Optimization of foam concrete masonry blocks

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Abstract— Foamed concrete is a versatile material which consists primarily of a cement based mortar mixed with at least 20-25% of volume air. It is non-load bearing structural element which has lower strength than conventional concrete. Foam concrete is widely used in construction field and quite popular for some application because of its light weight such as reduction of dead load, non-structural partitions and thermal insulating materials. Strength of foam concrete depends upon the foam added. Stable foam production depends upon the type of foaming agent, concentration of foam, method of preparation of foam. In this study the compressive strength of foam concrete was conducted for the specimens. Specimens were made to find out the Suitable foam concentration, by adding 2g, 5g, 8g, 10g of sodium lauryl sulphate in 100ml, 500ml, 1000ml respectively. Volume of foam by weight of cement added to the concrete is estimated at 5%, 10%, 15%, and 20%. In order to increase the strength of foam concrete, test were conducted on specimens with Flyash as the partial replacement of cement and quarry dust as the partial replacement of sand at varied percentages. Based on the experimental investigations optimization the foam concrete masonry blocks with an appreciable strength and density is carried out.

Keywords— foam concrete, lightweight concrete, mortar, foam, flyash, quarry dust, interlocking masonry blocks, sodium lauryl sulphate, compressive strength.

1.INTRODUCTION

1.1 FOAM CONCRETE

Concrete is the second most widely consumed substance on earth, after water. In concrete construction, self-weight represents a very large proportion of the total load on the structure, hence there are clearly considerable advantages in reducing the density of concrete by using Light Weight Concrete(LWC). The chief of these are the use of smaller sections and the corresponding reduction in the size. Furthermore, with lighter 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. LWC also gives better thermal insulation than ordinary concrete. The practical range of densities of lightweight concrete is between 3.00 and 18.50 kN/m^3, the weight reduction of concrete structure would results in less structural steel reinforcement. One such LWC is foamed concrete.

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 1800 kg/m^3.

Foam concrete also known as foamed concrete, foamcrete, cellular lightweight concrete or reduced density concrete, is defined as a cement based slurry, with minimum of 20% (per volume) foam entrained into the plastic mortar, this differentiates foam concrete from (a)Gas or aerated concrete, where bubbles are chemically formed through reaction of aluminum powder with calcium hydroxide and other alkalis released by cement hydration and (b) Air entrained concrete, which has much lower volume of entrained air. Mostly no coarse aggregate is used for production of foam concrete. The correct term would be called as mortar instead of concrete. Sometimes it may be called as "Foamed Cement" or "Foam Cement" because of mixture of only cement and foam without any fine aggregate.

Fig.1.1 Foam Concrete

Foamed concrete possesses characteristics such as high strength-to-weight ratio. Using foamed concrete reduces dead loads on the structure and foundation, contributes to energy conservation, and lowers the labor cost during construction. It also reduces the cost of production and transportation of building components compared to normal concrete and has the potential of being used as a structural material.

Foam concrete contains unique characteristics that can be exploited in civil engineering works. It requires no compaction but will flow readily from an outlet to fill restricted and irregular cavities, and it can be pumped over significant distances and heights, thus it could be thought of as a free flowing self setting material.

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 infill's due to easy production process from manufacturing plants to final position of the applications. In practice, foamed concrete has been commonly used in construction applications in different countries such as Germany, UK, Philippines, Turkey, and Thailand.

Historically, the Romans first realized that by adding animal blood into a mix of small gravel and coarse sand with hot lime and water and agitating it, small air bubbles were formed making the mix more workable and durable. However, the first Portland cement based foamed concrete was patented in 1923 by Axel Eriksson[1] . Further, the initial comprehensive review was conducted by Valore [2] on cellular concrete. Over the past 20 years, substantial improvements in production equipment and better super plasticizers, foam agents have permitted the use of foamed concrete in a larger scale and many efforts have been made to study the characteristics and behavior of foamed concrete comprehensively in order to simplify its usage in structural applications. So far, some researchers reported that the foamed concrete possesses superior properties such as low density which helps to reduce structural dead loads, foundation size, labor, transportation and operating costs. Besides, it enhances the fire resistance, thermal conductivity and sound absorbance due to its textural surface and micro-structural cells.

1.2 CONSTITUENT MATERIALS

Foamed concrete consists of basic and supplementary components. The basic components are cement, sand, and water for mortar, plus aggregates to produce concrete, while the supplementary materials are fly ash and silica fume.

1.2.1 Binder

Cement is the most dominant binder in foamed concrete. The types of cement used in the foamed concrete are ordinary Portland cement, rapid hardening Portland cement, calcium sulpho aluminates cement, and high alumina cement, which can be used in ranges between 25% and 100% of the binder content. However, other supplementary materials such as silica fume, fly ash, lime, and incinerator bottom ash can also be replaced with a percentage of cement ranging between 10% and 75%.The supplementary materials are used to improve mix design consistency, long term strength and to reduce costs. Each supplementary material may contribute to properties of foamed concrete in different fashions. For instance, the purpose of using silica fume is to strengthen the foamed concrete in a short time due to their filler characteristics and pozzolanic behavior, while fly ash needs a longer time to reach the maximum strength comparing to cement. Therefore, the supplementary materials should be used as partial replacements according to desirable foamed concrete properties.

Concrete with densities between 800 and 1200 kg/m3 have been produced using lightweight coarse aggregate in foamed cement matrix

1.2.2 Foam Agent

Foaming agents required for producing aqueous stable foam can be either natural based like resin soap and glue, hydrolyzed protein such as keratin, cattle hooves and fish scales, blood, saponin and casein or synthetic based like detergents (sodium lauryl sulfate, alkalyaryl sulphonate.1 Synthetic foaming agents are preferred for the following advantages; (i) allows a greater control over density of material than protein based foams2 (ii) possess permanent properties (since they are produced in accordance with technical requirements) and (iii) longer working life. Proper selection of foaming agent is essential as the type of foaming agent used influences the final strength of foamed materials.Foam agents control the concrete density through a rate of air bubbles created in the cement paste mixture. Foam bubbles are defined as enclosed air-voids formed due to the addition of foam agent. The foam agents are commonly synthetic, protein-based, detergents, glue resins, hydrolyzed protein, resin soap, and saponin.The most common foam agents are synthetic and protein based. The protein based foam agents result in a stronger and a more closed-cell bubble structure which permits the inclusion of greater amounts of air and also provides a more stable air void network while the synthetic ones yield greater expansion and thus lower density. The content of the foam agent has a considerable effect on properties of both fresh and the hardened concrete. It is reported that the excessive foam volume results in a drop in flow. However, the flow is significantly affected by mixing time. Greater the mixing time, the more the entrained air, though, prolonged mixing may cause the loss of entrained air by dropping the air content. Moreover, water-reducing chemical admixtures are likely to cause instability in the foam and subsequently are not usually used. The air voids range between 6% and 35% of the total volume of final mix in most foamed concrete applications. The foam is produced by blending the foam agent, water and compressed air (generated by an air-compressor) in pre-calculated proportion ratios in a foam generator calibrated for a discharge rate.

1.2.2 Water and Plasticizers

A water requirement in foamed concrete depends upon the constituents and the use of admixtures. Water content is also governed by the uniformity, consistency and stability of the desired mix. Low water content caused the mix to be too stiff and bubbles broke during mixing which resulted in an increased density. Similarly, at high water content, the slurry was too thin to hold the bubbles which caused segregation of the foam from the mix and consequently the final density was increased. In general, the water to cement ratio range was suggested to be from 6.5% to 14% of the target density. Furthermore, the quality of used water counts in the production of foamed concrete. Water used for the foamed concrete mix design should be clean, fresh and absolutely drinkable. However, undrinkable water could also be used when foamed concrete gains 90% of strength at 7–28 days similar or equal to samples made with water from a municipal supply.

The plasticizers are significantly utilized to improve workability and to stabilize the compatibility of foamed concrete. They are practically defined as water reducers used to increase the performance of fresh concrete by easing its mobility and plasticity; however, no significant effects on concrete segregation were observed. One of the most popular plasticizers in the foamed concrete production is FluorosSurfactant (FS1). The FS1 is generally used to reduce the amount of mixing water and also marginally accelerates the strength gain of the produced foamed concrete. The plasticizers content is approximately between 0.45% and 5% of foam agent volume.

2. LITERATURE REVIEW

Sathya Narayanan.al[1] Studies deals with the identification of suitable set accelerator for foam concrete made using sodium lauryl sulphate as foaming agent, that is facilitating demoulding time within 2 h. As conventional accelerators, calcium chloride, calcium nitrate, triethanol amine were not-effective in foam concrete, alum and Class-C fly ash were tried. Demoulding test was performed to the mixes having optimum density (1200–1300 kg/m3).from the studies it showed Class-C fly ash has been identified as the most appropriate accelerator for foam concrete mix with SLS. Use of Class-C fly ash as (i) complete replacement of sand and (ii) combination mixes provide flexibility in its adoption as an accelerator. Class-C fly ash was observed as a potential set-accelerator, facilitating demoulding at 90 min.

Y.H. Mugahed Amran et.al[2] The paper dealt with the studies of properties and applications of foamed concrete, which included a review of foamed concrete constituents, fabrication techniques, and properties of foamed concrete. Foamed concrete consists of basic and supplementary components. This paper provided a review of foamed concrete constituents, fabrication techniques, and properties of foamed concrete. It also aimed in providing a comprehensive insight into possible applications of foamed concrete in the construction industry today.

The compressive strength is considered as the primary function of the desirable density design, as a main consideration for this lightweight concrete, which can finally be used to fabricate structural, non or semi-structural components. Meanwhile, durability is another property of foamed concrete that needs to be at a level which can effectively allow it to resist the aggressive environments. This can be achieved by selecting the most suitable type of foam agent added. Foam agents produce a uniformed distribution of pores, where they decrease the segregation problem in an early state, prevent the ingression of chloride, prohibit sulphate attack and increase the time range during fire while enhancing its fire resistance. Stable foamed concrete production depends on many factors such as type of foaming agent, method of preparation of foaming agent to initiate a uniform or homogeneous distribution of air voids (bubbles), design calculation accuracy of the mixture, and foamed concrete production, hence the enhancement of performance in fresh and hardened states are significantly elaborated. In order to produce foamed concrete with high consistency and stability, it is recommended to reduce the volume of foaming agent, using partial replacement of cement by either fly ash or silica fume which reduces the process of heat of hydration.

Ma Cong.al [3] Ordinary Portland cement, soil and foaming agent are the raw materials used to make soil-based foamed concrete. The effects of foam content and silica fume on the physical properties of soil-based foamed concrete, such as the dry density, 28-day compressive strength, thermal conductivity, water resistance and pore structure, were studied. The experimental results indicate that the foam and silica fume contents have a large impact on the physical properties of soil-based foamed concrete. The thermal conductivity, density, water resistance and compressive strength decrease with increasing volume fractions of foam. The compressive strength, the thermal insulation and water resistance are all improved by increasing the content of silica fume. Soil-based foamed concrete consisting of 20% silica fume with a density of 800 kg/m3, compressive strength of 7.5 MPa and thermal conductivity of 0.16 W/m K can be used as water-resistant lightweight concrete. The hygroscopic tests were performed and the results indicate that

the addition of silica fume has some effect on the hygroscopic property of soil-based foamed concrete. Several fitting curves have been obtained, the fitted functions developed by the Kumaran model and Cubic function have better fitting parameters.

Kanagalakshmi et.al[4] A study on the effect of quarry dust as sand replacement material on compressive strength of foam concrete was conducted because of its low strength, some material is used in order to increase the foam concrete strength. This project was carried out to determine the compressive strength of foam concrete by using quarry dust as partial sand replacement material. This report presents the feasibility of the usage of quarry dust as 10 %, 20 %, 30 %, 40% and 50% for sand in foam concrete. Mix design was formulated and developed for four different proportion of quarry dust in foam concrete. Tests were conducted on cubes to study the compressive strength of concrete made of quarry dust and results were compared with the control foam concrete. It is found that the compressive strength of foam concrete made of quarry dust is nearly 43% more than the control foam concrete. Based on the results of the experimental investigation, it is proposed that burnt clay bricks can be effectively replaced with the foam concrete blocks. Finally cost benefit assessment was done to prove the economy of the foam concrete bricks.

Hilal et.al [5] studied on void structure and strength of foamed concrete made without/with additives. Study has been undertaken to investigate the effect of different additives on the strength foamed concrete by characterizing air-void size and shape parameters and identifying the influence of these parameters and changes to cement paste microstructure on strength. Nine different mixes, made using a preformed foam, were investigated with varying density (nominally 1300, 1600 and 1900 kg/m^3) without/ with additives (silica fume, fly ash and super plasticizer) used either individually or together. Optical microscopy and scanning electron microscopy were used in this investigation. Compared to the conventional mixes, inclusion of additives (individually or in combination) helped to improve both the cement paste microstructure and air-void structure of foamed concrete. For a given density, although the additives in combination led to increased void numbers, higher strength was achieved due to reduced void size and connectivity, by preventing their merging and producing a narrow void size distribution. Furthermore, super plasticizer has the most beneficial influence on voids when used alone and it further improves void structure (smaller and number voids) when used in combination with other additives. Not only enhancement of void structure but also improved cement paste microstructure both contribute to the strength of the foamed concrete.

Zhaoming Huang et.al [6] Studied on proportioning and characterization of Portland cement-based ultra-lightweight foam concretes. Due to desirable thermal insulation properties, superior fire-resistant and higher durability, ultra-lightweight foam concretes are recommended to achieve energy efficiency in buildings. Generally, aluminate cement, sulphoaluminate cement and other quick hardening cementations materials are used to control the stability of air-voids in foam concretes. These special cementations materials are relatively expensive and not universally available, retarding the application and popularization of foam concretes. In the present study, the proportioning and properties of Portland cement based ultra-lightweight foam concrete were investigated. The results show that ultra-lightweight foam concretes with apparent density of100–300 kg/m^3 can be prepared using Portland cement, fly ash, hydrogen peroxide and chemical admixtures. Collapse and air-voids escape can be avoided by adding thickening agent and foam stabilizing emulsion into foam concretes. Most of pores in ultra-lightweight foam concretes were non-connected pores with size of 2.0–4.0 mm, resulting in a lower thermal conductivity, desirable compressive and tensile strengths

.**Hwang and Tran[7]** investigated Foamed Light Weight Aggregate (FLWA) manufactured with Hydrogen Peroxide (HP) as a foaming agent and using cold-bonded agglomeration process, a relatively low-polluting, energy efficient method of FLWA production. Foamed lightweight aggregate for self-consolidating concrete were surface treated to improve the performance of the aggregates. Moreover, 8 types of FLWA were used as coarse aggregate to produce Self Consolidating Concrete (SCC). A variety of tests were conducted to evaluate the effects of the foaming agent and the surface treatments on the properties of the cold-bonded lightweight aggregate. The workability, unit weight, and strength of the SCC specimens were determined in accordance with established standards. The FLWA type with the lowest specific gravity was binary mixture of 80% Fly Ash (FA) and 20% Ground Blast Furnace Slag (GBFS) at an HP concentration of 7%, with a specific gravity of 1.27. The cold-bonded lightweight fly ash aggregate manufactured for this study used hydrogen peroxide as the foaming agent in order to produce a porous microstructure inward aggregate that reduced the specific gravity of light weight aggregate. The self-consolidating FLWA concrete designed achieved uniform mixtures with fresh densities ranging from 21.06kN/m^3 to 18.89 kN/m^3. Additionally, all mixtures of SCC made with the 8 types of aggregates showed excellent workability: (1) slump flow: 660–750 mm; (2) V-funnel time: 18–31 s; (3) Passing Ability(PA): 0.8; (4) the rounded shape and smooth surface of LWA with surface modification enhanced the flowability, viscosity, and passing ability of SCC. Specific gravities of FLWA were 13% less than unfoamed LWA.Moreover, the foaming agent negatively affected water absorption and strength of LWA, which were later improved by surface treatment. The 28-day compressive strength of all SCC specimens ranged from 38.3 to 47.8 MPa, which exceeds the minimum strength required. Furthermore, the compressive strength of SCC related strongly to the strength and water absorption of FLWA. The stronger strength of FLWA resulted in stronger SCC, while the increase in water absorption of FLWA reduced compressive strength of SCC.

Kozlowskia et.al [8] studied fracture energy of foamed concrete based on three-point bending test on notched beams. A series of static loading tests was performed to determine the fracture properties of foamed concrete of varying density. Beams with dimensions of 100×100×840 mm with a central notch were tested in three-point bending. Then, remaining halves of the specimens were tested again as un-notched beams in the same set-up with reduced distance between supports. The tests were performed in a hydraulic displacement controlled testing machine with a load capacity of 5kN. Apart from measuring the loading and mid-span displacement, a Crack Mouth Opening Displacement (CMOD) was monitored. Based on the load – displacement curves of notched beams the values of fracture energy and tensile stress at failure were calculated. Subsequently, the flexural tensile strength was obtained on un-notched beams with dimensions of 100×100×420 mm. Moreover, cube specimens 150×150×150 mm were tested in compression to determine the compressive strength. An increase of the density of foamed concrete results in an increase of Fracture Energy (G_F) and maximal tensile stress (σ_t). For the notched beams of density of 488 to 1024 kg/m^3 the mean values (based on five specimens per mix) of $G_{F\mu}$(based on the load-deflection relationship) and σ_t obtained were of 1.39-12.54 N/m and 0.112-0.555MPa respectively. The $G_{F(CMOD)}$to $G_{F(u)}$ratio for all tested beams was constant and equals 0.37±0.01; The mean value of flexural tensile strength (based on ten specimens per mix) obtained for the un-notched beams of density of 488-1024 kg/m^3 was 0.163-0.585MPa.

Zhihua et.al [9] Studied on the preparation and characterization of super low density foamed concrete from Portland cement and admixtures. Foamed concrete with its super low density of between 150kg/m^3 and 300kg/m^{3}was prepared by means of chemically foaming and so called mixing and foaming process in laboratory. Conventional Portland cement was selected as the main binding material instead of rapid hardening special cement such as sulfo aluminate cement. Chemical and physical admixtures were properly introduced for the regulation of the rheological property and hardening speed of the fresh cement mixture slurry as well as the physical properties of the hardened foamed concrete. Ultrafine Ground Granulated Blast Furnace Slag Powder(UGGBFSP) with its Blaine specific surface area 800 m^2/kg, was used in experiment to regulate the rate and amount of hydration heat evolution and to control the temperature raise of the freshly placed foamed concrete in order to prevent it from uneven volume deforming or cracking. Hydrogen peroxide (H_2O_2) is selected as a chemical foaming agent to avoid the side effect such as retarded setting and delayed hardening of the cement paste caused by the introduction of some organic physical foaming agent which is believed to be one of the reasons causing the collapse or sinking of the freshly placed foamed concrete. Polycarboxylate Super plasticizer (SP) is used to reduce the w/c ratio of the cement mixture slurry as far as possible. Alkali free Setting Accelerator (SA) synthesized in laboratory with alumina sulfate as its main constituent and with its solid content 40% was selected for regulating the setting time of the cement in order for the mixture slurry to set and harden quickly as possible immediately after foaming and placing, meanwhile to keep the mixture slurry with a good flowability before and during foaming. Besides, Polypropylene Fiber(PF) and Styrene Arylate Emulsion(SAE) and Organic Silicone waterproofing agent(OS), and Foam Stabilizer(FS) with sodium dodecyl benzene sulfonate as its main constituent were also introduced into the fresh mixture slurry of Super low density Foamed Concrete(SFC) in order to improve the volume integrity and toughness and water resistance of the hardened foamed concrete. Thus he concluded that SFC with its dry density between 150 kg/m^3 and 300kg/m^3 can be prepared with Portland cement as binding material and with the proper addition of ultrafine blast furnace slag powder and with the aid of some physical and chemical admixtures by means of the so called mixing and foaming process.

2.1. OBJECTIVES

From the literature review, it was identified that many studies have been carried out on light weight concrete considering the future possibilities. It was noted that very few studies have been conducted on Lightweight Foamed Concrete(LFC) which has a great potential in future. Based on the review conducted, it was observed that the majority of investigations were limited to evaluating the foam concrete properties, rather than focusing on characteristics of foam itself.

The objectives of the work may be summarized as:

- To determine the optimum concentration of foam in foam concrete.
- To investigate the optimum percentage of foam to be added to mortar so as to reduce density with desired strength.
- To find out the optimum replacement of cement with fly ash and sand with quarry dust to the optimized foam concrete to make it more light weight with desired strength.
- Study the performance of optimized foam concrete masonry blocks of 300mm x 200mm x 150mm.

2.2. SCOPE

- This study is limited to optimization of light weight foam concrete in laboratory without coarse aggregate.
- To find the optimum foam concentration by adding Foaming agent sodium lauryl sulphate at 2g, 5g, 8g, 10g at 100ml, 500ml, 1000ml of water respectively.
- To investigate and compare the different dosages of foam to be added to mortar (variations adopted are 0%, 5%, 10%, 15%, and 20%) to make it light weight and to use it in foamed concrete studies.
- To investigate the effect of replacement of cement with freely available fly ash and sand with quarry dust(Various percentages) to the optimized foam concrete to obtain maximum strength.
- Further optimization of foam concrete in interlocking masonry blocks.

2.3. METHODOLOGY

1. Cement sand proportion taken is 1:1,1:2,1:3
2. Finding the optimum amount sodium lauryl sulphate in water as category I.
3. Finding the optimum amount of foam percentage by weight of cement to be added
to mortar for foamed concrete which is designated as category II.
4. Finding the optimum amount of cement replacement by fly ash and sand replacement by quarry dust in LFC (category III).
5. Comparison of optimized foamed concrete blocks from category III to commercially available solid blocks available in the market.
6. Studying the performance of foam concrete masonry blocks by constructing a wall of 1m x 1m

3. MATERIALS AND METHODS

3.1 GENERAL

The common ingredients of foam concrete are cement, fine aggregate, foaming agent and water. The physical and chemical properties of each ingredient has considerable role in the desirable properties of concrete like strength and workability.

3.1.1 Portland Cement

Portland cement is the most common type of cement in general use around the world, used as a basic ingredient of concrete. Portland cement is also used in mortars(with sand and water only) for plasters and screeds, and in grouts (cement/water mixes squeezed into gaps to consolidate foundations, road-beds, etc.). When water is mixed with Portland cement, the product sets in a few hours and hardens over a period of weeks. In principle, the strength continues to rise slowly as long as water is available for continued hydration, but concrete is usually allowed to dry out after a few weeks and this causes strength growth to stop.For any given set of materials, there is an optimum cement content beyond which little or no additional increase in strength is achieved from increasing the cement content. Ordinary Portland cement of 53 grade (Deccan cement) conforming to IS:12269 is being used in the investigation. The cement was tested for various physical properties according to relevant Indian Standards.

3.1.1.1 Specific gravity of cement

The specific gravity of cement was determined using Le Chatelier apparatus and the specific gravity test of cement as per IS specifications. Kerosene which does not react with cement is used in the test.

3.1.1.2 Standard consistency of cement

The percentage of water required to produce a cement paste of standard consistency is that particular percentage of water which allows the Vicat plunger to penetrate for a depth of 5mm to 7mm from the bottom of the Vicat mould. Standard consistency of cement is found using an apparatus called Vicat Apparatus and the test was conducted according to IS specifications.

3.1.1.3 Initial setting time of cement

Initial setting time was found by using the Vicat Apparatus and the test was conducted as per IS specifications. [11]

The results obtained in the tests on cement are tabulated in Table 3.1.

Table 3.1 Physical properties of Cement

Sl.No	Properties	Values
1	Specific Gravity	3.125
2	Standard consistency	30%
3	Initial setting time(in minutes)	65

3.1.2 Fine Aggregate

Fine aggregate is the inert or chemically inactive material, most of which pass through a 4.75mm sieve and contains not more than 5% coarser material. The fine aggregates serve the purpose of filling all the open spaces in between the coarse particles. Thus, it reduces the porosity of the final mass and considerably increases its strength. The fine aggregate to be used in this study is manufactured sand. Aggregate which is passing through 1.7mm sieve is being used as they are much fine otherwise bubbles of foam will get break up making the concrete more stiffer and denser.

3.1.2.1 Specific gravity of fine aggregate

Specific gravity of fine aggregate was determined as per the procedure described in IS specifications [12] and is tabulated in Table 3.2.

Table 3.2 Specific Gravity of Fine Aggregate

Weight of the sample (W_1 kg)	0.5
Weight of the pyconometer + water (W_2 kg)	1.534

Weight of pyconometer + water + sample (W_3 kg)	1.846
Specific gravity	2.66

3.1.2.2 Sieve analysis of fine aggregate

Sieve analysis of fine aggregate was done as per the test procedure specified in the IS code.

Fineness modulus = 3.553

According to Table 4 of IS 383:1970, the fine aggregate is from Zone II

3.1.2.3 Water absorption of fine aggregate

The water absorption of fine aggregate was determined as per the procedure laid down in the IS code [18] and is given in Table 3.3

Table 3.3 Properties of Fine Aggregate

Sl no.	Properties	values
1	Specific gravity	2.66
2	Fineness modulus	3.553
3	zone	II
4	water absorption	10.2%

3.1.3 Water

The common specifications regarding quality of mixing water is water should be fit for drinking. Such water should have inorganic solid less than 1000 ppm. This content lead to a solid quantity 0.05% of mass of cement when w/c ratio is provided 0.5 resulting small effect on strength. Water used in the study was potable water. The water used for concreting should have a pH value lying in between 6 and 8 and it should be free from organic matter.

3.1.4 Fly Ash

Fly ash, the most widely used supplementary cementations material in concrete, is a by-product of the combustion of pulverized coal in electric power generating plants. The particle sizes in fly ash vary from less than 1µm (micrometer) to more than 100µm with the typical particle size measuring under 20µm. Fly ash is primarily silicate glass containing silica, alumina, iron, and calcium. Minor constituents are magnesium, sulphur, sodium, potassium, and carbon. The relative density (specific gravity) of fly ash generally ranges between 1.9 and 2.8 and the colour is generally grey or tan.

Fly ash used in this study was low calcium (ASTM Class F) Fly ash and it is use as filler by replacing it with sand The specific gravity of Fly ash as provided by the supplier is 2.5. The major influence on the fly ash chemical composition comes from the type of coal. The physical and chemical characteristics depend on the combustion methods, coal source and particle shape.

Fig.3.1 Fly Ash

3.1.5 Quarry dust

Quarry dust, a by-product from the crushing process during quarrying activities is one of those materials being studied, especially as substitute material to sand as fine aggregates. Quarry dust have been used for different activities in the construction industry such as for road construction and manufacture of building materials such as lightweight aggregates, bricks, tiles and autoclave blocks. Researchers have also been conducted to study the effects of partial replacement of sand with quarry dust in the properties of freshly mixed and hardened concrete applications. It was deduced from those studies that partial replacement of sand with quarry dust without the inclusion of other admixtures resulted in enhanced workability in the concrete mixes. The basic tests on quarry dust were conducted as per IS-383-1987 and its specific gravity was around 1.95. Wet sieving of quarry dust through a 90 micron sieve was found to be 78% and the corresponding bulking value of quarry dust was 34.13. Quarry dust has been used for different activities in the construction industry such as road construction and manufacture of building materials. As the properties are good as sand, the quarry dust is used as fine aggregate in replacement with sand in cement concrete. The advantages of quarry dust are cost effective, easily available, consumption reduces the pollution in environment and effectively used as a replacement material for river sand. Further, Hundreds of stone crushing plants in our country generate several thousand tons of quarry dust every day. This quarry dust is considered to be solid waste material. If it is possible to use this in making mortar/concrete by replacement of river sand, then it will solve the problem of its disposal. Moreover, the utilization of quarry dust, which can be called as manufactured sand after removal of micro fines below 150 micron size by sieving, has been accepted in the industrially advanced countries of the West as the river sand, which is one of the constituents used in preparation of cement mortar/concrete, has become highly expensive and scarce. Usage of quarry dust as partial replacement to river sand/natural sand further modified by partial replacement of pozzolanic materials like fly ash is receiving more attention these days as their use generally improves the properties of cement/concrete.

Fig 3.2 Quarry Dust

3.1.6 Sodium Lauryl Sulphate

Sodium lauryl sulphate (SLS) is a synthetic detergent (cleaning agent) and surfactant (which means it makes bubbles). It has a high pH as it is an alkali substance and has the appearance of a white powder. Sodium lauryl sulphate is sometimes referred to as the coconut surfactant because it can be manufactured from coconut oil. Being derived from inexpensive coconut and palm oils, Sodium coco-sulphate is essentially the same compound, but made from less purified coconut oil. Sodium lauryl sulphate (SLS) is a cheap, very effective cleansing and foaming agent (foams quickly). It is probably the most commonly used anionic surfactant in the personal-care business. It's an ingredient in a wide range of personal care products such as soap, shampoo and conditioners, bubble bath, moisturisers, cleansers, facial scrubs and shaving cream and toothpaste but in lower concentrations. Sodium lauryl sulphate is used to remove oily stains because it has a thickening effect that helps form lather. It is used in dishwashing liquids and laundry detergent. It's also used, in much higher concentrations, in industrial products such as car wash soap, engine degreasers, and floor (carpet) cleaners. SLS is an excellent foaming agent, and this is one of the reasons it's included in many personal care products, such as toothpaste. Sodium lauryl sulphate gives thick, rich foam . Properties of SLS is tabulated in Table 3.4.

Fig. 3.3 Sodium lauryl sulphate

Table 3.4: Properties of Sodium Lauryl Sulphate

Formula	$NaC_{12}H_{25}SO_4$
Molar mass	288.372 g/mol
IUPAC ID	Sodium lauryl sulphate
Melting point:	206 °C

3.2. PROPORTIONING AND PREPARATION OF FOAM CONCRETE

Often trial and error process is adopted to achieve foam concrete with desired properties Even though the strength of foam concrete depends on its density, for a given density, the strength can be increased by changing the constituent materials. Also, for a given density, the foam volume requirement depends on the constituent materials Hence for a given strength and density requirement, the mix design strategy should be able to determine the batch quantities. There are mainly two foaming techniques adopted (a)Pre-foaming (b)Mix foaming technique.

Pre-formed foaming is preferred to mix-forming technique due to the following advantages:

(i) lower foaming agent requirement.

(ii) A close relationship between amount of foaming agent used and air content of mix.

Most common types of mixers (tilt drum or pan mixer used for concrete or mortar) are suitable for foam concrete. The type of mixer and batching and mixing sequences of foam concrete depends upon pre-formed foam method or mix-foaming method.

4. EXPERIMENTAL PROGRAMME

The experimental investigation starts with the preparation of control mix of cement sand proportion of 1:1, 1:2, 1:3.

The first stage dealt with optimizing cement sand ratio of 1:1.The optimum amount of sodium lauryl sulphate in water is determined by adding 2g, 5g, 8g and 10g of foaming agent in 100ml, 500ml and 1000ml of water respectively. The mix was optimized with the compressive strength of foamed concrete in varying foam concentration.

Further optimum percentage of foam by weight to be added to the mix is determined. Foamed concrete mixes were prepared with 5%, 10%, 15%, 20% of foam by weight of cement. The control mix was optimized with the compressive strength of foamed concrete in different percentages of foam.

The third stage dealt with the replacement of cement with fly ash as its specific gravity is less than that of cement and sand filler with quarry dust is carried out which can bring down the self weight and to achieve the targeted compressive strength. Different percentages of replacement with flyash and quarry dust is carried out at the ratios 10-0, 20-0, 30-0, 40-0, 50-0 and 30-0, 30-10, 30-30, 30-40, 30-60, 30-80, 30-100 respectively.

The fourth stage dealt with the study of performance of foam concrete interlocking masonry blocks by constructing a wall of 1m X 1m.

4.1 TEST TO BE CONDUCTED ON CONCRETE

4.1.1 Fresh Concrete

Concrete workability is the relative ease with which a fresh mix can be handled, placed, compacted, and finished without segregation or separation of the individual ingredients. Good workability is required to produce concrete that is both economical and high in quality. Fresh concrete has good workability if it can be formed, compacted, and finished to its final shape and texture with minimal effort and without segregation of the ingredients.

4.1.1.1 Spread test of mortar

The spread test gives the quick assessment of the fluidity of high-slump concrete mixes. Equipment for the spread test comprises of a suitable base, a standard slump cone, metal scoop and a metric rule.

The base should be clean, flat, smooth-surfaced, and rigid and non-absorbent with a lateral dimension of not less than 600mm. It should be level and free from vibration during the test. Here a levelled glass plate is used as a base surface. Standard slump apparatus, a mini slump cone mould was used. The steps involved in spread tests are:

Place the moistened cone, narrow end downwards, on the centre of the base plate.

a) Remix the concrete sample thoroughly and then fill the slump cone taking care to avoid segregation.

b) Subject the cone to a quick vertical lift. Hold the upper end of the cone until the flow of concrete ceases.

c) Remove the slump cone and measure the spread of the concrete orthogonally.

d) Average of two measurements is reported as the spread of the mix.

Fig 4.1 spread test on mortar

Fig 4.2 slump cone

4.1.2 Hardened Concrete

The following moulds were used to cast the concrete specimens for various studies as per IS : 516-1959.

1) 70.8mm x 70.8mm x 70.8mm moulds were used to cast mortar cubes to determine the compressive strength of concrete.

2) 300mm x 200 mm x 150mm moulds were used to cast concrete blocks to determine the compressive strength of concrete.

Fig 4.3. 70.7mm x 70.7mm x 70.7mm cubes

Fig 4.4. 300mm x 200 mm x 150mm blocks

The specimens in the mould were covered and kept at room temperature for 24 hours. These were then kept submerged in water for curing.

For determining the hardened properties the test specimens were removed from the water bath and the surface was removed using a dry cloth, immediately before testing. Testing of hardened concrete plays an important role in controlling and conforming the quality of cement concrete works. The main purpose of testing hardened concrete is to conform that the concrete used has developed the required strength.

4.1.2.1 Compressive strength

Out of many test applied to the concrete, this is the most important test, which gives an idea about all the characteristics of concrete. By this single test one judge that whether concreting has been done properly or not. The test is conducting according to IS 516:1959.

Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, and quality control during production of concrete etc.

Clean the bearing surface of the testing machine. Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast. Align the specimen centrally on the base plate of the machine. Rotate the movable portion gently by hand so that it touches the top surface of the specimen. Apply the load gradually without shock and continuously at the specified rate till the specimen fails. Record the maximum load as denoted by equation 4.1 and note any unusual features in the type of failure.

$$Compressive\ strength = \frac{Load\ applied\ in\ Newtons}{Cross\ sectional\ area\ in\ mm^2} \quad (4.1)$$

4.1.2.2 Density of the mix

After preparing the mix, wet densities and dry densities of each mix containing different proportions of foam volume was found out and compared .The wet density is found out by weighing each mould filled with the mortar mix and dividing the value by the volume of mould. The cube specimens shall be dried to constant mass and then cured for 3 days, 7 days and 28 days. The overall volume is computed in cubic meters. The blocks shall then be weighted in kilograms to the nearest 10gm.Thus dry densities is found out by using equation 4.2 weighing the dried cube specimens and the same is repeated at 3, 7 and 28 days of curing of mortar cubes.

$$Density = \frac{Weight}{Volume} \quad (4.2)$$

5. RESULTS AND DISCUSSIONS

5.1 MECHANICAL PROPERTIES OF FOAMED CONCRETE

5.1.1 Spread Test on Foamed Concrete

After raising the slump cone, the spread flow of the mortar is measured using tape. Average of the measurement is taken in 2 opposite directions. Mix which is both stiffer and heavily flowing one is avoided. Mix with average flow of 100mm is obtained as optimum without any stiffness and segregation.

5.1.2 Density of the control mix

The wet and dry densities of the specimens with trial mixes 1:1, 1:2, 1:3 calculated at 3, 7 and 28 days and are tabulated in Table 5.2.

Table 5.1: Wet and Dry Densities of control mixes with 1:1, 1:2, 1:3 mix

Control mix ratio	Wet density(kg/m^3)	Dry Density (kg/m^3)		
		3days	7days	28days
1:1	1897	1891	1886	1882
1:2	1830	1824	1817	1812
1:3	1792	1796	1791	1782

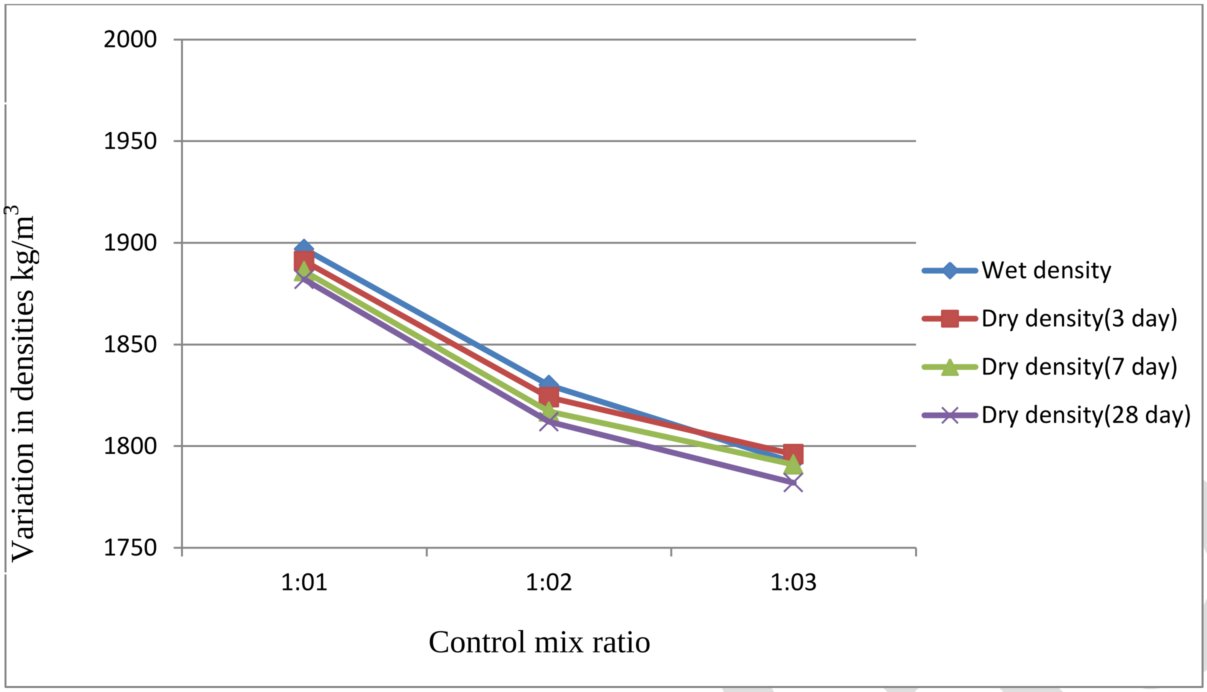

Fig 5.1 Wet densities and dry density of control mixes

5.1.2 Compressive strength of the control mix

The compressive strength of the specimens with trial mixes 1:1, 1:2, 1:3 calculated at 3, 7 and 28 days and are tabulated in Table 5.3

Table 5.2 : Comparison in Compressive strength of control mixes with 1:1, 1:2, 1:3 mix

Control mix ratio	Compressive Strength (N/mm^2)		
	3 days	7 days	28 days
1:1	22.5	32.5	57
1:2	21.15	27.6	44.12
1:3	19.84	25.84	41.15

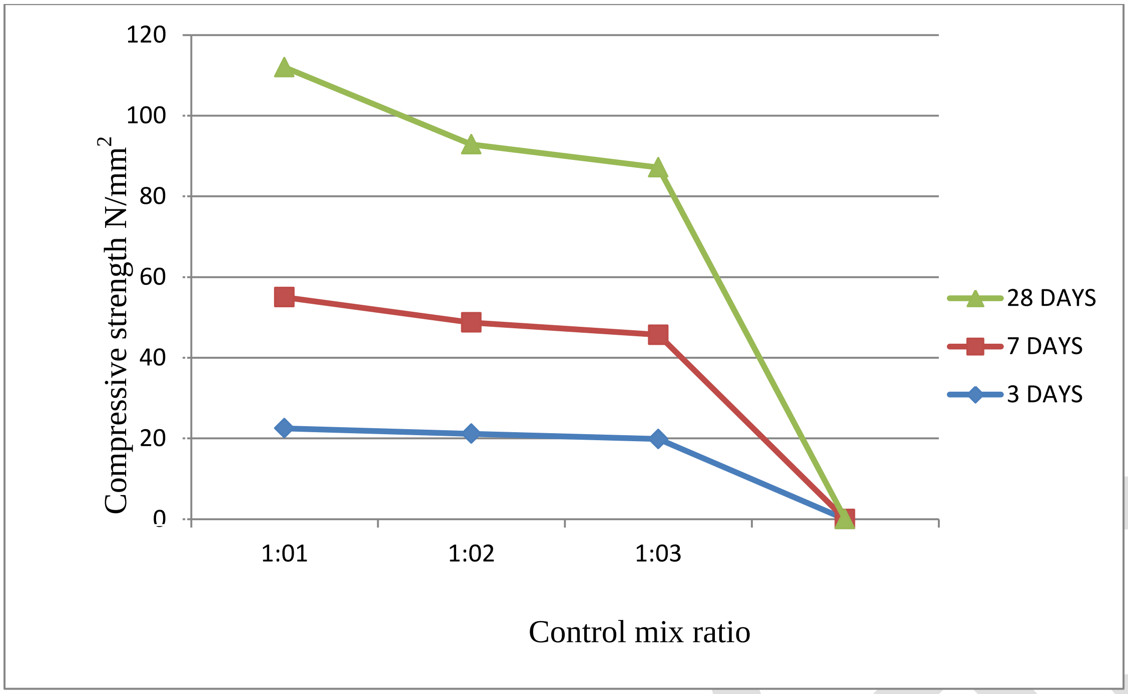

Fig 5.2 Compressive strength of control mixes

From the above observations the compressive strength showed a higher value when the mix proportion is taken as 1:1. i.e. 1 part of cement and 1 part of sand. Fixing the control mix of 1:1 the further experiments with foam concrete is carried out.

5.2 OPTIMIZATION OF CONCENTRATION OF FOAM

The concentration of foam is optimized by adding 2g, 5g, 8g, 10g of foaming agent(Sodium lauryl sulphate) in 100ml, 500ml ,1000ml of water. Corresponding values are found out.

5.2.1 Density of foam concentrations

The wet and dry densities of foamed concrete with different percentages of foam are calculated at 3, 7 and 28 days and are tabulated in Table 5.4 to 5.7

Table 5.3: Wet and Dry Densities of Foamed Concrete with 2g sodium lauryl sulphate concentration

Water (ml)	Wet density(kg/m^3)	Dry Density (kg/m^3)		
		3days	7days	28days
100	1708	1701	1695	1688
500	1730	1724	1717	1712
1000	1742	1736	1731	1722

Table 5.4: Wet and Dry Densities of Foamed Concrete with 5g sodium lauryl sulphate concentration

Water (ml)	Wet density(kg/m^3)	Dry Density (kg/m^3)		
		3days	7days	28days
100	1669	1652	1657	1658
500	1680	1677	1667	1662

1000	1691	1686	1681	1678

Table 55: Wet and Dry Densities of Foamed Concrete with 8g sodium lauryl sulphate concentration

Water (ml)	Wet density(kg/m^3)	Dry Density (kg/m^3)		
		3days	7days	28days
100	1625	1619	1616	1611
500	1638	1631	1626	1621
1000	1658	1651	1643	1639

Table 5.6: Wet and Dry Densities of Foamed Concrete with 10g sodium lauryl sulphate concentration

Water (ml)	Wet density(kg/m^3)	Dry Density (kg/m^3)		
		3days	7days	28days
100	1586	1581	1578	1574
500	1594	1589	1585	1579
1000	1612	1609	1605	1602

From the observations of Tables 5.4 to 5.7, it can be noticed that, with the different concentrations of foam, there is reduction in density compared to conventional concrete. As the foam concentration goes on increasing the weight of foam concrete also get decreased which makes it more lightweight.

5.2.2 Compressive strength of concentration of foam

The specimens with varying dosages of foam concentration were tested for compressive strength at the 3rd, 7th and 28th day of curing and the results are tabulated in Table 5.8 to 5.11

Compressive strength is calculated for 2g sodium lauryl sulphate in 100ml, 500ml, 1000ml respectively and corresponding values are tabulated.

Table 5.8 Compressive strengths with 2g sodium lauryl sulphate

Water (ml)	Compressive Strength (N/mm^2)		
	3 days	7 days	28 days
100	7.1	10.09	14.96
500	7.9	11.05	15.31
1000	8.52	12.24	16.18

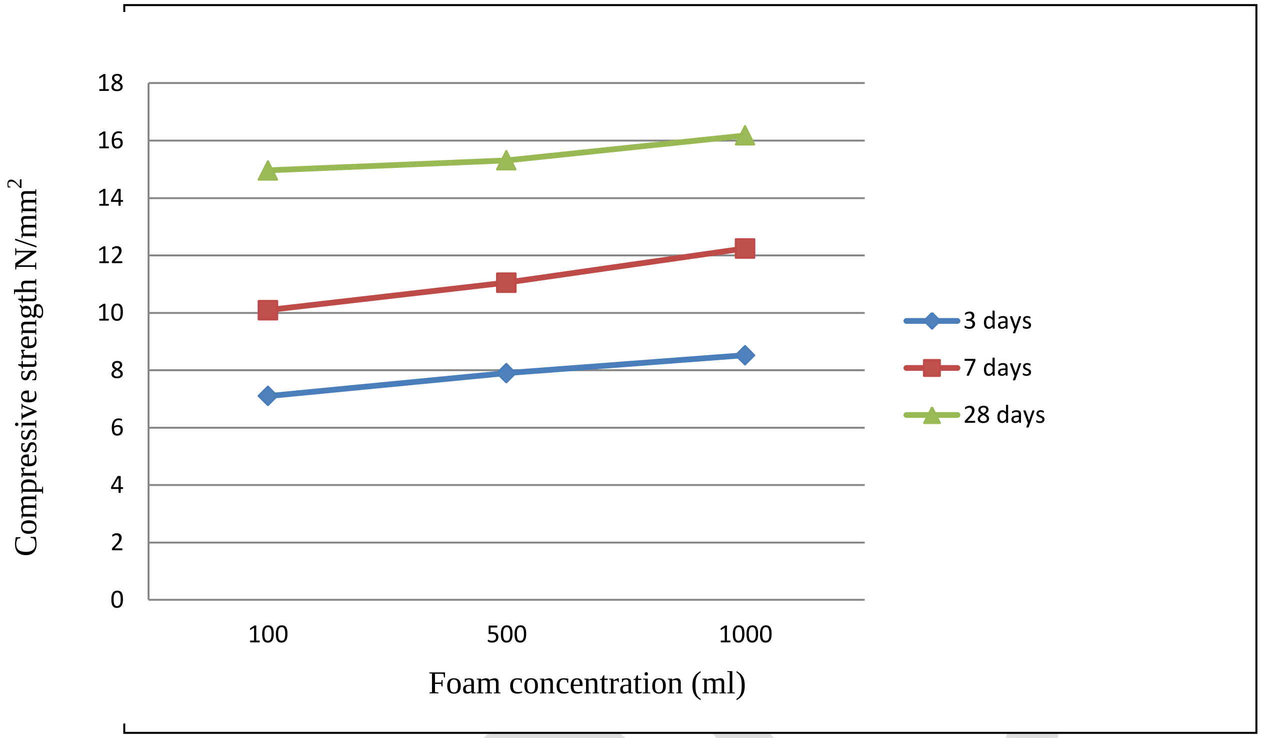

Fig 5.3 Compressive strengths with 2g sodium lauryl sulphate

Compressive strength is calculated for 5g sodium lauryl sulphate in 100ml, 500ml, 1000ml respectively and corresponding values are tabulated.

Table 5.9 Compressive strengths of 5g sodium lauryl sulphate

Water (ml)	Compressive Strength (N/mm^2)		
	3 days	7 days	28 days
100	6.1	9.5	13.85
500	6.8	10.75	14.75
1000	7.25	11.50	15.6

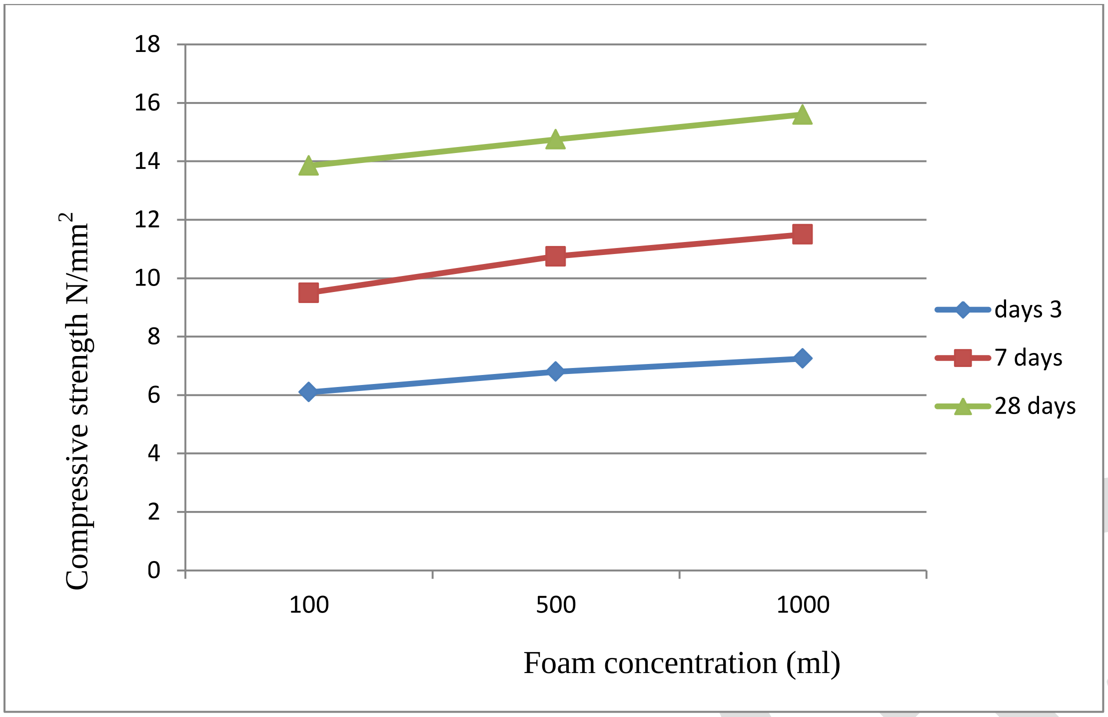

Fig 5.4. Compressive strengths with 5g sodium lauryl sulphate

Compressive strength is calculated for 8g sodium lauryl sulphate in 100ml, 500ml, 1000ml respectively and corresponding values are tabulated.

Table 5.10 Compressive strengths of 8g sodium lauryl sulphate

Water (ml)	Compressive Strength (N/mm^2)		
	3 days	7 days	28 days
100	5.8	8.09	11.80
500	6.2	9. 5	12.25
1000	6.5	10.5	14

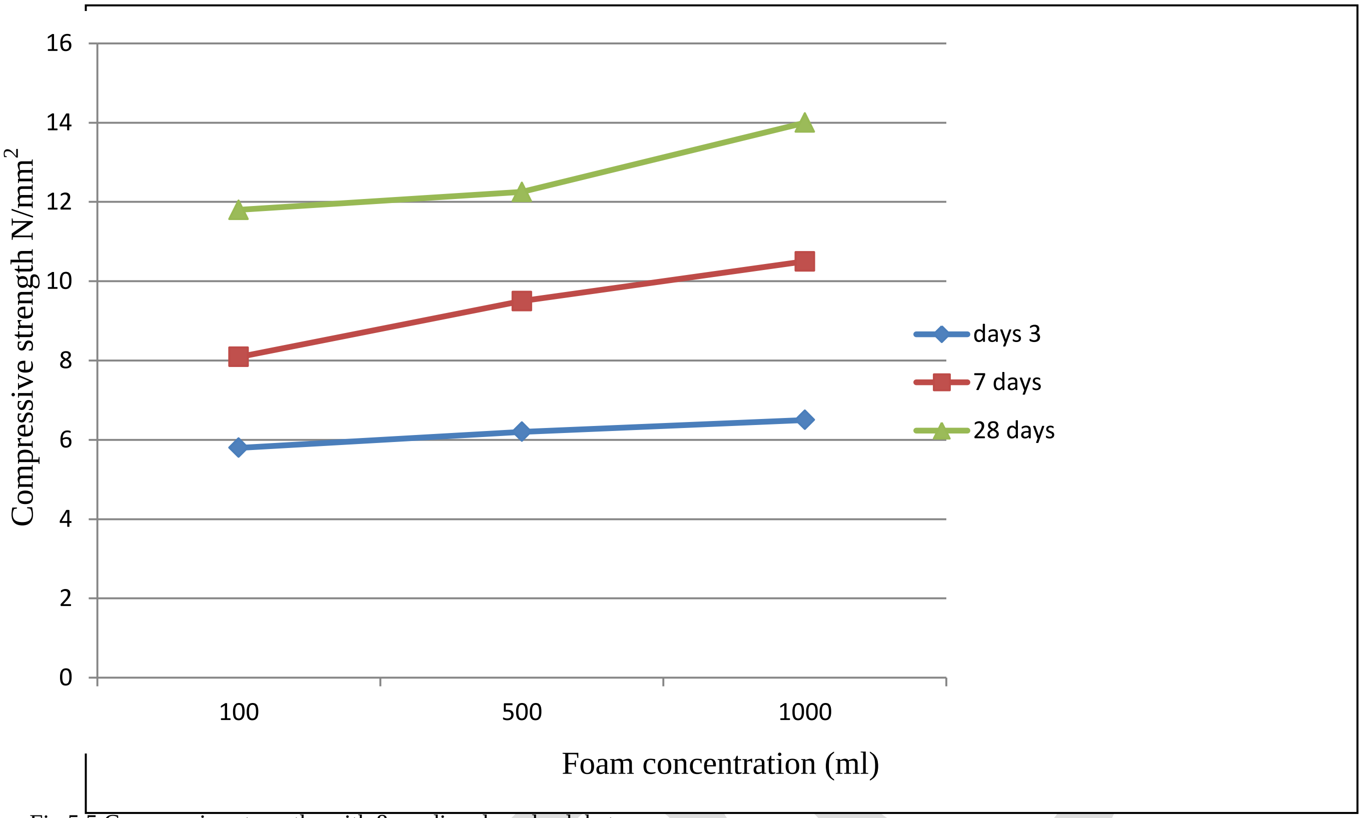

Fig 5.5 Compressive strengths with 8g sodium lauryl sulphate

Compressive strength is calculated for 10g sodium lauryl sulphate in 100ml, 500ml, 1000ml respectively and corresponding values are tabulated.

Table 5.11 Compressive strengths of 10g sodium lauryl sulphate

Water (ml)	Compressive Strength (N/mm^2)		
	3 days	7 days	28 days
100	3.40	5.8	9.5
500	4.5	7.25	10.36
1000	5.5	9.30	12.5

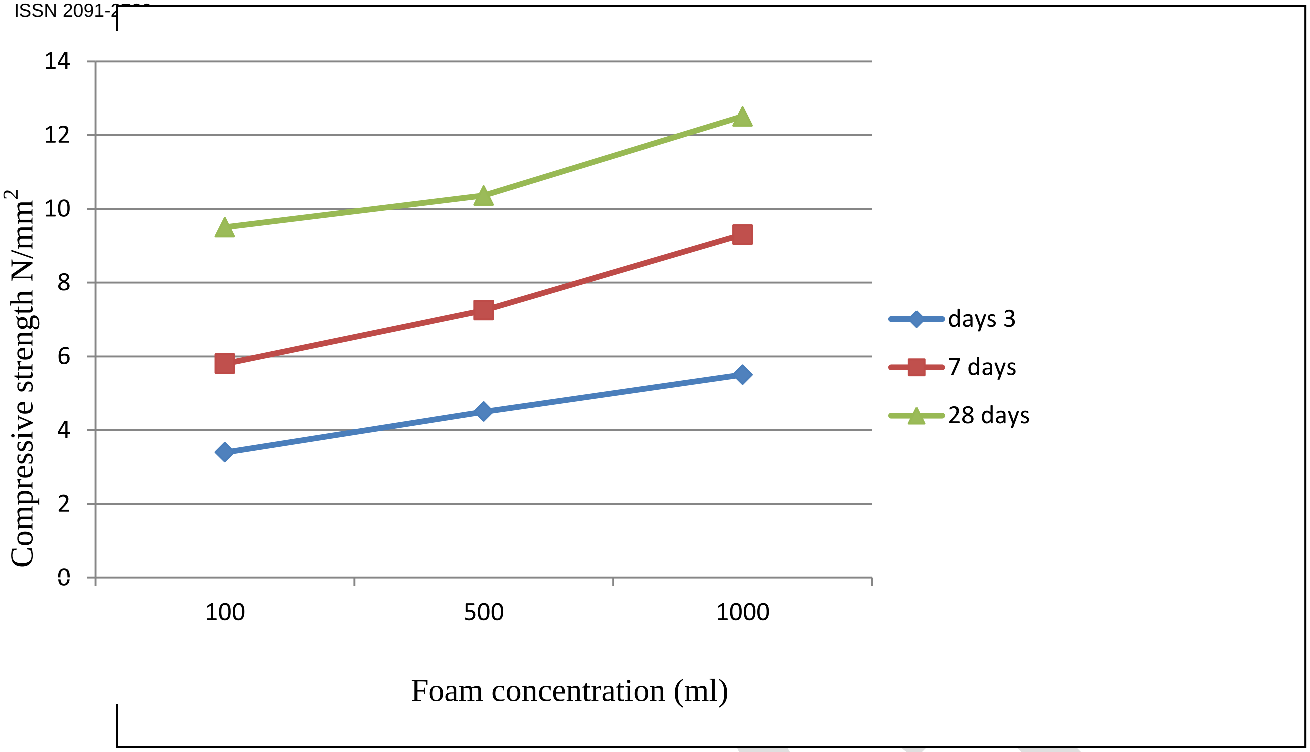

Fig 5.6 Compressive strengths with 10g sodium lauryl sulphate

From the observations of Table 5.8 to 5.11, it can be noticed that, the foam concentration of 5g shows the higher compressive strength, with desired density compared to other concentration, and it is noticed that the strength decreases when it comes to higher concentration of foaming agent. Optimizing the foam concentration of 5g in 100ml of water the Percentage Variation of Foam is calculated.

5.3 OPTIMIZATION OF FOAM VOLUME IN CONCRETE

The amount of foam that should be added to concrete is optimized by making 3 specimens each with 5%, 15%, 20%, 25% foam volume. The results are valued and tabulated.

5.3.1 Density of foam volume

The wet and dry densities of foamed concrete with different percentages of foam are calculated at 3, 7 and 28 days. Wet and dry densities of specimens at 3, 7 and 28 days are tabulated in Table 5.12.

Table 5.12: Wet and Dry Densities of Foamed Concrete with Percentage Variation of Foam

Foam % by weight of cement	Wet density(kg/m^3)	Dry Density (kg/m^3)		
		3days	7days	28days
0%	1897	1891	1886	1882
5%	1669	1652	1657	1658
10%	1582	1578	1573	1564
15%	1549	1544	1537	1532
20%	1512	1508	1502	1497

From the observations of Table 5.12, it can be noticed that, with the addition of foam by weight, there is reduction in density compared to conventional concrete. As the percentage of foam goes on increasing the weight of foam concrete also get decreased which makes it more lightweight.

5.3.2 Compressive strength of foam volume

The specimens with varying dosages of foam with were tested for compressive strength at the 3rd, 7th and 28th day of curing and the results are tabulated in Table 5.13

Table 5.13. Comparison of compressive strength with various percentages of foam

foam (% by wt of cement)	Compressive Strength (N/mm^2)		
	3 days	7 days	28 days
0%	22.5	32.5	57
5%	6.7	12.5	15.5
10%	5.4	7.6	12.57
15%	3.10	8.4	9.06
20%	2.9	3.8	6.5

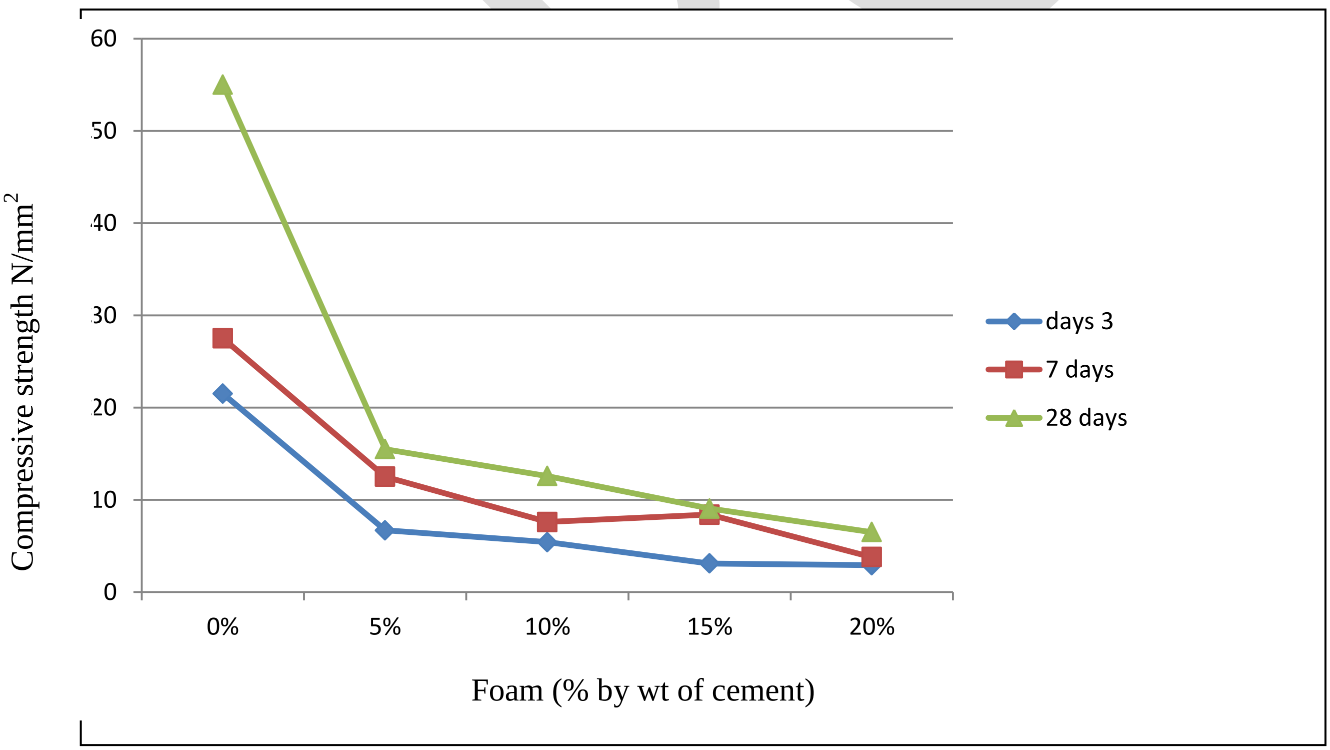

Fig 5.7 Compressive strength with various percentages of foam

From the observations of Table 5.13, it can be noticed that, with the addition of foam by weight, the foamed concrete specimens shows significant reduction in compressive strength. Thus reduction increases with increasing percentage of foam and the compressive strength is very low when the percentage of foam reaches about 20% by weight of cement. Thus, the optimum percentage of foam by weight of cement is fixed as 5%.

5.4 REPLACEMENT OF CEMENT BY FLYASH

5.4.1 Density of replacement of cement by flyash

The wet and dry densities of foamed concrete with replacement of cement by flyash is calculated at 10-0,20-0,30-0,40-0,50-0. Wet and dry densities of specimens at 3, 7 and 28 days are tabulated in Table 5.14

Table 5.14. Wet and Dry Densities of Foamed Concrete Variation in percentages of Cement by Flyash

Replacement (%)	Wet density(kg/m^3)	Dry Density (kg/m^3)		
		3days	7days	28days
10-0	1649	1642	1637	1634
20-0	1632	1628	1623	1620
30-0	1624	1619	1614	1597
40-0	1595	1591	1586	1583
50-0	1583	1579	1576	1572

Fig 5.9 Wet and Dry Densities of Foamed Concrete Variation in percentages of Cement by Flyash

5.4.2 Compressive strength of replacement of cement by flyash

Compressive strength of foamed concrete with replacement of cement by flyash is calculated at 10%-0, 20%-0,30%-0,40%-0,50%-0 at 3rd, 7th and 28th day of curing and the results are tabulated in Table 5.15

Table 5.15. Comparison of compressive strength of Variation in percentages of Cement by Flyash

Replacement (%)	Compressive Strength (N/mm^2)		
	3 days	7 days	28 days
10-0	8.2	9.5	15.5
20-0	7.5	8.8	18.2
30-0	6.8	8.1	23.8
40-0	5.6	7.5	23.5
50-0	5.1	6.2	22.5

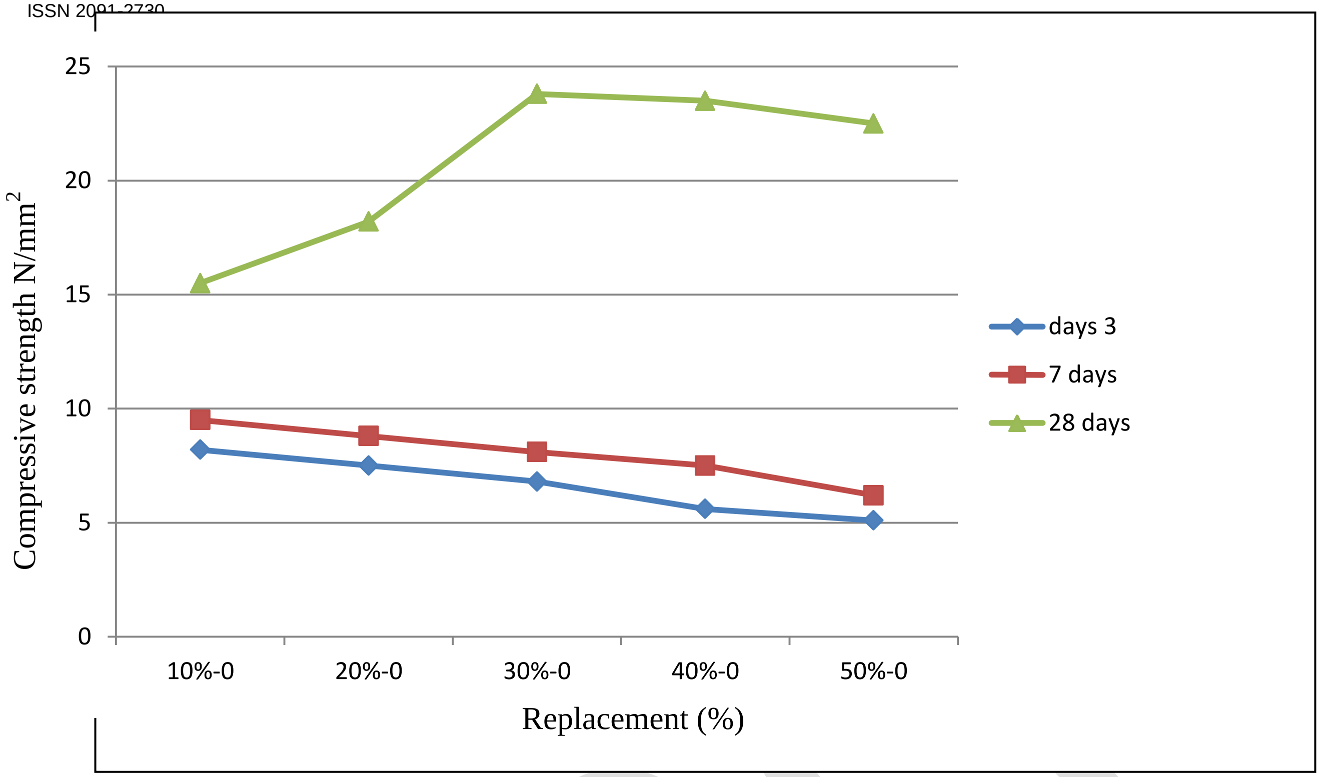

Fig 5.8 Compressive strength of Variation in percentages of Cement by Flyash

From the observations of Table 5.15, it can be noticed that, As the level of flyash replacement increases the early-age strength decreases. However, long-term strength development is improved when fly ash is used. The percentage replacement is found optimum when 30% cement is replaced by flyash. The compressive strength shows a decrease in value when the replacement percentage increases

5.5 REPLACEMENT OF CEMENT BY 30% FLYASH AND PERCENTAGE VARIATION IN SAND BY QUARRY DUST

5.5.1 Density of replacement of cement by 30% flyash and percentage variation in sand by quarry dust

The wet and dry densities of foamed concrete with replacement of cement by flyash and sand by quarry dust are calculated .Wet and dry densities of specimens at 3, 7 and 28 days are tabulated in Table 5.16

Table 5.16. Wet and Dry Densities of Foamed Concrete Replacement in Cement by 30% Flyash and Variation in percentages of Sand by Quarry dust

Replacement (%)	Wet density(kg/m^3)	Dry Density (kg/m^3)		
		3days	7days	28days
30-0	1628	1622	1620	1618
30-20	1620	1616	1613	1610
30-30	1613	1608	1594	1591
30-40	1589	1584	1582	1589
30-60	1581	1578	1572	1578
30-80	1574	1571	1579	1576
30-100	1568	1566	1563	1561

5.5.2 Compressive strength replacement of cement by 30% flyash and percentage variation in sand by quarry dust

Compressive strength of foamed concrete with replacement of cement by 30% flyash and sand by quarry dust are calculated at 30-0, 30-20, 30-30, 30-40, 30-60, 30-80, 30-100 at 3rd, 7th and 28th day of curing and the results are tabulated in Table 5.17

Table 5.17. Comparison of Compressive strength of Foamed Concrete Replacement in Cement by 30% Flyash and Variation in percentages of Sand by Quarry dust

Replacement (%)	Compressive Strength (N/mm^2)		
	3 days	7 days	28 days
30-0	7.6	9.2	18.3
30-20	8.33	10.16	21.4
30-30	6.6	8.3	23.5
30-40	8.4	10.5	22.25
30-60	8.2	9.53	21.8
30-80	7.83	8.62	20.5
30-100	6.60	9.5	19.6

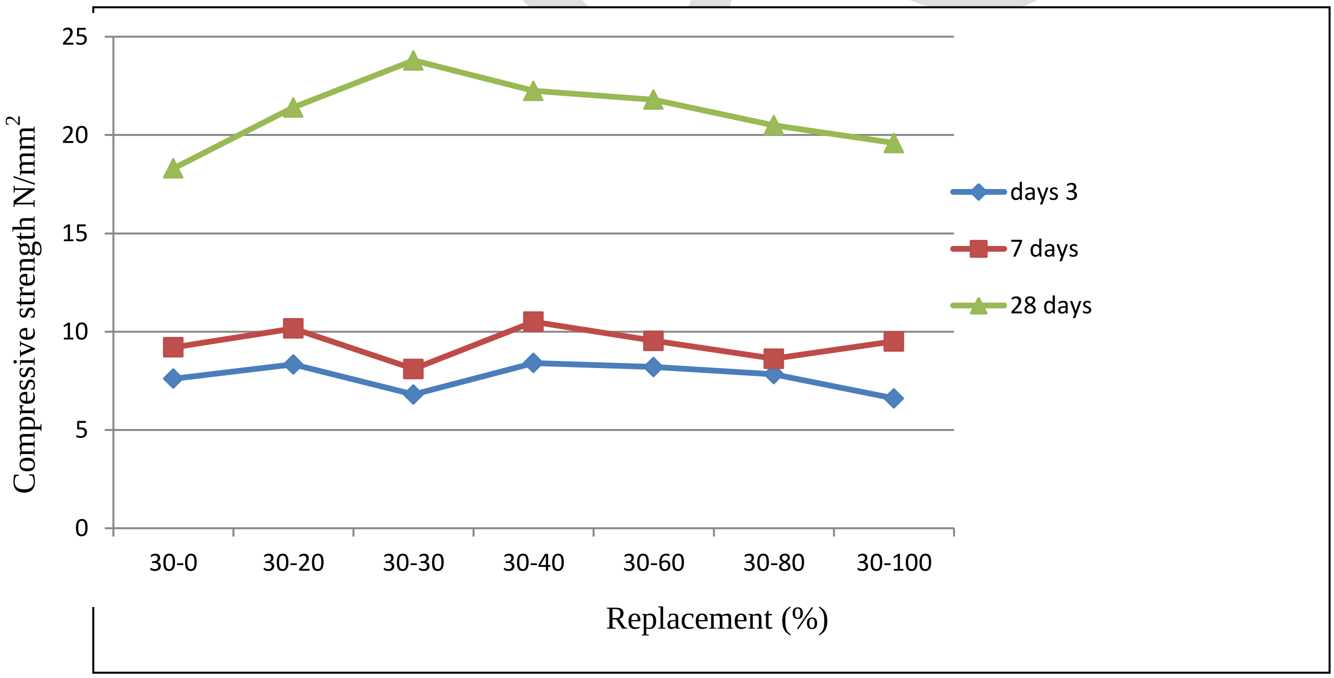

Fig 5.9. Compressive strength of Foamed Concrete Replacement in Cement by 30% Flyash and Variation in percentages of Sand by Quarry dust

From the observations of Table 5.17., it can be noticed that, the Replacement of the sand with quarry dust shows an improvement in compressive strength of the concrete in the presence of fly ash. Quarry dust can be a suitable partial replacement material to sand to produce concretes with fair ranges of compressive strength. It shows an increase in compressive strength up to 30% replacement. As the level of replacement increases the compressive strength decreases.

5.6 OPTIMIZATION OF FOAM CONCRETE INTERLOCKING MASONARY BLOCKS

5.6.1 Density of foam concrete interlocking masonry blocks

Foam concrete masonry block of 300mm*200mm*150mm is made and Wet, Dry densities of the specimens at 3, 7 and 28 days are tabulated in Table 5.18

Table 5.18.Wet and dry density of foam concrete interlocking masonry blocks

Foam Volume	Replacement Ratio(Flyash-Quarry dust)	Wet Density(kg/m^3)	Dry Density (kg/m^3)		
			3days	7days	28days
5%	30-30	1688	1684	1679	1675

5.6.2 Compressive strength of foam concrete interlocking masonry blocks

The compressive strength of foam concrete masonry block with dimension 300mm*20mm*15mm are calculated at 3^{rd},7^{th} and 28^{th} day of curing and tabulated in table 5.19

Table 5.19 Compressive strength of foam concrete interlocking masonry blocks

Replacement (%)	Compressive Strength (N/mm^2)		
	3 days	7 days	28 days
30-30	1.98	2.96	10.82

Thus, foam concrete interlocking masonry blocks with optimized quantities showed a desirable 28 day strength as per the codal specifications.

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CONCLUSIONS

From the study of foamed lightweight concrete it is found fly ash and quarry dust which is a waste products have sufficient potential as the replacement of cement and sand for making much lesser denser and stronger bricks. Following are the conclusions derived from the experimental results:

- Foam concentration as optimized at 5g of sodium lauryl Suphate when added to 100ml of water.

- Strength was maximum attained when 5% of foam by weight of cement were added to the concrete.
- Fly ash which is a waste product from coal industry replaces cement which makes the foamed concrete much less denser and stronger 30% replacement showed better strength.
- The use fly ash which is freely and readily available can make foamed concrete cost effective.
- Replacement of quarry dust which is again a waste product , makes the concrete less denser and enhances the strength.. It showed the maximum strength when 30% of sand is replaced by quarry dust.
- Foamed light weight blocks can be used for wall panels, insulating panels over the wall to make it more thermal insulating.
- Fly ash and quarry dust used enables the large utilization of waste product which brings down the exploitation of natural resources; reduce the emission of green house gases.

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