International Journal of Civil Engineering Research.
ISSN 2278-3652 Volume 8, Number 1 (2017), pp. 1-14

http://www.ripublication.com

Foam Concrete

MD Jalal*, Aftab Tanveer, K Jagdeesh and Furqan Ahmed

**Department of Civil Engineering, Jayaprakash Narayan College of engineering, Mahabubnagar-509001, Telangana, India.*

1. INTRODUCTION

One of the methods of reducing the density of concrete relies on the introduction of stable voids within the hardened cement paste or mortar. The voids can be produced by gas or by air. Because a foaming agent introduces the air, the concrete produced is called foam concrete.

Foam concrete is a vast majority of concrete containing no large aggregates, only fine sand and with extremely lightweight materials containing cement, water and foam. It can be considered relatively homogeneous when compared to normal concrete, as it does not contain coarse aggregate phase. However, the properties of foamed concrete depend on the microstructure and composition, which are influenced by the type of binder used, methods of pre-foamation and curing The main advantage of foam concrete is its lightweight, which ensures economy of walls of the lower floors and foundations. It has several advantages and since it is porous in nature, it provides thermal insulation and considerable savings in the material. The important applications of foamed concrete include structural elements, non-structural partitions and thermal insulating materials. Manufacturers developed foam concretes of different densities to suit the above requirements and these products were used in trench reinstatement, bridge abutment, void filling, roof insulation, road sub base, wall construction, tunneling etc

2. FOAM CONCRETE:

Fig. 1

Foam concrete is a very fluid, lightweight cellular concrete fill material, produced by blending a cement paste (the slurry or mortar), with a separately manufactured, pre-formed foam. The density of foam concrete is determined by the ratio of foam to slurry and densities range typically between 300 and 1600 kg/m^3. Sand, pulverized fuel ash (PFA), quarry dust or limestone dust may be used to further enhance the properties of foam concrete.

Foam concrete is created by uniform distribution of air bubbles throughout the mass of concrete. The foam cells must have walls, which remain stable during mixing, transportation, pumping and placing of fresh concrete. The cells, or bubbles are discrete and range in size between 0.1 and1mm. Foam concrete is a free flowing and can be placed without compaction.

3. HOW FOAM CONCRETE IS MADE?

The raw materials used for the production of foam concrete are, binding agent, aggregates, foaming agent, and water.

- **Binding agent:**

Cement is the most commonly used binding agent. Other binder materials like quarry dust and fly ash can also be used in conjunction with cement.

The quarry dust can be used as an additional filler material. Quarry dust consists mainly of excess fines generated from crushing, washing and screening operations at quarries. The material properties of this waste, vary with the source, but are relatively constant at a particular site.

A good fly ash should have high fineness, low carbon content and good reactivity, which would enhance the technical advantage to the properties of foamed concrete

- **Aggregates:**

For constructing and heat insulating foam concrete production with density grade D500 and higher as well as for constructive foam concrete aggregates are used. Quartz sand is usually used.

- **Foaming agents:**

Foaming agents can be divided into two main groups:

- Natural foaming agents
- Synthetic foaming agents

Natural waste based foaming agents ordinarily used in the industry are tannic extracts of leather industry, sub soaped lye, sulfite lye – they are the products with sufficiently varying properties. They have a limited storage life. Due to inconsistency of raw material composition and complicacy in their production, the chemical composition and main component content in the foaming agent obtained is varied.

Synthetic foaming agents are produced in accordance with technical requirements so that they have permanent properties and working life much longer; this gives them application advantages.

Foaming agent selection must be carried out for the particular production in dependence on production capacity, foam concrete mix production method and regional conditions.

The foam is mainly added as a base material and the main requirement is that it must be capable of remaining stable and not collapsing during pumping, placement and curing. The density of the foam is about 110 kg/m^3 and investigators reported that foam materials below this density are to be manufactured with care.

Preparation:

Fig.1 shows automated batching equipment for the production and placement of foam concrete.

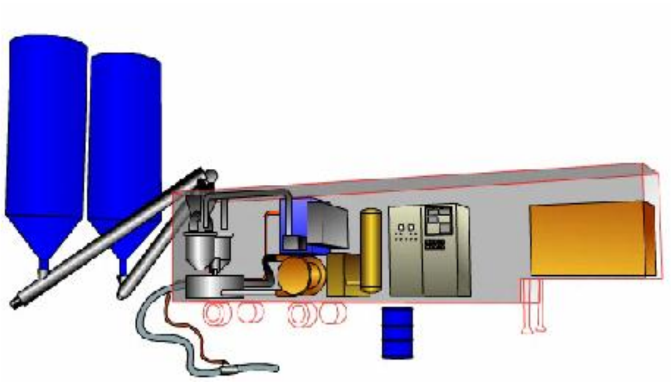

Fig. 2

Cement and sand are stored in different silos. The desired ratio of cement sand and fly ash are programmed into the computer to produce desired amount of slurry.

The dry materials and water are thoroughly mixed together with high-speed impellers. Slurry is dropped into a buffer tank, which is continuously agitated to prevent it from segregation.

The pre-formed foam is generated in specialized foam production equipment. Foaming agent and water is mixed in a separate tank and compressed air is supplied to it based on the amount of foam required.

The pre formed foam is then injected to slurry to produce the foam concrete. With minimal personnel foam concrete can be placed.

- **Curing:**

Cellular concrete is generally air-cured. Applying heat, steam or chemicals might accelerate curing. A curing compound prevents excessive loss of water after casting and consequently increases strength.

4. PROPERTIES OF FOAM CONCRETE:

Table 1.

Characteristics	**Type of foam concrete (cast density)**										**Unit**
Cast density	400	500	600	700	800	900	1000	1200	1400	1800	Kg/m3
Cube compressive strength (28days)	0.1.3	2.0	3.0	3.0	4.5	5.5	6.5	10.0	12.0	16.0	Mpa
Tensile strength (28days)	0.1	0.2	0.3	0.35	0.45	0.55	0.65	1.1	1.2	1.6	Mpa
Thermal conductivity	0.11	0.13	0.15	0.18	0.22	0.26	0.30	0.40	0.55	0.77	W/mk

Compressive strength:

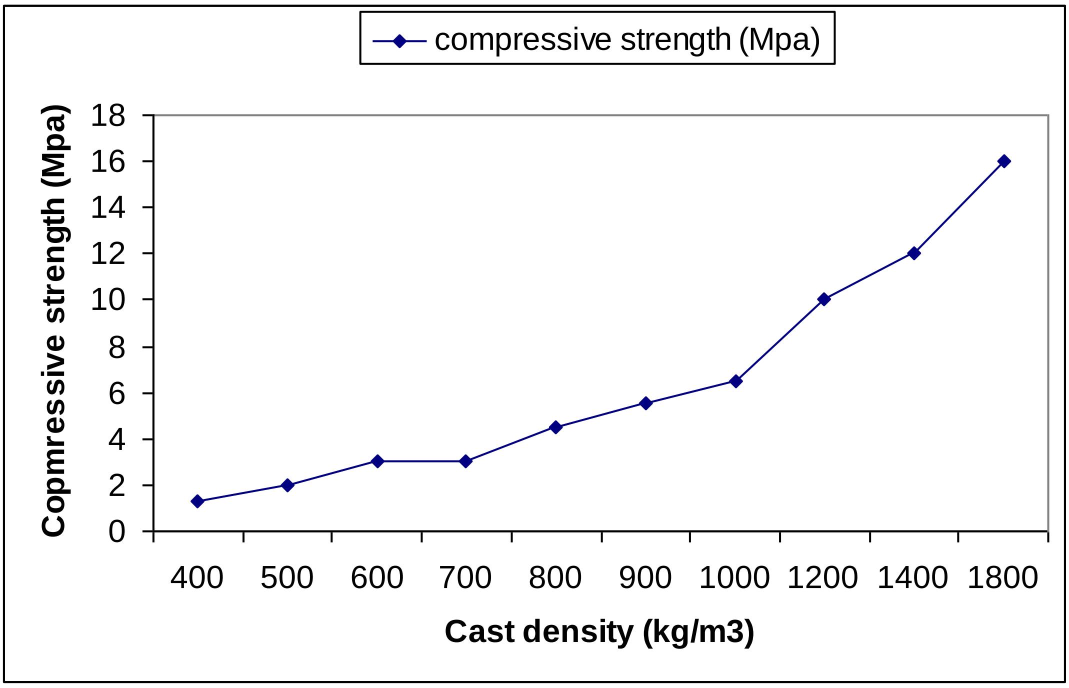

Fig.3 Relation between compressive strength and Cast density.

High early strength can be achieved by the use of rapid hardening cement. Increasing the quantities of sand and cement and decreasing the amount of foam yield higher densities and consequently higher strength. Thus concrete density, cement type and content, water/cement ratio; foam type and curing regime will influence the compressive strength.

Fire Resistance

Foam concrete is an inorganic material and therefore unlikely to catch fire. Tests carried out in several countries, including tests to ASTM Standards, show that a load bearing foam concrete slab wall, 15cm thick, has a fire resistance exceeding 7 hours.

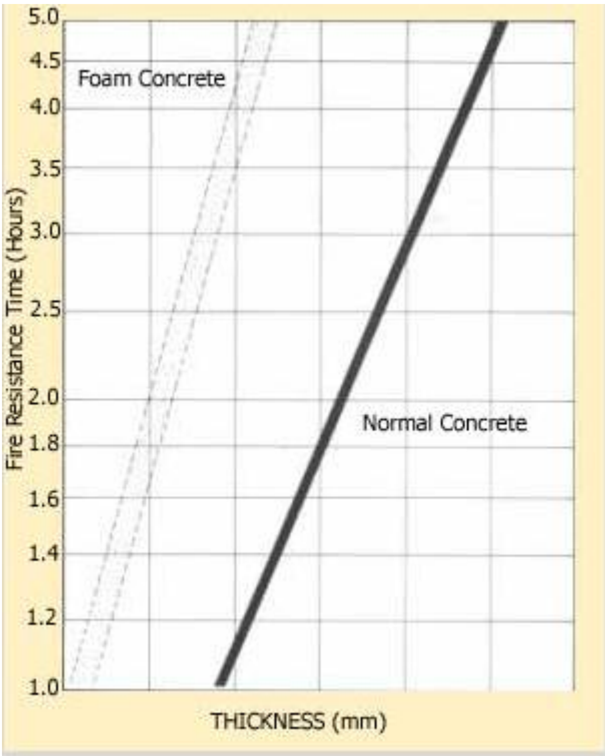

Fig.4 Relation between fire resistance and thickness of foam concrete wall

Thermal Conductivity

The main characteristic feature of foam concrete is its low thermal conductivity, which gives it better insulation properties. This is due to the great number of closed cavities that form the multi–cellular structure and results in a 50mm layer of foam concrete, with a density of 400kg/m^3, having approximately the same excellent heat insulation value as a 25mm thickness of cork.

The typical values of thermal conductivity of foam concrete are shown in table 2.

Table 2

Type of foam concrete	Sort of foam concrete according to average density	Non-autoclave foam concrete	
		28 day compressive strength MPa**	Thermal Conductivity W/mk
Heat-insulated	D400	1	0.1
	D500	1.4	0.12
Constructional-heat-insulated	D600	3.5	0.14
	D700	5	0.18
	D800	7	0.21
	D1000	10	0.24
Constructional	D1100	14	0.34
	D1200	17	0.38

Low coefficient of permeability

The hydraulic conductivity of porous materials generally decreases with an increasing amount of air in the pores of the material. Foam concrete is made up with a matrix of non-interconnecting micro bubbles, or air voids, thus the material has a relatively low permeability.

Low water absorption

The solid matrix of cementitious slurry surrounding the fine cell structure of the foam concrete greatly reduces the capillary action of moisture through the material.

Freeze and thaw resistance.

Foam concrete has excellent freeze thaw resistance.

Energy absorbing qualities

Due to the dense cell structure of foam concrete, as the material is compressed during an impact, the resistance of the foam concrete increases absorbing the kinetic energy. And since hardened foam concrete forms a solid matrix, the material is not vulnerable to seismic shock waves, thus ideal for bridging over soils susceptible to liquefaction. (Recommended by the U.S. Bureau of Reclamation in fault zones).

Susceptibility to breakdown

Unlike some synthetic lightweight fill materials, hardened foam concrete is not susceptible to breakdown due to hydrocarbons, bacteria, or fungi, and is insect and rodent proof. The protein based, foaming agent forms a durable micro bubble, and is not affected by hydrocarbons or other chemicals that may be present during placement of the foam concrete when it is in its liquid state. With some foaming agent there may be detrimental effects of the finished foam concrete.

5. ADVANTAGES:

- **Low density and high strength:**

Typical cast densities of foam concrete range between 350 and 1600 kg/m^3, giving 28 day compressive strengths of 0.2 to 18.0 N/mm^2. Due to its low density, foam concrete imposes little vertical stress on the substructure - a particularly important attribute in areas sensitive to settlement.

- **High fluidity:**

Foam concrete pumps easily with relatively low pressures via hose over long distances. The material is naturally self-leveling and fills the smallest voids, cavities and seams. When placing in excavations, foam concrete conforms to every sub grade contour.

- **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.

- **Self-Leveling and self-compacting:**

Foam concrete is naturally self-leveling and self-compacting, filling the smallest voids, cavities and seams within the pouring area.

- **Reliability:**

Foam Concrete is very long-lived material. It does not decompose and is as durable as rock.

- **Resistance to cold and warmth:**

Foam Concrete is very effective isolating material. Buildings constructed from foam concrete are able to accumulate cold or heat, which allows to greatly minimizing conditioning or heating expenses. It is ideal material for countries with hot and cold climate.

- **Microclimate:**

Foam concrete control air humidity in a room by absorbing and output of moisture during the day and night. Also in foam concrete houses favorable average temperature during the day is maintained.

- **Acoustic-insulation:**

Foam concrete has a high property of acoustical absorption.

- **Superior fire-resistant:**

Foam concrete is extremely fire resistant and well suited to applications where fire is a risk.

- **Eco-compatibility:**

Foam concrete does not produce any toxic substances, as it is ecologically clean

- **Variety of usage:**

Foam concrete use for producing construction blocks, thermal and acoustic insulation of roofs, floors, warming of pipes, production of collapsible blocks and panels of partitions in buildings, as well as floors and basements foam concrete of higher density.

6. OPERATIONAL & COST EFFICIENCIES:

- **Settlement free construction:**

In conforming to the principle of equilibrium, the effective stress of the underlying soil remains unchanged from that existing prior to excavation and thus settlement of the construction is prevented.

- **Cost saving:**

Foam concrete allows saving big money as it can be applied directly on existing marginal ground such as peat or poor soils. Minimal lateral loading enables reduced building costs for earth retaining structures. Foam concrete allows construction on marginal ground reducing the need for piled foundations. High volume equipment with rapid installation reduces installed unit cost. Foam concrete requires lower maintenance costs due to the durability of foam concrete and lack of settlements.

- **Time saving:**

The application of foam concrete can be a great time saver over conventional ground treatment methods for settlement free construction. No waiting period for consolidation of sub soils, eliminating the need for surcharging .No need for removal and replacement with large amounts of borrow soils. Removal of minimal amount of soil to be replaced with foam concrete. Reduce or eliminate the need for piling, sand drains, or grade beams

- **Rapid construction:**

Foam concrete blocks are lightweight, big sizes and high accuracy dimensions. It increases the construction speed for several times. Also it is easy to cut channels and holes for electrical wiring, sockets, and pipes.

7. APPLICATIONS:

Based on the density, Foamed concrete is divided into the following types:

- Constructive foamed concrete with grade by density from D1000 to D1200
- Constructive and heat insulating foamed concrete with grade by density D500-900;
- Heat-insulating foamed concrete with grade by density D300-500.

- **In the construction of walls and floors:**

Foam concrete of density between 300 - 500 kg/m³ is primarily used for the construction of walls and roofs as foam concrete provides thermal resistance, acoustic insulation and fire resistance.

- **Void fill**

Foam concrete of density between 600 - 800 kg/m³ is used for void filling, such as in landscaping (above/underground construction), filling voids behind archways and refurbishing damaged sewerage systems, as well as producing masonry units. Foam concrete is extremely flowable and easily pumped; it completely fills even the tiniest voids. Rather than spending time and money for excavation and removal of underground structures, foam concrete can provide a simpler more economical solution for abandonment of sewers, tunnels, and underground tanks, and naturally occurring voids

For example:

1.It was required to infill a number of disused fuel tanks in a depot of waste and recycling contractor in south London. Around 500 cubic meter of foam concrete with a cast density of 550kg/m3 at a 28 day compressive strength of 2N/mm2 was used to infill the tanks.

Fig. 5

2. Culvert fill:

A project in South Dakota USA was carried out in 2000 where it had become necessary to replace an existing bridge structure with a super span steel plate bridge culvert to be back filled with soil. Original granular backfill has caused settlement to the footings and hence distortion of the structure. It was decided to remove the original fill and replace with lightweight 500-kgs/m^3 density foam concrete.

Fig. 6

3. Subway infill:

These pictures show a project in Milton Keynes, UK, where a network of six pedestrian subways was required to be in filled with lightweight foam concrete. The mix specified for this contract was an 800 kg/m^3 density, 8 N/mm^2 compressive strength at 28 days.

Fig. 7

4. Tunnel infill:

The arched tunnel - built in the 19th century as part of a cement works - measured 5.0 meters high and 4.5 meters wide. The foam concrete was required to be pumped some 300 meters away. The project was completed over seven days using foam concrete with a 350 - 400 kgs/m^3 cast density and a 28 day compressive strength of 0.5 N/mm^2.

Fig. 8

- **Light weight foundations:**

With densities as low as 300 kg/m^3, foam concrete imposes little vertical stress on the surrounding sub-structure. This is particularly important in areas sensitive to settlement. In excavations with poor soil, foam concrete form 100% stable lightweight foundations and can be designed using the principle of equilibrium**.**

- **Pre casting:**

An increasing use of lightweight foamed concretes is in the production of blocks and pre-cast panels. The ability of the material to made lightweight with excellent sound and thermal properties whilst at the same time easy and economic to produce.

- **Road construction**

Due to the dense cell structure of foam concrete, as the material is compressed during an impact, the resistance of the foam concrete increases, absorbing kinetic energy - especially useful in the design of aircraft arrestor systems at airports or roads. In case of soft compressible soils foam concrete can be used to minimize settlement. Foam concrete provides a load-reducing fill to prevent the settlement. A stable, long-lasting solution can be obtained as a result of the excellent freeze/thaw resistance and low-density properties of foam concrete.

8. CONCLUSION:

The initial findings have shown that the foam concrete has a desirable strength to be an alternative construction material for the industrialized building system. The strength of foam concrete is low for lower density mixture. Significant reduction of overall weight results in saving structural frames, footing or piles and rapid and relatively simple construction.

The density is reduced due to the increment of voids throughout the sample caused by the foam and hence the decrease in the compressive strength of the concrete. Foam concrete requires no vibration or compaction and it fills all cavities, voids and seams over a long distance. It offers fast and settlement free construction with good heat insulation and air content. It has good thermal insulation, good freeze/thawing properties and has excellent fire resistance properties.

REFERENCES:

[1] "Concrete technology" by M.S.Shetty
[2] Properties of concrete" by A.M.Neville.
[3] www.foamconcrete.co.uk
[4] www.provoton.com
[5] www.pdf-search-engine.com