The Preparation of Foam Cement and Determining Some of Its Properties

Qassim Abd Saloum.
Directorate of Material Research, Ministry of Science and Technology/Baghdad.
Mustafa Zaid Abdullah.
Directorate of Material Research, Ministry of Science and Technology/Baghdad.
Email:musttafazaid25@yahoo.com
Ansam Adnan Hashim
Directorate of Material Research, Ministry of Science and Technology/Baghdad.

Received on: 9/1/2013 & Accepted on: 6/3/2014

ABSTRACT

The purpose of this research is to prepare samples of foam cement with different mixing ratios of raw materials. Several exams have been performed such compressive strength which was (5.9 N/mm^2) and density (0.903 gm/cm^3) for some samples.

These values show that this material is suitable to be used as untraditional building material for construction of nonstructural walls. Due to its liquidity, foam cement is suitable to be used for mold casting, surface repairing and voids filling for walls.

تحضير السمنت الرغوي وتحديد بعض خواصها

الخلاصة

يهدف البحث الى تحضير نماذج من الاسمنت الرغوي باستخدام نسب خلط مختلفة للمواد الاولية. وقد اجريت بعض الفحوص لتحديد خواص الاسمنت الرغوي المحضر اذ وجد أن بعض النماذج لها انضغاطية تبلغ (5.9 N/mm^2) وكثافة مقدارها (0.903 gm/cm^3). أن هذه القيم تجعل من الممكن استخدام مادة الاسمنت الرغوي كمادة بناء غير تقليدية لعمل بلوكات البناء المستخدمة في بناء الجدران غير الهيكلية. ونظرا للسيولة الجيدة التي يمتلكها الاسمنت الرغوي بالامكان صبه في القوالب بسهولة واستعماله في تصليح السطوح وملئ فجوات جدران البناء.

INTRODUCTION

Foam concrete is either a cement paste or mortar, classified as lightweight concrete, in which air-voids are entrapped in mortar by suitable foaming agent. It possesses high flowability, low selfweight, minimal consumption of aggregate, controlled low strength and excellent thermal insulation properties [1]. By proper control in a dosage of foam, a wide range of densities (400–1600 kg/m3) of foamed concrete can be obtained for application to structural, partition, insulation and filling grades. Although the material was first patented in 1923[1,2], its construction applications as lightweight non- and semi-structural material is increasing in the last few years. The first comprehensive review on cellular concrete was presented by Valore in 1954 and a detailed treatment by Rudnai and Short and Kinniburgh in 1963[1,3], summarizing the composition, properties and uses of cellular concrete, irrespective of the method of formation of the cell structure. Recently, Jones and McCarthy have reviewed the history on the use of foam concrete, constituent materials used, its properties, and construction application, including some projects carried out world wide[1,4]. The production of stable foam concrete mix depends on many factors; selection of foaming agent, method of foam preparation and addition for uniform air-voids distribution, material section and mixture design strategies, production of foam concrete, and performance with respect to fresh and hardened state are of great significance [1,5]. The aim of this research is to prepare foam cement with good specifications in terms of compressive strength, density and liquidity to be used in the construction of non-structural walls.

Theoretical part

Properties of foam cement

Physical and chemical properties of foam cement depend on several factors, including methods of pores formation in the material ,arrangement and distribution of pores and its kinds (that were closed or open or connected) , type of foaming agents, solidification conditions and other factors. The properties of foam cement are interrelated; so the thermal conductivity coefficient, in the dry atmosphere, mainly depends on the density value of foam cement, type of foaming agents, solidification conditions and other factors have very few effects on the thermal conductivity property: As an example, porous walls, where porosity and density controlled by thermal conductivity process for foam cement [6].

The pores which formed in foam cement are two types, surface pores (macro porosity) and internal pores (micro porosity). The pore structure of cementation material, predetermined by its porosity, permeability and pore size distribution, is a very important characteristic as it influences the properties such as strength and durability. The pore structure of foam cement consists of gel pores, capillary pores as well as air-voids (air entrained and entrapped pores). As foam cement being self-flowing and self-compacting cement and without coarse aggregate, the possibility of entrapped air is negligible. The air-voids in the foam cement can be characterized by a few parameters like volume, size, size distribution, shape and spacing between air-voids. The air-void distribution is one of the most important micro properties influencing strength of foam cement, where the foam cement with narrower air-void distributions shows higher strength [5].

The Density of foam cement can be either in fresh or hardened state. Fresh density is required for mix design and casting control purposes. A theoretical equation for finding fresh density may not be applicable as there can be scatter in the results caused by a number of factors including continued expansion of the foam after its discharge (i.e. the interaction that happens between the foam and other components of the cement did not reach to its final stage), in addition to that there may be loss of foam during the mixing process [7]. Many physical properties of foam cement related to/depend upon its density in a hardened state. While specifying the density, the moisture condition needs to be indicated as the comparison of properties of foam cement from different sources can have little meaning without a close definition of the degree of dryness [8]. As the properties are expressed in terms of dry density, the relationships proposed in literature between dry and fresh density are summarized in table (2) [9].

Hydration rate of foam cement has an important influence on the properties of foam cement where drying process of foam cement (reduce the humidity) lead to contraction distortions (shrinkage deformations), these distortions depend on the first level of hydration and the level of balance between the moisture of cement and the environment, the low hydration of foam cement (include of deflationary distortions) is posses a few resistant of cracks compared with foam cement which has appropriate hydration, so the resistance of foam cement are depend on the water content of the foam cement during the formation [4].

The foaming agents type plays an important role in influencing the properties of foam cement; a description of commonly used natural material-based and Synthetic foaming agents as well as the method of preparation of foam cement also have an important influence on the properties of foam cement where foam cement is produced either by pre-foaming method or mixed foaming method. The Pre-foaming method comprises of producing a base mix and stable preformed aqueous foam separately and then thoroughly blending foam into the base mix. In mixed foaming, the surface active agent is mixed along with base mix ingredients and during the process of mixing; foam is produced resulting in cellular structure in cement [10]. The foam must be firm and stable so that it resists the pressure of the mortar until the cement takes its initial set and a strong structure of cement is built up around the void filled with air [11].

Advantages of foam cement

Foam cement is multiple benefits as follows [12]:

• Strong walls. • Good thermal and sound insulation (save the energy). • Quick and easy achievement. • Flexibility. • Light weight (easy shipping and construction).

• Appropriate cost of complex building.

Experimental part

Used Materials:

The used materials for preparing foam cement are:

Cement

Cement used in this research is the sulfate-resistant cement (bridge marker), this cement is distinct from other types of cement by low- tripartite stockings alumina (C_3A) content which are responsible for interaction with sulfate ions in the soil or water and caused expansion in the cement and occurrence of cracks, the cement is a fine powder ,it is composed from four basic components which are: -(C_3S Silicate tricalcium , C_2S silicate dicalcium , C_3A aluminate tricalcium , C_4AF aluminate iron tetracalcium).

Foaming agent:

Foaming agent used in this research is animal protein based cement foam agent is made from select animals (cattle, sheep) keratin protein as the main raw material, the finished products produced through a series of hydrolysis reactions, the specifications of cement foam agent are shown in table (1).

Silica powder : - silica powder used in this research is local Ramadi silica powder (Erdhuma sand glass) of grain size (less than 17 µm) to composition (82%) of silica oxide, (8.4%) of aluminum oxide, (6.3%) of calcium oxide and (2.3%) of magnesium oxide.

Red sand :

used in this research the Iraqi red sand (Habbaniyah sand) of fine grain size (68 μm) which consists of (73.2%) of silica oxide, (0.8%) aluminum oxide, (0.9%) of iron oxide, (5.2%) of calcium oxide, (3.1%) of magnesium oxide, (14.5%) of sodium oxide and (0.6%) of potassium oxide.

Kaolin :

kaolin used in this research is local Ramadi kaolin powder (Dukhla kaolin) of grain size (300 μm), which consists of (47.14%) of silicon oxide, (34.74%) of alumina oxide, (1.26%) of iron oxide, (1.2%) titanium oxide,(0.25%) magnesium oxide, (0.07%) of sulfur trioxide, (< 1 %) of calcium carbide and (14.06%) is loss of incineration**.**

Samples preparation and devices

Different samples of cement foam were prepared with different mixing proportions as shown in table (3) where Often trial and error process is adopted to achieve foam cement and determine its characteristics [13]. Where the foam was prepared by using a foam-generating device (which consists of air compressor (20 bar) and storage tank (170 liter)), where the foam pumped under pressure (2 bar) and the water pumped under pressure (3 bar) until reach to better homogeneous foam, then the foam and basic mixture for each sample transported to laboratory mixer with continuous mixing for (10 minutes) to obtain a homogeneous foam cement , then followed by a molding process where hand-molding technique was used in this stage, where the molds made of iron, the tests (compressive strength, density and durability) were calculated for all prepared samples by using the compressive strength test device (Toni pact 3000 – Germany).

RESULTS AND DISCUSSION

In this research, different samples of foam cement with different compositions had been prepared as shown in table (3) .Because most physical properties of foam cement depend on the dry density, these values had been determined. The compressive strength of all samples had been measured after immersing in water for a period (29) day. Depending on these results the most suitable samples were detected by comparing with international values that had been published. Trial and error method is universally used to detect the best composition [15], This method is used in this study to find the best suitable composition of foam cement.

As shown in table (4) and figures (1,2,3), the samples no.(8 and 9) have the most suitable compression values of (6.1 Mpa , 5.9 Mpa) respectively, and density of (1.009 , 0.903 gm/cm^3) respectively, these values are compatable with universal values, which can be used for structural building materials (block).It is found that using the optimum value of foam to water ratio leads to best cohesive and adhesive values of foam with the basic mixture which they have a significant effect on the stability of foam cement [14]. At low densities of foam cement, foam ratio controls the strength of foam cement [14,15]. The suitable foam ratio leads to best porosity of foam cement by arranging the pores, the distance among them and their volumes. It is found that a large dispersion of pores within the foam cement (increasing small pores and reducing large pores) leads to the best properties of foam cement. The distribution of pores within foam cement is the most imported factor affecting the strength of foam cement [16]. Samples no. (8 and 9) which had been immersed in water for a period (29 day) show low water penetration. This was detected by cutting their block samples and observing water penetration which is found to be restricted to surface of the block. This phenomenon is expected because water absorption by foam cement decrease with decreasing of density (increasing of pores number). The decrease of the volume of pores and increasing their number lead to form capillary pores which will form very quirky way to water flow within foam cement which damping water penetration phenomenon [16,17].

As shown in table (4), sample no. (1) has the minimum values of density and compression strength .This low compression strength is due to that for low densities of foam cement (0.5-1 gm/cm^3) , the compression strength decreases with increasing of pores diameter. At high densities of foam cement (greater than 1 gm/cm^3), the distance among the pores have the major effect on the compressive strength, where the compression strength increases with increasing these distance [18, 19]. The increase of foam ratio leads to increase of formation of pores and may be united together to form large volume pores, this increase in pore volume leads to decrease in compression strength and density.

The addition of red sand of particle size (less than 68 µm), as in sample no. (2), leads to increase the values of compression strength and density. As it is known the addition of red sand leads to increase the density, which leads to increase in the compression strength (the compressive strength of foam cement is a function of density) [20,21]. Also it's found that the addition of other fine fillers has a great influence on the uniformity of pore distribution which leads to increase in the strength of foam cement.

In samples no. (1 and 3) the increase in the water ratio (increase the hydration) leads to raise the compression strength and density. The water ratio has a great effect on the shrinkage deformations that occur inside the foam cement, the low hydration ratio increase the shrinkage deformations which leads to decrease the strength of foam cement compared with that suitable hydration ratio. It is found that the suitable hydration make to reduce the shrinkage by a ratio of (12-50%) [22, 23].

In sample no. (4), the addition of fine silica powder (less than 17 µm) leads to increase the compression strength and density, as mentioned before, the addition of fine filler improves the mechanical properties of cement in general[24].

It is found that the addition of foam (1 liter) to the basic mixture, with the addition of Kaolin, as in sample no. (5), leads to decrease the compression strength compared with the addition of red sand, as sample no. (6), because the red sand reduce the shrinkage inside foam cement [25].

The increase of cement ratio has led to increase the compression strength and density of sample no. (7) Compared with sample no. (3), which has a lower cement ratio, this attributed to the fact that the increasing cement by high ratio (within stability and adhesion limit), will leads to increase density and compression strength. The small increase in cement ratio has only a minor effect on the cement properties, as in normal cement [20, 25].

CONCLUSIONS

In this research, we have good results linked with the preparation of foam cement and study some its properties, where we have reached important conclusions are as follows:

1. Preparation of foam cement conformity with international standards
2. The prepared foam cement posses good liquidity can be used to treat the cracks in buildings, or as separators between the walls.
3. Using local materials which makes the possibility of research applying on commercial level in the housing projects.
4. In general, most samples have low densities (lower than the density of water), where these samples float when immersed with water and posses lightweight, low cost as well as fast achievement (i.e. quick and easy formation).

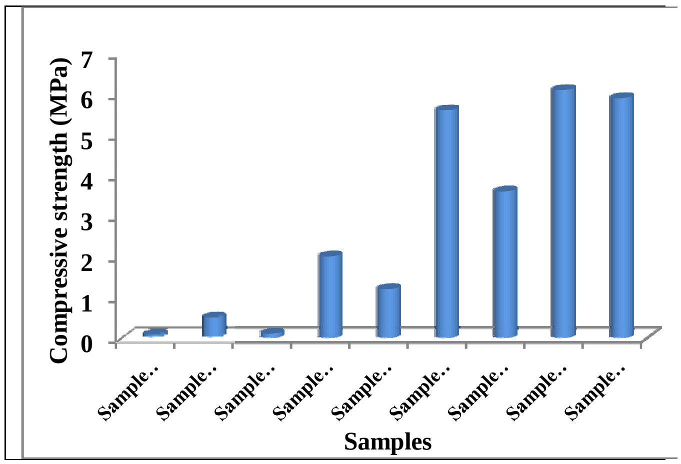

Figure (1) shown compressive strength values of samples.

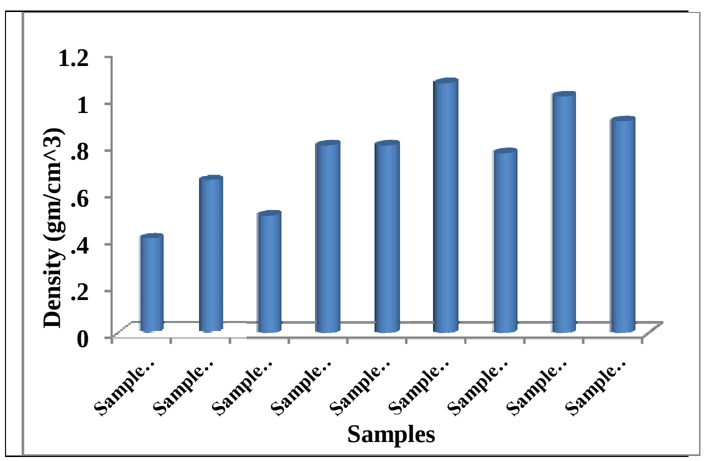

Figure (2) shown the density values of samples

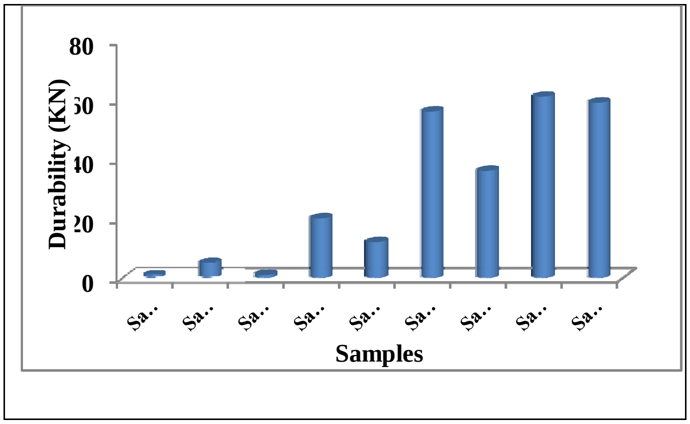

Figure (3) shown the durability values of samples.

Table (1) The specifications of cement foam agent.

Appearance	Brown viscous liquid
Density(kg/L)	1.2
PH value	6.8
Inorganic salt(%as Na_2SO_4)	1.3
Absorb ability %	23

Table (2) The relationships between dry and fresh density [5].

Reference	Equation	Remarks
ASTM C 796-97 [8]	Dry density = $(W_c + 0.2W_c)/V_{batch}$	W_c and V_{batch} are weight of cement and volume of batch, respectively.
ACI committee 523 [9]	Dry density = 1.2C +A	C and A are weight of cement and aggregate in kg per cubic meter of cement.
Kearsley [10]	γ dry = 0.868 γ cast _ 55.07	γ Casting density range of 700–1500 kg/m^3. Cement–fly ash mixture of varying fly ash–cement ratio (F/C = 0–4).

Table (3) The mix proportions for cement foam samples.

Samples	**Materials**					
	Cement	**Foam**	**Water**	**Silica**	**Kaolin**	**Red sand**
Sample no.(1)	600 gm	1.5 L	210 ml	-	-	-
Sample no.(2)	600 gm	1.5 L	210 ml	-	-	240 gm
Sample no.(3)	600 gm	1.5 L	300 ml	-	-	-
Sample no.(4)	600 gm	1.5 L	300 ml	300 gm	-	-
Sample no.(5)	600 gm	1 L	300 ml	-	200 gm	-
Sample no.(6)	600 gm	1 L	300 ml	-	-	200 gm
Sample no.(7)	900 gm	1.5 L	300 ml	-	-	-
Sample no.(8)	600 gm	750 ml	300 ml	-	-	-
Sample no.(9)	600 gm	750 ml	300 ml	200 gm		

Table (4) The values of compressive strength, density and durability of all samples.

Samples	Tests		
	Compression strength (MPa)	Durability (KN)	Density (gm/cm^3)
Sample no.(1)	0.08	0.8	0.4
Sample no.(2)	0.5	5	0.65
Sample no.(3)	0.1	1	0.5
Sample no.(4)	2	20	0.8
Sample no.(5)	1.2	12	0.8
Sample no.(6)	5.6	56	1.065
Sample no.(7)	3.6	36	0.766
Sample no.(8)	6.1	61	1.009
Sample no.(9)	5.9	59	0.903

REFERENCES

[1] K. Ramamurthy *, E.K. Kunhanandan Nambiar, G. Indu Siva Ranjani, "A classification of studies on properties of foam concrete", Cement & Concrete Composites, pp. (388–396), (2009).

[2] Kadabra, "Light weight cement", Kuranda Village Ctr, Australia (2010).

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

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

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

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

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

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

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

[10] 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).

[11] 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).

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

[13] 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).

[14] Valore RC. “Cellular cement part 2 physical properties’’. ACI J;50:(36–817),(1954).

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

[16] 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).

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

[18] Nambiar EKK, Ramamurthy K., “Air-void characterization of foam cement”. Cem Concr Res;37:(30–221),(2007).

[19] 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).

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

[21] Tikalsky PJ, Pospisil J, MacDonald W., ‘ A method for assessment of the freezethaw resistance of preformed foam cellular concrete”. Cem Concr Res;34:(93–889),(2004).

[22] Nambiar EKK, Ramamurthy K., “Fresh state characteristics of foam cement”, ASCE Mater Civ Eng;20:(17–111),(2008).

[23] Tam CT, Lim TY, Lee SL., “ Relationship between strength and volumetric composition of moist-cured cellular cement”, Mag Concr Res;39:(12–8),(1987).

[24] Nambiar EKK, Ramamurthy K., “ Samples relating mixture composition to the density and strength of foam cement using response surface methodology”, Cem Concr Comp;28:(60– 752),(2006).

[25]D.Hull , " An Introduction to composite Materials " , 1st edition , first published , Cambridge University Press U.k., (1980).