International Journal of Innovative Research in Engineering & Management (IJIREM)
ISSN: 2350-0557, Volume-9, Issue-1, February 2022
https://doi.org/10.55524/ijirem.2022.9.1.108
Article ID IJIRDP-1160, Pages 510-515
www.ijirem.org

Experimental Research on foam Concrete with Partial Replacement of Fine Aggregates by Blast Furnace Slag, Fly Ash, and Glass Powder

G Bathi Reddy[1], K. Ashok Kumar[2], and A. Prasad[3], G. Vamsi Krishna[4], M. D. Syam Kumar[5]

[1, 2,3,5]Assistant Professor, Department of Civil Engineering, Pace Institute of Technology and Sciences, Ongole, Andhra Pradesh, India

[4]M.Tech Scholar, Department of Civil Engineering, Pace Institute of Technology and Sciences, Ongole, Andhra Pradesh, India

ABSTRACT- Although foam concrete was initially intended to be avoid filler and insulating material, interest in its structural qualities has grown again due to its reduced weight, material savings, and potential for extensive use of waste materials like fly ash. This paper's main objective is to review the present state of knowledge on foam concrete, where sand is partially replaced by glass powder, fly ash, and blast furnace slag in various weights and proportions. The review highlights the necessity for creating new pathways by doing in-depth research on materials, mixture design, and methods to maximise the potential of this material for structural applications.

KEYWORDS- Foam concrete, Light weight, blast furnace slag, fly ash and glasspowder and compressive strength.

I. INTRODUCTION

Foam concrete is a lightweight concrete that is either a cement paste or a mortar in which air spaces are captured in the mortar mix by an appropriate foaming agent. In general, foam concrete is classified as cellular concrete. [1]Its essential characteristics are high flowability, low self weight, minimal aggregate consumption, regulated low strength, and adequate thermal insulation capabilities.[2] A wide range of regulated densities of foamed concrete from 400 to 1800 kg/m3 may be produced by exercising adequate control over correct foam dosage, providing flexibility in making products for specific applications (structural, partition, insulation and filling grades). Several studies on the qualities of foam concrete have been conducted in the past[4].

Valore presented the first comprehensive review of cellular concrete in 1954, and Rudnai and Unedited accepted version of the paper titled "A Classification of Studies on Properties of Foam Concrete" authored by Ramamurthy, K., Nambiar., E.K.K, and Indu Sivaranjani, G. Cement and concrete composites, Volume 31, Issue 6, July 2009, 388-396 2 Short and Kinniburgh summarised the composition, qualities, and applications of cellular concrete in 1963, regardless of the manner of cell structure production.

McCarthy examined the history of foam concrete, the basic materials utilised, its qualities, and building applications, as well as various projects completed across the world. These assessments also contain functional attributes like as fire resistance, thermal conductivity, and acoustic properties. However, information on the fresh state qualities, durability, [3] and air-void system of foam concrete is few. The production of stable foam concrete mix is dependent on many factors, including the choice of foaming agent, foam production method, foam concrete production method, type of mixer, mixing duration, and mix consistency, and thus a review that compiles the various factors affecting foam concrete production is required. Despite the fact that the material was initially invented in 1923, its use in building as a lightweight non- or semi-structural material is growing Throughout the previous couple years.

To maximize its potential as a structural material, the technical control requirements of foam concrete production in terms of constituent materials (material selection, mixture design strategies, and foam preparation and addition for uniform air void distribution) and performance in the fresh and hardened states are more important. The current obstacles experienced in foam concrete manufacturing, particularly process selection, problems encountered in mixing, transporting, and pumping if necessary across long distances, must also be addressed from the standpoint of foam concrete manufacturers. With the aforementioned considerations in mind, this article categorizes studies on foam concrete according to its component materials, mix proportioning, manufacture, and fresh state and hardened qualities.

II. LITERATURE REVIEW

Ramamurthy et al., Fly ash can be used in foam concrete as a partial or complete filler alternative to boost compressive strength while retaining a high strength-to-density ratio. However, its extensive use in structural applications has been limited due to a lack of scientific and engineering expertise.[1] The batch sizes for a certain strength and density need should be determined by the mix design approach. However, if the mix proportions are known, the bulk of the proposed batch quantity calculation methods can be applied. An economical foaming agent and foam generator are necessary for this product to be utilised more widely in underdeveloped countries.[5] The emphasis must be on developing chemical admixtures that are compatible, with various forms of coarse aggregate serving as reinforcement, including enhancing the material's potential as a structural material Drying causes shrinkage[6]

Maheshkumar H. Thakrele 2014 [2], presented an experimental inquiry into foam concrete Two foam concrete mixes with and without sand are generated,[7] and efforts have been made to choose the foam concrete mix proportions for the goal plastic density of 1900 kg/m3.[8] 18 concrete cubes are constructed and evaluated for mixes, and its physical (Density) and particular structural (Compressive Strength) qualities are studied, and also their Specific Strength and Percentage.

Raman Kumar et.al [3], highlighted that concrete is a critical component used in the construction industry all over the world, where the fine total is common sand The use of sand in construction activities leads in compelled mining. Because of incredible mining, natural assets are being depleted[9], which causes an increase in scour profundity and, on occasion, surge risk. As a result, the use of alternative materials in concrete is becoming unavoidable. Marble is an important material used in the construction industry. It shows that in figure 1.Marble powder is produced by handling plants during the cleaning and cutting of marble squares, and around 20 - 25% of the processed marble is converted into powder form[10]. One of today's major environmental challenges is the destruction of marble powder material from the marble industry. This study proposes employing waste marble powder developed by the business itself as a fine total in solid, replacing ordinary sand. The substitution is done partially and totally in the amounts of 10%, 15%, and 20%,[11] and the influence on cement characteristics is determined.[12] The strength gain of foamed concrete is compared to the strength gain of regular weight concrete, and the findings are given.[14].

III. MATERIALS

A. Cement

It is a cementing element that is similar to Portland stone found in the United Kingdom. By calcining to the point of incipient fusion, an intimate and correctly proportioned combination of argillaceous and calcareous materials known as clinker is generated, which may be defined as Portland cement. To guarantee that the clinker generated after burning has the correct composition, the raw material quantities must be calculated carefully. Standard Portland cement is available in three grades: 33 Grade (IS269:1989), 43 Grade (IS 8112:1989), and 53 Grade (IS 8112:1989). (IS 12669-1987).

B. Foam

Foam bubbles are introduced into the cement paste and the concrete produced to obtain the low specific gravity of foam concrete. Foam bubbles are air gaps surrounded by the wall of a foaming agent solution. Synthetic foaming compounds, such as resin soap, and protein-based foaming agents, such as hydrolyzed protein, are both common. Preformed foam is made by combining the foaming agent, water, and compressed air (figure 1, and 2 created by an air compressor) in predefined quantities in a foam generator calibrated for a discharge rate. The density of the foam, the dilution ratio of the agent, the foaming process, the pressure of the compressed air, and the mixing and blending procedure with the mortar all have an impact on its quality. Furthermore, the mortar's workability is critical for the uniform introduction of foam.

Figure 1: Foam mechanisms

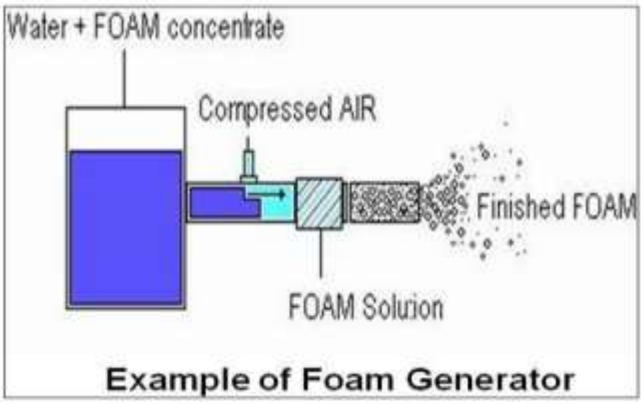

Figure 2: Example of Foam generator

C. Fine aggregate

Sand (> 0.07 mm) is used in mortar and concrete as a fine aggregate. Silica in the form of granules. Standard sand is the sand used in mix design (IS: 650). Ennore Sand is ordinary sand in India and Leighton-Burrard Sand in the United Kingdom. Ennore, Tamil Nadu, should be used to acquire the standard sand. It shows that figure 2.It should be quartz, light grey, or white in colour and devoid of silt.

D. Substitute materials in fine aggregates

1) Fly ash

Fly Ash of "Class-F" obtained from the thermal power plant is employed in the current experiment. Cement is utilised with fly ash amounts of 20% and 30% by weight. Fly ash has the following physical characteristics, as depicted (see table 1).

Table 1: Properties of Fly Ash

S.No.	Properties	Values
1	Silica (SiO_2)	56.87 %
2	Aluminium trioxide (Al_2O_3)	27.65 %
3	Ferric oxide (Fe_2O_3 + Fe_3O_4)	6.28 %
4	Titanium dioxide (TiO_2)	0.31 %
5	Magnesium oxide(MgO)	0.34 %
6	Loss of ignition (LOI)	4.46 %
7	Specific gravity of Fly Ash	2.12

2) Blast furnace slag

Slag from blast furnaces is an iron byproduct. Blast furnace slag, a type of non-biodegradable waste, is produced in large quantities by the iron industry. It can be used as a substitute for fine aggregate in concrete from local companies. after the blast furnace has melted the iron ore, limestone, and coke. Blast furnace slag is created during the melting process when the silicates and aluminates in the coke ash and ore combine with the lime in the flux (see table 2).

Table 2: Properties of blast furnance slag

S.No.	Properties	Values
1	Silica (SiO_2)	56.87 %
2	Aluminium trioxide (Al_2O_3)	27.65 %
3	Ferric oxide (Fe_2O_3 + Fe_3O_4)	6.28 %
4	Titanium dioxide (TiO_2)	0.31 %
5	Magnesium oxide(MgO)	0.34 %
6	Loss of ignition (LOI)	4.46 %
7	Specific gravity of Fly Ash	2.12

3) Glass powder

Shop-bought glass powder and broken glass sheets are not recycled and are disposed of in landfills. Glass powder is used in concrete to create a safer environment. The cost of foam concrete can be decreased by using this waste glass powder in place of sand. Waste material is glass powder. They are broken down in the breaker and processed to create fine particles like sand.

4) Recycled or waste material

Many researchers have acknowledged effectively employing waste or recycled materials as constituent elements of foam concrete, including sewage sludge ash [cook and walker, 1999], crushed excavated material, slaked lime, crushed broken ceramic bricks, and waste from brown coal combustion.

5) Additives or mixtures

Additives or mixes may be employed to achieve a specific modification in the characteristics of newly mixed or cured concrete. According to ACI 523.3R-93 [American Concrete Institute, 1993], admixtures must correspond to ASTM C260 and C494 (American Society for Testing and Materials, 1994 and 1992, respectively). Admixtures such as water-reducing agents, repellents, retarders, and accelerators are frequently utilised. Foam concrete is the construction of high-strength foam concrete utilising the pre-foaming technique, which generally has a low water/binder ratio and so requires the employment of a water-reducing agent. detailed the development of a high-strength foam concrete in which water made up just 0.19 percent of the mass of cement, silica fume, and ultra-fine silica stone powder. The super plasticizer dose was 3% by weight of the blended powder to provide a flow value of roughly 180mm, as calculated by JISR5201 [Japanese Architectural Association, 1998]. Any additive used in foam concrete should be checked for compatibility with the other constituents in the mix since admixtures might react unfavourably with the foaming agent [American Concrete Institute, 1993.

6) Bricks

The fundamental building blocks used in masonry construction are bricks. Compared to stone, bricks are easier to construct and require less labour during installation. Bricks have different properties depending on the soil they are made of. According to IS 3495 (Part 1): 1992, bricks in India typically have a strength between 7 and 10 N/mm2.
The test method for determining several brick qualities, such as compressive strength, water absorption, efflorescence, and warpage, is provided in the IS 3495 (Part 1 to 4): 1992. This Indian Standard does not prescribed a test protocol for brick's modulus of elasticity.

7) Aerated Concrete's Qualities

- Water absorption: Foamed concrete has extremely little water absorption because of its tight cellular structure. However, the absorption of water increases with air content. Typically, it represents less than 5% of the volume.
- Compressive strength: Numerous elements, including density, age, moisture content, the physical and chemical properties of the constituent materials, and mix proportions, have an impact on the compressive strength of foamed concrete. Controlling the variances in the mix proportions, cement type, sand content, and other fillers, as well as the production process, is preferred for uniform quality. The compressive strength rises with density under the same testing conditions and materials. Due to the reaction with the CO2 in the surrounding air, the compressive strength will keep growing indefinitely. However, throughout the first 12 months, the increase in strength is almost linear, unlike dense-weight concrete, which levels out much earlier. Foamed concrete develops strength at a faster rate than that:
- Tensile strength: With an ultimate strain of roughly 0.1 percent and a tensile strength of up to 0.25 times its compressive strength, foamed concrete can be cured in a variety of ways
- Shear strength: In comparison to compressive strength, shear strength typically ranges between 6 and 10%. There may be a need for shear reinforcement in roofing and flooring systems.
- Shrinkage: During the setting phase, foamed concrete shrinks like all cement-based products. The amount and type of cement in the mixture, the water-to-cement ratio, the type of curing process, the size of the element, the amount of sand, and the density of foamed concrete all affect shrinkage. The first 28 days, followed by the

installation of soundproofing screeds in multi-story homes and businesses, are when shrinkage is most noticeable. This density range of concrete is also appropriate for bulk-fill applications.

- Inline system (wet method): This system's development was primarily prompted by the need for greater product quality assurance as well as the industrial demand for less dense materials. These systems use the same kind of foam generator and foaming agents as the pre-foam method, but they differ in that they accept wet base materials into a separate hopper and combine the foam through a totally different process.
- Pre-foaming method: In the pre-foaming method, base mix and stable preformed aqueous foam are produced separately and then thoroughly blended with the base mix.

IV. MIXING

Mix concrete proportions and foam concrete production

Even though there are no standardised processes for mix proportions of foamed concrete, the standard recommendations for w/c ratio, free water content, and maintaining a unit volume remain in effect. The fundamental design requirement, however, becomes a predefined target plastic density. Because foamed concrete will desorb between 50 and 200 kg/m3 of the total mix water, depending on the concrete plastic density, early curing regime, and future exposure circumstances, it should be noted that designing for a given dry density is difficult. The trial-and-error approach is widely employed to get the desired properties in foam concrete. Classification of foam concrete manufacturing systems) McCormick developed a reasonable proportion strategy for a given mixture percent and density based on solid volume computation (1967).

ASTM C 796-97 specifies a technique for determining the quantity of foam required to produce cement slurry with a specified w/c ratio and target density. Nambiar and Ramamurthy's (2006b) standard mixture design formulae determine mixture components for a given 28-day compressive strength, filler-cement ratio, and fresh density (i.e., percentage foam volume, net water content, cement content, and percentage fly ash replacement). In most circumstances, if the quantities of the combination are known, the batch quantities may be calculated..arget plastic density, D = c + W + f

- *Where c = PC +FA fine f = FA coarse + sand*
- Free water content,

$$W = \frac{w}{c} X(\mathrm{PC} + \mathrm{FA\ fine} + \mathrm{FA\ coarse}$$

Although the density of foam concrete influences its strength, the strength of a particular density may be enhanced by changing the component ingredients. Furthermore, the amount of foam required for a specific density is determined by the materials employed to create it (Nambiar and Ramamurthy, 2006b). As a result, the mixture design approach should be capable of determining batch amounts for a given strength and density requirement. Equations (1) and (2) are used to calculate the total mix water (W, kg/m3) and fine aggregate content (f, kg/m3) using the required plastic density (D, kg/m3), water/cement ratio (w/c), and cement content (c, kg/m3) as inputs. Pre-formed foam was mixed with mortar (i.e., sand fine aggregate) or paste (i.e., no sand, just FA coarse fine aggregate) "base" mix and blended in the laboratory using a normal slanted revolving drum mixer until uniform consistency was reached. The plastic density was calculated in accordance with BS EN 12350-611 by weighing a sample of foamed concrete in a container that had previously been pre-weighed and had a known capacity.Plastic density tolerance was established at 50 kg/m3 of the required value, in accordance with typical industry practise for the manufacturing of foamed concrete. Because foamed concrete adhered tightly to the mould, the specimens were cast in household plastic "cling" film-lined steel moulds it shows in figure 3 to 5.

V. RESULT & DISCUSSION

A. *Compression Test: (1MPa = 1N/mm^2)*

Table 3: For Foam Concrete Mix – 1 (Containing Cement & Fine Aggregates

S.No.	Properties	Values
1	Silica dioxide	36%
2	Aluminum oxide	13%
3	Calcium oxide	41%
4	Magnesium oxide	7%
5	Iron	0.5%
6	Manganese oxide	0.8%
7	Specific gravity	2.2%
8	Absorption	1.5%

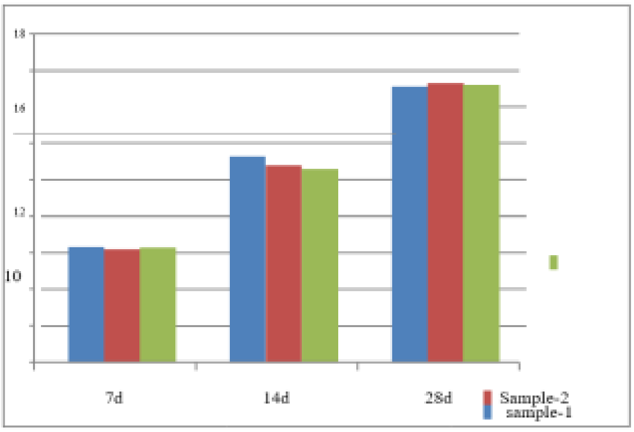

Figure 3: compression test trial-1

There is no fluctuation in compressive strength, according to the graph above. As the curing period increases, so does the compressive strength.

Table 4: For Foam Concrete Mix– 2 (Containing Cement, Blast Furnace Slag & fly ash)

S.No	Age Of Concrete	Cross Sectional Area(mm2)	Load (KN)	Compressive Strength (N/mm2)	Avg compressive strength(Mpa)
1.	7 days	22500	43	1.91	1.91
2.		22500	44	1.95	
3.		22500	42	1.86	
4.	14 days	22500	110	4.88	5.00
5.		22500	115	5.11	
6.		22500	113	5.02	
7.	28days	22500	200	8.9	9.00
8.		22500	205	9.11	
9.		22500	202	8.97	

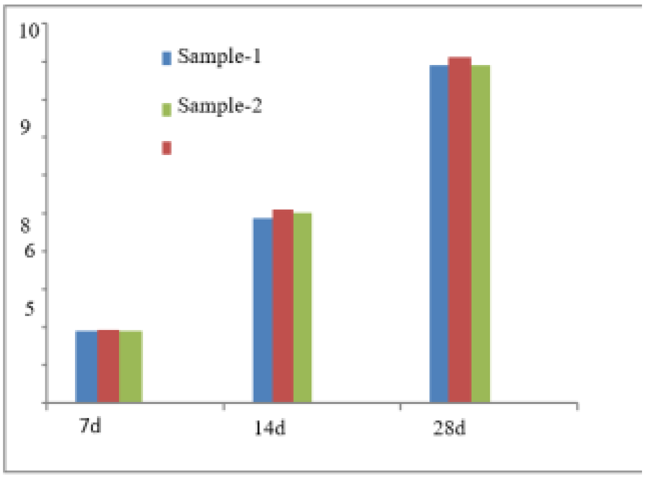

Figure 4: Compression test trial-2

According to the above figure 4, the compressive strength would be reduced by 40% when compared to trail-1 due to the quantity of fly ash we combine in this proportion. Fly ash has a poor compressive strength.

Table 5: For foam concrete mix-3 (containing cement blast furnace slag & fine aggregates, glass power)

S.no	Age of concrete	Cross sectional area(mm2)	Load (Kn)	Compressive strength (N/mm2)	Average compressive strength(MPA)
1	7 days	22500	56	2.4	2.41
2		22500	55	2.44	
3		22500	52	2.31	
4	14 days	22500	150	6.66	6.40
5		22500	152	6.75	
6		22500	153	6.80	
7	28 days	22500	255	11.33	11.32
8		22500	254	11.28	
9		22500	256	11.37	

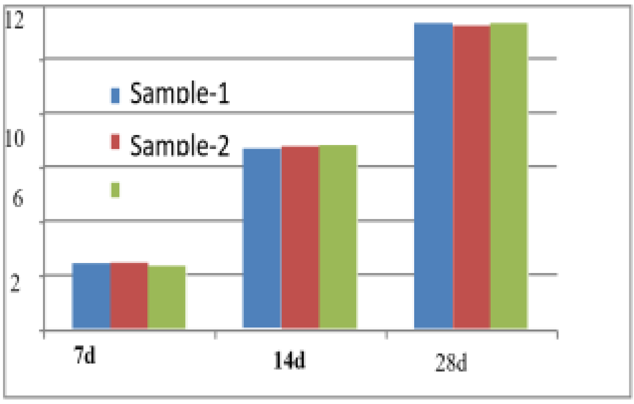

Figure 5: Compression test trial-3

According to the above table 5 and figure 5, the compressive strength will increase (by 25%) when compared to experiment 2. The compressive strength of the mixture rose when the fly ash concentration was lowered and glass powder was added.the comaprision shows that figure 5 as a test trail-3

VI. CONCLUSIONS

- The density of foamed concrete is inversely proportional to the amount of foam added to the slurry or mortar.
- Foam concrete's compressive strength and density improve with age.
- Fine aggregate raised the compressive strength of foamed concrete significantly.
- In this study, we compared foam concrete to other foam concretes that serve as substitutes for alternative fine aggregate replacement materials.
- Mix 1 is a pure foam concrete comprised of cement, tiny particles, a foaming agent, and water. It has a compressive strength of 15.230 Mpa after 28 days..
- To replace the fine aggregate in mix 2, 10% fly ash and 50% blast furnace slag by weight are utilised. It has a compressive strength of 9.0 Mpa after 28 days. Because fly ash has a low compressive strength, the compressive strength of mix-2 is 41% lower than that of mix-1.
- To replace the fine aggregate in mix 3, 40% blast furnace slag, 5% fly ash, and 10% glass powder are used by weight. It has a compressive strength of 11.332MPa after 28 days. The compressive strength decreased by 25% when comparing mix-3 to mix-1. While it has grown by 25% when compared to mix-2. Because we increased the amount of glass powder while decreased the amount of fly ash.
- Sand prices are rising, as previously stated. The original notion is validated if the amount of sand in a product is lowered by employing alternative materials. When compared to a regular foam concrete mix, the materials used to replace the sand in this experiment did not fulfil criteria.
- Foamed concrete grows strength faster than ordinary weight concrete at the beginning, and it gets stronger faster after 28 days than regular weight concrete.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

[1] Stella L. Marusin, "Ancient Cement Structures", Cement International, pp. (56– 58), (1 January 1996).

[2] "Pore cement", Conference Proceeding, International Scientific & conference, (2005).

[3] Regan PE, Arasteh AR. Lightweight aggregate foamed cement. Struct Eng; 68(9) :(167– 73), (1990).

[4] McCormick. FC. "Rational proportioning of preformed foam cellular cement", ACI Material Journal; 64 :(104–9), (1967).

[5] Herald of BSTU named after V. G. Shukhov – thematicissue"Foam cement", No.4, (2003).

[6] Byun KJ, Song HW, Park SS., "Development of structural lightweight foamed cement using polymer foam agent". ICPIC-98; (1998).

[7] ASTM Standard test method for foaming agents for use in producing cellular ent using preformed foam, ASTM C (97-796). Philadelphia; (1997).

[8] ACI committee 523. "Guide for cellular cements above 50 pcf, and for aggregate cements above 50 pcf with compressive strengths less than 2500 psi". ACI J; 72 :(50–66), (1975).

[9] Kearsley EP. Just foamed cement – an overview. In: Dhir RK, Handerson NA, editors. "Specialist techniques and materials for construction", London: Thomas Telford; (37–227),(1999).

[10] Koudriashoff IT, "Manufacture of reinforced foam cement roof slabs"; 21(1): (37– 48), (1949).

[11] Madjoudj M, Quenendec M, Dheilly RM. "Water capillary absorption of cellular clayed concrete obtained by proteinic foaming". In: Dhir RK, Hewelett PC, Csetenyi LJ, editors. Innovations and development in concrete materials and construction. UK: Thomas Telford; (21–513), (2002).

[12] Valore RC. "Cellular cement part 2 physical properties''. ACI J; 50 :(36–817), (1954).

[13] Nehdi M, Djebbar Y, Khan A., "Neural network sample for preformed foam cellular cement". ACI Mater; 98 :(9– 402), (2001).

[14] Kearsley EP., "The use of foamed cement for affordable development in third world countries". In: Dhir RK, McCarthy MJ, editors. Appropriate cement technology. London: E&FN Spon; (43–233), (1996).

[15] Visagie M, Kearsely EP., "Properties of foamed cement as influenced by air void parameters". Cement/ Beton; 101 :(8–14), (2002).

[16] Nambiar EKK, Ramamurthy K., "Air-void characterization of foam cement". CemConcr Res; 37 :(30–221), (2007).

[17] Durack JM, Weiqing, L., "The properties of foamed air cured fly ash based cement for masonry production", In: Page A, Dhanasekar M, Lawrence S, editors. In: Proceedings of 5th Australian masonry conference. Australia: Gladstone, Queensland ;(38–129), (1998).

[18] Tada S, Nakano S., "Micro structural approach to properties of mist cellular cement", In: Wittmann FH, editor. Autoclaved aerated cement, moisture and properties. Amsterdam: Elsevier; (71–88), (1983).