions.

5.2 Floor Screed

Foamed concrete can be used for floor screeds, creating a flat surface on uneven ground and raising floor levels.

5.3 Roof Insulation

Foamed Concrete is used extensively for roof insulation and for making a slope on flat roofs. It has good thermal insulation properties and because it is lightweight foamed concrete does not impose a large loading on the building.

5.4 Road Sub Base

Foamed Concrete is being used road sub base on a bridge. Foamed concrete is lightweight so that the loading imposed on the bridge is minimized.

6. MIXING, CASTING AND CURING OF FOAM CONCRETE SPECIMENS

Mixing of specimen is done keeping in view to compare the compressive strength and split tensile strength of foam concrete with coarse sand and foam concrete replacing coarse sand by stone dust. For compressive strength test 9 cubes of 150*150*150 mm are prepared with coarse sand and 9 cubes of same dimension with stone dust is prepared. Ordinary Portland cement of grade 33 is used, coarse sand, stone dust and foam is used to prepare the cubes. To prepare foam protein based foaming agent was used. Ratio used to prepare the foam using foaming agent was 1:40 by volume of water. 1 part of foaming agent was mixed with 40 parts of water. To prepare foamed concrete with coarse sand of target density 1000 kg/m^3 cement and coarse sand are mixed in the proportion of 1:1.5. Water ratio is kept to 0.35 by weight. 9 cubes of size 150*150*150 mm are prepared with coarse sand. In the same way 9 cubes with stone dust is prepared. Out of these 9 cubes 3 cubes are tested after 1 day curing, 3 cubes are tested at 7 days curing and 3 cubes are tested for 28 days curing.

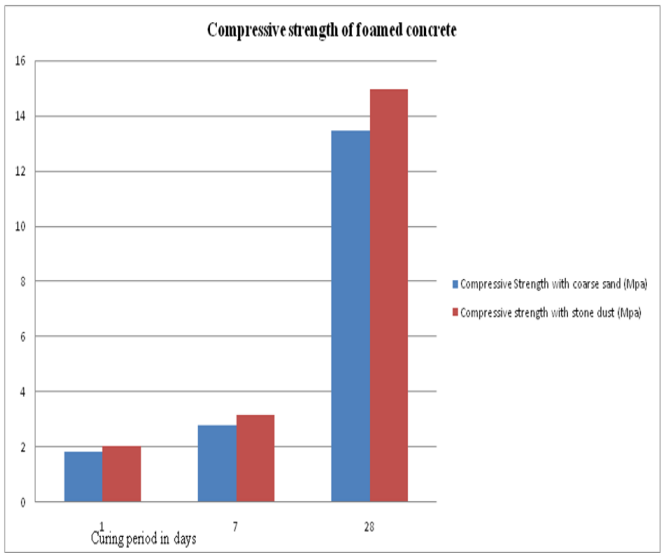
For split tensile strength 9 cylinders of dimension 150*300 mm are prepared with coarse sand and 9 cylinders are

prepared with stone dust. 3 cylinders are tested after 1 day curing, 3 cylinders are tested after 7 days curing and 3 cylinders are tested after 28 days curing. Mix design is same as for compressive strength.

7. RESULTS AND DISCUSSIONS

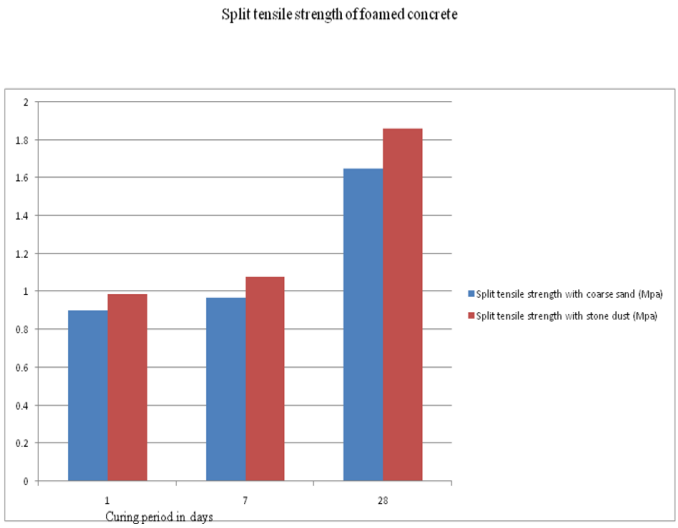
7.1 Compressive Strength

Cubes of dimension 150*150*150 mm are prepared with coarse sand and stone dust replacing coarse sand. These cubes were tested for 1, 7 and 28 days curing. With coarse sand compressive strength of foam concrete was found to be 1.82 MPa, 2.79 MPa, and 13.45 Mpa at 1, 7 and 28 days curing respectively. With stone dust the compressive strength was found to be 2.03 MPa, 3.18 MPa and 14.95 MPa at 1, 7 and 28 days curing respectively.



7.2 Split Tensile Strength

Cylinders of dimension 150*300 mm are prepared with coarse sand and stone dust replacing coarse sand. These cylinders were tested for 1, 7 and 28 days curing. With coarse sand split tensile strength of foam concrete was found to be 0.9 MPa, 0.97 MPa, and 1.65 Mpa at 1, 7 and 28 days curing respectively. With stone dust the compressive strength was found to be 0.99 MPa, 1.08 MPa and 1.86 MPa at 1, 7 and 28 days curing respectively.



8. CONCLUSIONS

- After comparing the compressive strength of foam concrete with coarse sand and foam concrete with stone dust the compressive strength was found to increase by 11.54% after 1 day curing, 13.98% after 7 days curing and increase by 11.15% after 28 days curing.
- After comparing the tensile strength of foam concrete with coarse sand and foam concrete with stone dust the tensile strength was found to increase by 9.10% after 1 day curing, 11.34% after 7 days curing and increase by 12.92% after 28 days curing.
- Increase in the compressive strength and tensile strength of foamed concrete signifies that stone dust can be used replacing coarse sand.

9. GROWTH TOWARDS SUSTAINABLE DEVELOPMENT

As they say that the development of a country always depends upon the construction works that are carried out in that country. The use of concrete in the world is second to water. So much use of concrete indicates that in future there will be a need for construction materials that are light weight, durable, simple to use and economic. In this respect foam concrete is a light weight concrete which can be used as building material. The major constituent of foam concrete has always been cement, coarse sand, foam and water. In addition to these constituents many admixtures have also been used to increase the strength of foam concrete. The

restricted supply of coarse sand has increased the cost of coarse sand and its steady supply can't be ensured. The consumption of good quality coarse sand for the utilization for construction work, the utilization of stone dust has been expanded. Stone dust is a substitute of coarse sand for construction and development purposes. Stone dust created from hard rock stone by pounding. The pulverized stone dust is of cubical shape with grounded edges, washed and evaluated to as a construction development material. The extent of stone dust is under 4.75mm. Under these conditions utilization of stone dust ends up noticeably inescapable. Use of stone dust avoids digging of river beds to get coarse sand which may prompt ecological fiasco like groundwater consumption, water shortage, a danger to the safety of bridges, dams and these fiascos make stone dust more eco friendly as compared to stone dust. The foam concrete arranged with such stone dust is eco-friendly and economical.

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