Bulgarian Chemical Communications, Volume 47, Special Issue D (pp. 56 – 62) 2015

The effects of anionic surfactants on the strength and environmental impacts of foamed concrete

Amir Hossein Fani*, Afshin Pourafshar

Department of Civil Engineering, College of Engineering, University of Tehran, 16-Azar Str., Tehran, Iran

Received June 26, 2015, Revised September 10, 2015

Foamed concrete is an all-around material that can be applied in a wide range of construction projects due to its low self-weight, high workability, controlled low strength, excellent thermal properties, etc. Foamed concrete is produced by injecting preformed stable foam or by adding a special air-entraining admixture known as a foaming agent such as synthetic surfactants into a base mix of cement paste or mortar. The hydrophilic and hydrophobic structure of the surfactant molecules helps entrain air bubbles and stabilizes them in the fresh cement paste. The aim of this paper is to investigate the effects of two types of anionic surfactants on the mechanical and physical properties and, moreover, the environmental impacts of foamed concrete. Additionally, the potential of polypropylene fibers in foamed concrete to enhance compressive and tensile strength is examined. Twenty-four different mixtures were cast with two types of anionic surfactant foaming agents (with densities of 960 and 1200 kg/m^3), Portland cement contents between 350 and 450 kg/m^3, two ratio of water to cement (w/c), and polypropylene fibers. The results of compressive and tensile strength, water absorption, and heat transfer coefficient tests are reported and analyzed.

Keywords: Foamed concrete; Surfactant; Mechanical properties; Environmental impact

INTRODUCTION

Foamed concrete is a kind of lightweight concrete which is lighter than normal concrete by mixing foams like surfactant foaming agents into cement slurry. The difference between foamed concrete and normal concrete is the use of aggregate in the foam concrete is eliminated and been replaced by the homogeneous cells created by air in the form of small bubble which utilize a stable air cell structure rather than tradition aggregates [1].

Foamed concrete is a highly workable, low-density material which can incorporate up to 50 per cent entrained air. It has a number of attractive characteristics. 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. Moreover, it has suitable compressive and tensile strength regarding its application and significant reduction of overall weight results in saving structural frames, footing or piles [2, 3]. Foamed concrete has good thermal and acoustic insulation as its structure is porous due to usage of surfactant foam [4]. Liquid water absorption into foamed concrete is low, while retaining high water vapor permeability. Freez-thaw resistance is excellent [5]. Foamed concrete is used for a variety of applications, ranging from thermal insulation and fire protection to void-filling and building elements with successively increasing density and strength requirements [6, 7].

Foamed concrete is made from Portland cement, water, foaming agent, and other additives if required. Portland cement is a hydraulic material which shall consist of at least two-thirds by mass of calcium silicates (CaO-SiO_2), the remainder consisting of aluminium and iron containing clinker phases and other compounds. The ratio of CaO to SiO_2 shall not be less than 2. The magnesium oxide content (MgO) shall not exceed 5.0% by mass [8].

Synthetic or protein-based foaming agents (surfactants) can be used to produce foam. In this study, we perform tests using two types of synthetic surfactant foaming agents. The chemical composition of a surfactant must be stable in the alkaline environment of concrete. Foam bubbles are formed under the condition where air can be flowed into the solution through stirring or air injection after reducing the surface tension of solution with the surfactant. The surface tension of water is generally 72~73 mN/m but the surface tension of solution with the surfactant lowers to 40~50 mN/m so foam bubbles are easily formed [9, 10].

Synthetic surfactants are classified into four main types according to the nature of their hydrophylic group, i.e. that part of the molecule that is soluble in water. Figure 1 shows four types of surfactants and their structures. Hydrophilic and hydrophobic nature of the surfactant molecules helps entrain air bubbles and stabilizes them in the fresh cement paste [11].

To whom all correspondence should be sent:
E-mail: amir.fani@ut.ac.ir

© 2015 Bulgarian Academy of Sciences, Union of Chemists in Bulgaria

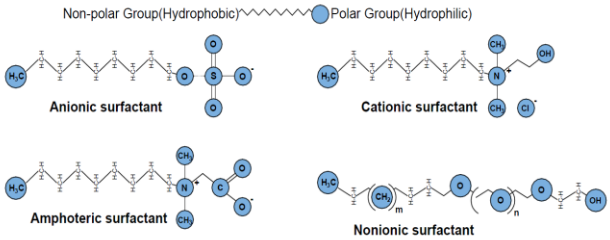

Fig 1. Classification and chemical structure of surfactants

There are many studies in the literature on foam concrete in terms of foaming agents, constituent materials, mix proportioning, production methods, and fresh and hardened properties of foam concrete [12].A description of commonly used natural material-based and synthetic foaming agents have been presented by Valore [13], Taylor [14] and Laukaitis et al [15]. Du and Folliard [16] attempted to provide a framework for understanding the fundamental aspects of air entrainment in concrete. An investigation was carried out by Nambiar and Ramamurthy [17] on characterizing the air-void structure of foam concrete by identifying few parameters and influence of these parameters on density and strength. Additionally, Cui-hua [18] discussed the effects of the amount of surfactants on improving foam stability using change of foaming times and foam volume along with time as the evaluation indexes for performance of the foaming agent.

Puttappa and Ibrahim [19] designed 27 mixtures of foamed concrete and carried out an experimental and analytical study to evaluate the mechanical properties of lightweight foamed concrete. Chindaprasirt and Rattanasak [20] and Nambiar and Ramamurthy [21] presented the shrinkage behavior of preformed foam concrete for the influences of basic parameters such as density, moisture content, composition like filler-cement ratio, levels of replacement of sand with fly ash, and foam volume. Moreover, mechanical, thermal insulation, thermal resistance and acoustic absorption properties of geopolymer foamed concrete were tested and analyzed by Zhang et al. [22]. In addition, Brady et al. [6] and Tian et al. [23] discussed the application of foamed concrete in construction, geotechnical and roadway projects.

This paper examines the effects of two types of anionic surfactants on the mechanical and physical properties and the environmental impacts of foamed concrete. The environmental impacts are investigated in terms of energy consumption. Moreover, the potential of polypropylene fibers in foamed concrete to improve compressive and tensile strength is studied. Twenty-four different mixtures were cast with two types of anionic surfactant foaming agents (with densities of 960 and 1200 kg/m3), Portland cement contents (350, 400 and 450 kg/m3), the ratio of water to cement (w/c) of 0.5 and 0.55, and polypropylene fibers. The results of compressive and tensile strength, water absorption, and Heat transfer coefficient tests undertaken in this study are reported and analyzed in order to evaluate the influence of surfactants and other factors.

EXPERIMENTAL METHOD

The best method for evaluating the performance of new mixtures is conducting tests which can assess the properties of the mixtures. In this paper, we carry out a laboratory study to measure the strength, durability and environmental criterion of foamed concrete. The compressive strength, indirect tensile strength, water absorption, and heat transfer coefficient tests are performed to analyze the properties of the mixtures.

Materials

Foamed concrete typically consists of cement, water, foaming agent and other additives. The cement used in this study is Portland cement type II of Tehran meeting Iran standard specificationNo. 389 ISIRI [24]. Portland cement type II in Iran is used to produce concrete which the medium hydration heat is requiredfor and the sulphate attack is in the moderate range. This kind of cement is applicable in all concrete structures and in soil and water environments in which sulfate ion concentration is relatively low.

The quality of water in concrete is significant in view of the fact that the impurities in water may affect the cement setting and also have an adverse effect on the strength of concrete. As a general rule, the water with the PH level between 6 and 8 and without salty taste can be applied for constructing concrete. To avoid any possible errors in the mixtures, distilled water with electrical conductivity (EC) of 8.5 to 11 μSiemens/cm, total dissolved solids (TDS) about 9.5 to 11 ppm, the maximum amount of silica (SiO_2) equal to 0.105 ppm, and PH level about 6.5 to 7.5 is used for the mixtures.

In this study, polypropylene fibers are applied to prevent shrinkage and cracking of foamed concrete at early ages (plastic shrinkage) in some mixtures. Polypropylene fibers are used to obtain a much better and stable surface and more resistant piece of foamed concrete. It reduces the danger of micro cracks greatly. It predicts that this increases the lifetime of the foamed concrete specifically where this is exposed to changing weather condition. The half of mixtures are constructed by polypropylene fibers with a short cut of 12 mm and the ratio of 0.5 kg/m^3.

Hydrophilic and hydrophobic structure of the surfactant molecules helps entrain air bubbles and stabilizes them in the fresh cement paste. Surfactant molecules, defined as surface-active agents, consist of a hydrophobic and a hydrophilic moiety that are clearly separated in the molecular structure. The polar part engages in electrostatic interactions (hydrogen bonding, dipolar interactions, ionic bonding etc.) with surrounding molecules, e.g. water and ions. The non-polar part, on the other hand, associates with neighboring non-polar structures via hydrophobic and van der Waals interactions. 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 concrete [9].

Increase of surfactant concentration is not proportional to decline of surface tension and this is because the CMC (Critical Micelle Concentration) is consistent according to the surfactant. However, the molecular activity varies depending on the type of the surfactant so the surface tension differs as well. In this study, two types of anionic surfactants is used to construct the specimens and evaluate the effects of them on the properties of foamed concrete. The first surfactant foaming agent which is named as surfactant type A is this study has a density of 960 kg/m^3, foaming agent dilution of 1:25, PH value of 7, and foam stability time of 35 minutes. In addition, the second anionic surfactant foam has a density of 1200 kg/m^3, foaming agent dilution of 1:25, PH value of 7, and foam stability time of 45 minutes. It is named as surfactant type B in the production of the specimens of this study.

*Laboratory equipment and constructing specimen***s**

Laboratory equipment required for constructing foamed concrete mixtures include foam generator, foamed concrete mixer which has a horizontal axis of rotation, laboratory oven to dry samples, caliper, molds, laboratory balance, and curing pond. After removing the specimens form the molds, they are stored in a saturated limewater to achieve the desired properties for its intended use. The curing pond is kept at a temperature of 25°C.

As mentioned before, 24 mixtures of foamed concrete are designed in order to carry out tests. 3 cube molds with dimensions of 15 cm, 3 standard cylindrical molds with a diameter of 15 and a height of 30 cm, 3 cube molds with dimensions of 10 cm, and 3 cubic molds with dimensions of 10×10×2 cm are employed for compressive strength, indirect tensile strength, water absorption and heat transfer coefficient tests, respectively. In general, weight ratio is not used for foamed concrete mixture because density of hardened concrete varies up to 10 percent. Therefore, foamed concrete is introduced usually based on the volume ratio. In this study, the design of all mixtures is volumetric. It means that the foam volume in the mixture is achieved regarding specifying volume of water and cement and ignoring the volume of polypropylene fibers (which are used in some mix designs) as shown in equations 1 and 2. Moreover, according to equation 3, the amount and volume of surfactant is achieved based on the mixing ratio of water and foaming agent. In the following equations, V_c, V_w, V_s and $V_{p.p}$ denote cement, water, surfactant, and polypropylene volume, respectively.

$$V_c + V_w + V_s + V_{p.p} = 1000\ litr \quad (1)$$

$$V_{p.p} \cong 0,\ V_C = \frac{M_c}{\rho_c},\ V_w = \frac{M_w}{\rho_w} \quad (2)$$

$$V_s = 1000 - \frac{M_c}{\rho_c} - \frac{M_w}{\rho_w} \quad (3)$$

In general, in these 24 mixtures, two different types of anionic surfactant foaming agents which are introduced in the previous section, three cement content (350, 400and450 kg/m^3), two water to cement ratio (w/c=0.5 and w/c=0.55), and two state for consume polypropylene (without polypropylene fibers and with polypropylene fibers) are used.

In order to construct laboratory specimens, three steps of preparation laboratory equipment and weighing raw material, mixing the material in the blender, and molding are required. In this study, the same mixing method is used for all 24 mixtures in the laboratory. In the first step, the blender is turned and the weighed water is poured into the blender. As the blender is running, the weighing cement is poured within 30 seconds. After pouring the cement completely in the blender, cement and water should be mixed completely for 90 seconds. At the end of 90 seconds, the surfactant foam is added slowly to the mixture by turning on the foam generator and simultaneously, blender is working and mixing when the foam poured in the blender tank.

Polypropylene fibers are used in the half of the designed mixtures. The time of adding the fiber into the blender tank is after the injection of surfactant into the blender. After completing foam injection into the blender, it is necessary to mix the materials for 4 minutes in the blender tank for homogenizing the mix. After making the mixtures, specimens should be cured. They are embedded in a saturated limewater to achieve the desired properties for its intended use. The curing pond is kept at a temperature of 25°C.

Tests

Compressive strength tests

Since the compressive strength is one of the important properties of concrete and foamed concrete, information about this parameter has an important role in quality control of foamed concrete. Compressive strength testing in standard ASTM C869-91 [25] is done on cylindrical specimens of 30 × 15 cm and in the standard BSI [26] compressive strength tests is done on cube specimens of 15 cm. In this study, cube mold with dimensions of 15 cm is used to test the 28-day compressive strength. Before performing tests, the specimen dimensions must be measured with an accuracy of at least mm and then placed in a hydraulic jack. Loading speed is 50 KN per minute. Compressive strength is measured based on Equation 4.

$$f_c = \frac{P}{A_c} \tag{4}$$

In equation 4, *P* is the imposed force of hydraulic jacks on specimens in kg and A_c (in square centimeters) is side of the specimens placed under load. The compressive strength of the specimens (f_c) is obtained in terms of kg per square centimeter.

Tensile strength test

The purpose of this test is to determine the tensile strength of concrete by split method of cylindrical specimens. In this method by applying a diameter compressive force on the cylindrical specimen of foamed concrete placed horizontally between two pages of test device, tensile strength is determined by split method. Forms that can be used in this experiment are cylindrical which its height is twice its diameter. ASTM C496-96 [27] standard is used to test the tensile strength and the used molds have 15 cm of diameter and 30 centimeter of height.

Performing this test is required to use two pieces of steel with a thickness of 5 mm and a width of 2 cm and a length of at least 30 cm above and below the point of support on the jack. Loading speed in this test like the compressive strength is 50 KN per minute. The relationships between tensile stresses of split method and the applied load is shown in equation 5.

$$f_t = \frac{2 \times P}{\pi \times L \times D} \tag{5}$$

In this equation, f_t is splitting tensile strength in kg per square centimeter, *P* is the maximum load in kg, and L and D are the height and diameter of the cylindrical specimen, respectively.

Water absorption

The water absorption determination test is done by modeling ASTM C642 [28] standard on three cube specimens of 10 cm. After incubating in the water for 27 days, these specimens are transferred to the stove with ventilation a temperature of 45 °C. The dry weight of the specimens are measured after 14 days in a way that the obtained weight difference by weighing the interval of 24 hours is less than 0.1% of the weight of dried specimen. Afterwards, the dried specimens were immersed in water and the water level is within 5 ± 25 mm above the surface of specimens. Specimens at intervals of 1, 3, 24, 48 and 72 hours were taken out of the water and surface water were dried by a fabric and weighed. Thus, the percentage of absorbed water is determined regarding the weight of the dry specimen and the weight at mentioned time intervals.

Heat transfer coefficient

The high thermal resistance of foamed concrete in comparison with conventional concrete results in saving energy. To illustrate this feature in foamed concrete, heat transfer coefficient tests are conducted. Heat transfer coefficient expresses the rate of heat transfer between a solid surface and the liquid by convection. This test is performed on the simple method proposed by Raeisi et al. [29] on 3 specimens with dimensions of 10 × 10 × 2 cm. In the paper of Raeisi et al., a simple laboratory method is introduced to calculate the heat transfer coefficient of foamed concrete based on empirical formula to determine the heat flow.

RESULTS AND DISCUSSION

In this section, the results of laboratory tests, including compressive strength, indirect tensile strength, water absorption, and heat transfer coefficient, are reported and analyzed. All experiments are carried out in the laboratory of concrete and building materials of University of Tehran.

The 28-day compressive strength of foamed concrete is a function of some characteristics such as the type of surfactant foaming agent, the content of cement, water to cement ratio, and polypropylene fibers. In order to evaluate the effects of various factors on the compressive strength, a diagram of compressive strength according to dry density and water to cement ratio of 0.5 and 0.55 is plotted in figures 2-1 and 2-2.

The effects of the type of surfactant and polypropylene fibers on the compressive strength are shown in Figures 2-3 and 2-4. Figure 2-3 is related to the specimens containing surfactant foam type A and figure 2 is related to the foam type B. Moreover, in these figures, dashed lines present the mixtures containing fiber.

As shown in Figures 2.1 and 2.2, dry density and also the 28-day compressive strength are increased with the increase of the cement content in the mixtures. Changes in 28-day compressive strength in terms of dry density are shown by fitting a line to the water-cement ratio of 0.5 and 0.55. Comparison of Figures 2-1 and 2-2 shows that the increase in water to cement ratio form 0.5 to 0.55 reduces the 28-day compressive strength by 19.9 percent in average.

By comparing Figures 2-3 and 2-4, we find that the use of foam type B has a greater effect on improving the compressive strength and increases it by 8.3 percent. Moreover, figures 2-3 and 2-4 represent that using polypropylene fibers enhance the 28-day compressive strength significantly.

As shown in Figure 3, various factors influence the tensile strength of foamed concrete. Figures 3-1 and 3-2 are related to mixtures without fiber and with fiber, respectively. In these Figures, the tensile strength obtained by Brazilian cylinder test is fitted by a straight line according to dry density. As shown in figures, the increase in the cement content brings about higher dry density and tensile strength. Adding polypropylene fiber to the mixtures improves the tensile strength of all designs.

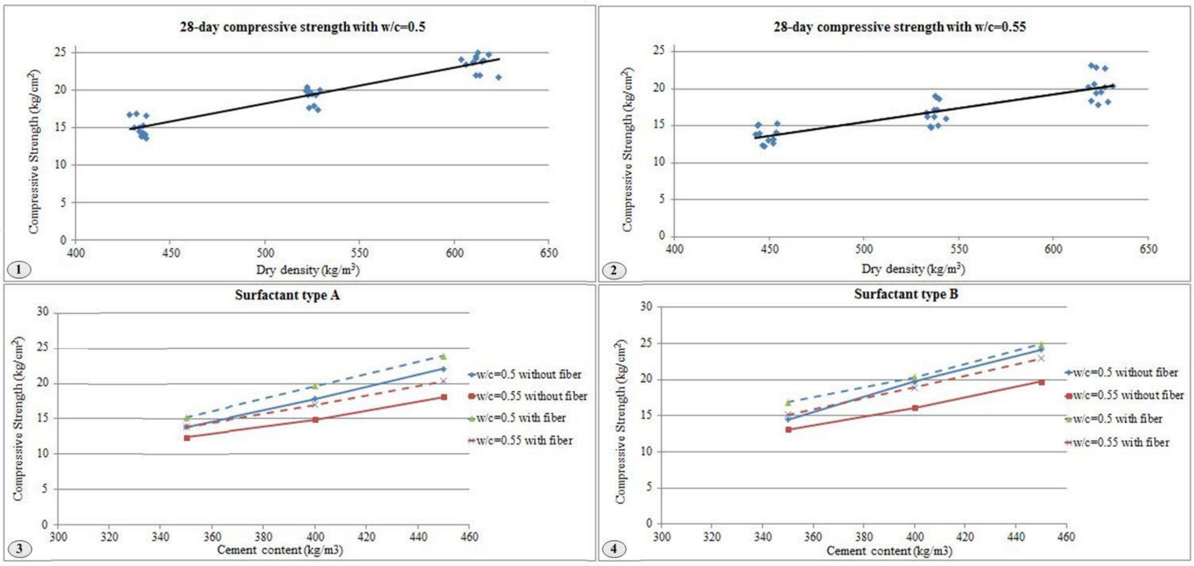

Fig. 2. Results of compressive strength test.

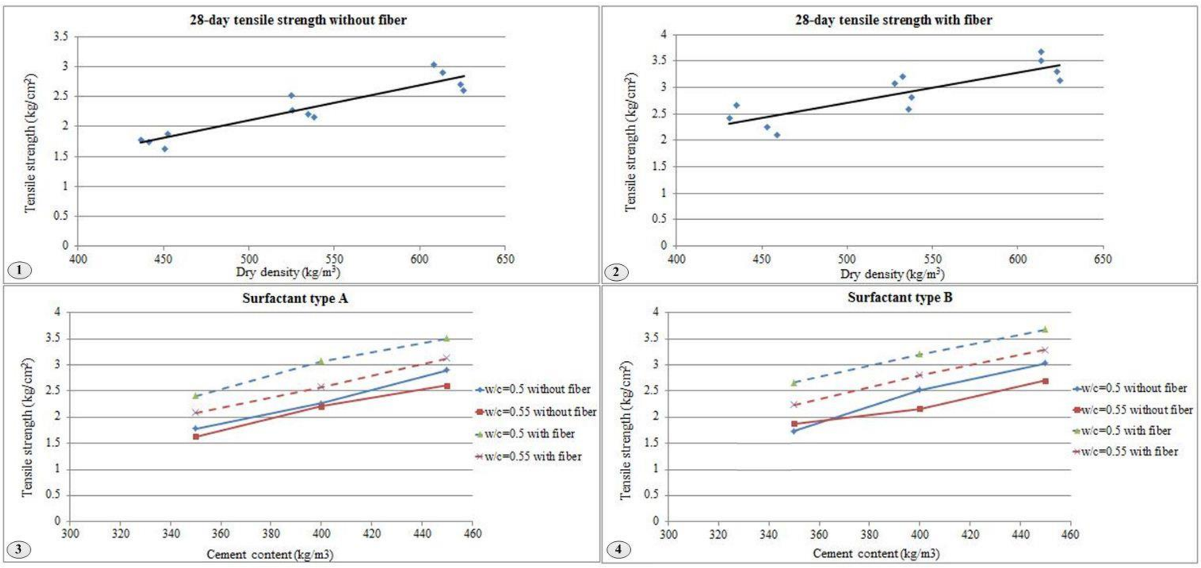

Fig. 3. Results of indirect tensile strength test.

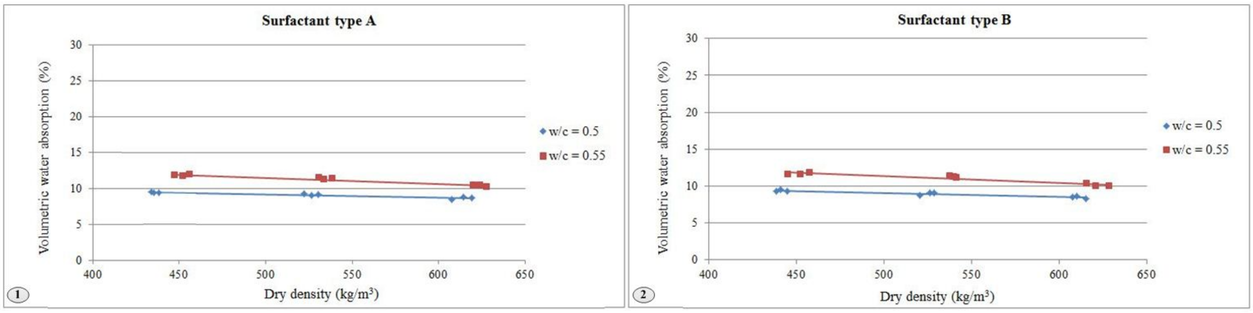

Fig. 4. Results of water absorption test.

Figures 3-3 and 3-4 are related to the specimens containing surfactant foam type A and type B, respectively. Additionally, dashed lines show the results of the specimens with fiber. The increase in water to cement ratio from 0.5 to 0.55 decreases the tensile strength by 10.6 percent. It can be concluded from figures 3-3 and 3-4 that the tensile strength of mixtures designed by surfactant type B is higher than type A by 5.8 percent. Moreover, adding polypropylene fibers has a positive effect on the tensile strength. The positive effect of using fibers in enhancing the tensile strength is more than the negative effect of the increase in the water to cement ratio.

ASTM standards accepted the volumetric water absorption criterion for determining the water absorption of specimens. In Figure 4, the effects of different factors such as the type of surfactant foam, content of cement, and water to cement ratio are displayed. According to the results in figure 4, the increase in density has little effect in reducing the volume of water absorption. The most important factor which influences the volumetric water absorption is water to cement ratio. As the ratio of water to cement is lowered from 0.55 to 0.5, the volumetric water absorption is also reduced by 22.7 percent. Additionally, the type of surfactant has approximately no effect on the water absorption.

Heat transfer coefficient of the mixtures containing surfactant type B is equal to 0.16 W/mk in average and foam type A is 0.18 W/mk. As can be concluded from the results, the performance of the mixtures with surfactant foam type B is slightly better than foam type A in terms of reducing energy loss, whereas the heat transfer coefficient of all mixtures is significantly lower than conventional concrete and natural lightweight aggregate concrete.

Heat transfer coefficient of natural lightweight aggregate concrete is approximately equal to 0.45 W/mk and conventional concrete is about 1.2 W/mk [29]. As a result, the performance of foam concrete in terms of thermal conductivity is much better than conventional concrete due to its lower density. Therefore, it can be led to reduce energy loss significantly.

CONCLUSION

Foamed concrete is a vastly workable, low density material incorporating up to 50% entrained air. Surfactant foaming agents can be used to produce foam. Surfactant molecules, defined as surface-active agents, consist of a hydrophobic and a hydrophilic moiety and help entrain air bubbles and stabilize them in the fresh cement paste. In this paper, the mechanical properties and environmental impacts of foamed concrete under the influence of surfactant chemical foaming is studied. For this purpose, 28-day compressive strength, indirect tensile strength, water absorption, and heat transfer coefficient tests were conducted on 24 designed mixtures.

Two types of anionic surfactant foaming agents (type A and type B) were employed to design the foamed concrete mixtures. The compressive and tensile strength of the experimental specimens with surfactant type B were higher than type A by 8.3 and 5.8 percent, respectively. The specimens of both types of surfactants showed the same performance regarding water absorption. Additionally, the thermal conductivity of the specimens with surfactant type B were slightly better than type A, whereas the heat transfer coefficient of all mixtures is significantly lower than conventional concrete and natural lightweight aggregate concrete. For instance, heat transfer coefficient of the foamed concrete mixtures are roughly 3 times better than natural lightweight aggregate concrete which leads to considerable lower energy loss.

Three cement contents of 350, 400 and 450 kg/m3 were used in experiments and it was shown that the increase in the cement contents improves the compressive and tensile strength and reduces the volume of water absorption fairly. Moreover, the water to cement ratio of 0.5 and 0.55 were applied in the mixtures. It was presented that, In general, the increase in water to cement ratio from 0.5 to 0.55 increases water absorption by 22.7 percent and reduces the compressive and tensile strength by 19.9 and 10.6 percent, respectively. In addition, the effect of polypropylene fibers on the compressive and tensile strength of foamed concrete was investigated. It was found that the 28-day strength of foamed concrete was substantially improved by the addition 0.5 percent by weight of polypropylene fibers.

REFERENCES

1. G. Bowen, L. Kaiping,. *New Wall Materials*, **7**, 30-32, (2008).
2. Z. Yunyan,. *Engineering Forum*, **15**, 134-156, (2005).
3. E. K. K. Nambiar, K. Ramamurthy, **20**, 2 (2008).
4. S. Ganesan, M. A. Othuman Mydin, M. Y. Mohd Yunos, M. N. Mohd Nawi,. *Applied Mechanics and Materials*, **747**, 230-233, (2015).
5. P. J. Tikalsky, J. Pospisil, W. MacDonald, *Cement and Concrete Research*, **34**(5), 889 (2004).
6. K. C. Brady, M. J. Green,. Foamed concrete: A Review of Materials, Methods of Production and Applications, project report/ CE/149/97 Transport Research Foundation Group of Companies, 1997.
7. L. Qing, J. Kang,. *Petrochemical Engineering and Construction*, **28**, 5 (2006).
8. G. C. Bye,. Portland Cement: Composition, Production and Properties,Thomas Telford Limited, London, second edition, 1999.
9. J. Ji-Yong, K. Jin-Man, *Journal of the Korea Institute of Building Construction*, **11**(6), 557 (2011).
10. T. Zhang, S. Shang, F. Yin, A. Aishah, A. Salmiah, T. L. Ooi, *Cement and Concrete Research*, **31**, 1009, (2001).
11. I. Girniene, A. Laukaitis, A. Dudik, *Materials Science*, **6**(4), 316-320, (2000).
12. K. Ramamurthy, E.K. K. Nambiar, G. I. S. Ranjani, *Cement and Concrete Composites*, **31**(6), 388 (2009).
13. R.C. Valore, *ACI J*, **50**, 773 (1954).
14. W.H. Taylor, Concrete Technology and Practice, Angus and Robertson, London, 1969.
15. A. Laukaitis, R. Zurauskas, J. Keriene, *Cem Concr Comp*, **27**, 41 (2005).
16. L. Du, K. J. Folliard, *Cement and Concrete Research*, **35**(8), 1463 (2005).
17. E. K. Kunhanandan Nambiar, K. Ramamurthy, *Cement and Concrete Research*, **37**(2), 221 (2007).
18. W. Cui-hua, *Chemical Materials for Construction*, **3**, 47-49, (2006).
19. C.G. Puttappa, A. Ibrahim, K.U. Muthu, H.S Raghavendra, in: International Conference on Construction and Building Technology, 491-500, (2008).
20. P. Chindaprasirt, U. Rattanasak, *Materials and Design*, **32**, 2 (2011).
21. E. K. Kunhanandan Nambiar, K. Ramamurthy, *Materials in Civil Engineering ASCE*, **21**, 11 (2009).
22. Z. Zhang, J. L. Provis, A. Reid, H. Wang, *Cement and Concrete Composites*, **62**, 22-32, (2015).
23. W. Tian, L. Li, X. Zhao, M. Zhou, N. Wang, in: International Conference on Transportation Engineering, ASCE, Southwest Jiaotong University, Chengdu, China, 2009.
24. http:// http://www.isiri.com/
25. ASTM, Standard Specification for Foaming Agents Used in Making Preformed Foam for Cellular Concrete, C869- 91 (2006).
26. BSI, Methods of test for mortar for masonry – part 11: Determination of flexural and compressive strength of hardened mortar, British Standards Institution, London, 1999.
27. ASTM, Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, C496-96 (2012).
28. ASTM, Standard Test Method for Density, Absorption, and Voids in Hardened Concrete, C642 (2006).
29. M. Raeisi, M. J. Mehrani, S. Nouri,. in:5th National Conference of Concrete, Tehran, Iran, 2013.