Investigation of foam volume on the penetration parameters of foamed concrete

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ABSTRACT

In this study performance of mixes with w/c ratio of 0.5 and foam contents of 20, 35 and 50%, with regards to absorption, capillary absorption and chloride ingress, were determined and compared to those of a base mix with the same proportions but without foam incorporation. A structural grade foam concrete with w/c ratio of 0.4 and foam content of 20% was also considered together with a conventional concrete of equal strength level. The results show that foam incorporation results in decreased absorption and capillary absorption and increased chloride diffusion. The discrepancy is due to presentation of absorption results on total concrete volume basis. By considering these results on paste volume basis, which is the penetrable phase, absorption results show the same trend as the chloride diffusion results. Incorporation of 20, 35 and 50 percent foam into the base mix resulted in increases of 12, 27 and 50 percent in paste absorption and 18, 55 and 155 percent in chloride diffusion values respectively. Increased foam volume resulted in larger and more connected air voids. Although foamed porosity has a negative effect on penetration characteristics, the structural grade foam concrete with its lower w/c ratio achieved similar levels of performance as the base mix and performed better than the conventional concrete of equal strength level.

KEYWORDS

Foamed concrete, water absorption, capillary absorption, porosity, chloride diffusion coefficient

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1. Introduction

Foamed concrete is based on incorporation of preformed air voids (foam) into cement paste and mortar. This lightweight concrete was initially used, mainly as a low density fill material. However intensive research has made possible production of structural and semi structural foamed concretes[1-3]. Previous research has mainly been concentrated on physical and mechanical characteristics of the material and durability aspects of foamed concrete have received less research attention. Information with regards to chloride ingress and chloride induced steel corrosion is particularly scarce[4, 5]. As structural applications of foamed concrete would inevitably require incorporation of steel reinforcement, durability of steel in foamed concrete against corrosion requires further investigation. The ingress of chlorides or carbonation of concrete can compromise the passive layer and active corrosion can start. Absorption is an important mechanism for the ingress of chlorides into concrete [6-8]. The effect of foam volume on absorption properties of foamed concrete has been investigated by a number of researchers. Majority of researchers have reported that foam incorporation results in decreased absorption when the results are reported as % by volume basis [9-11].

Diffusion which occurs due to ionic concentration gradients in the pore liquid of the cement paste phase, is also a major mechanism for penetration of chlorides in to concrete. Reported work on chloride diffusion of foamed concrete is very scarce.

Due to scarcity of reported work on the penetration of chloride ions into foamed concrete and also the importance of water absorption and diffusion phenomenon as the main mechanisms for ingress of ions into concrete, an experimental study was undertaken for investigating these issues.

2. Methodology

Effect of foam porosity on absorption, capillary absorption and chloride ingress was studied experimentally by water absorption, capillary absorption and rapid chloride migration test (RCMT). Performance of mixes with w/c ratio of 0.5 and foam contents of 20, 35 and 50% were determined and compared to those of a base mix with the same proportions but without foam incorporation. A structural grade foam concrete with w/c ratio of 0.4 and foam content of 20% was also considered together with a conventional concrete of equal strength level. The codes adopted for the mixes comprised of a letter indicating the mix type (B for the base mix, F for the foamed mixes and C for the conventional concrete), followed by a number showing the w/c ratio of each mix. Therefore, the foamed concrete mix with 20% foam porosity and w/c ratio of 0.5 is represented with the code (F20-0.5).

3. Results and Discussion

The results of water absorption test show that by incorporation of air voids in the form of foam porosity, concrete absorption is reduced. Absorption values show the volume of pores accessible by water which mainly includes the capillary and gel pores of cement paste. By adding foam to the base mix, the volume of cement paste is reduced and a lower volume of water is absorbed per unit volume of concrete. Reduced absorption due to foam incorporation has also been reported by previous researchers [9, 11]. The structural grade foam concrete with its lower w/c ratio and relatively low paste content has the lowest absorption among the mixes studied.

Foamed porosity does not appear to participate in capillary suction. According to She et al. [12] when water in capillary porosity of cement paste comes in contact with the air voids a water film quickly forms around the pores preventing further water penetration because of the inner air pressure in the air voids. the structural foamed concrete F20-0.4 exhibits the lowest capillary absorption among the mixes studied. Although the paste volume of this mix is somewhat higher than that of the foamed mix with 50% foam content, i.e. F50-0.5 mix, its lower w/c ratio of 0.4 has resulted in both a reduced and more tortuous capillary porosity.

The results of rapid chloride migration test show that incorporation of air voids has resulted in increased chloride diffusion coefficient of the foamed mixes compared to the base mix at the same w/c ratio. This is in contrast to the results of the absorption test which show an improvement due to foam incorporation. The following explanation can account for the observed discrepancy. Chloride ingress into concrete mainly takes place through the capillary porosity of the paste fraction. In the absorption tests however, although it is the paste porosity which is responsible for the absorbed water, the results are expressed as the volume of absorbed water divided by the total volume of concrete. In foamed concrete, paste volume is reduced by increased foam incorporation and therefore absorbed water per concrete volume is reduced, although paste absorption characteristics remain the same. Therefore, the logical way to for expressing the results of water absorption tests, is to give the results in the form of absorbed water against the paste volume, i.e. paste absorption. The results show that paste absorption actually increases with incorporation of foam porosity, which is now in agreement with the trend shown by the RCMT test results. The increased paste absorption due to foam incorporation is due to the fact that during the absorption test some of the air voids are filled with water because of the small head of water present in the test. Therefore, although the paste quality in the base mix and the foamed mixes F20-0.5 and F50-0.5 are the same, the water which entered some of the air voids of the foamed mixes in the absorption test contribute to absorption of the paste fraction, increasing it further compared to the base mix. In a similar manner also in the RCMT test the water entering into some of the entrained air voids contribute to increased diffusion paths in the paste, resulting in deeper chloride penetration and a higher coefficient of diffusion. Incorporation of 20, 35 and 50 percent foam into the base mix resulted in increases of 12, 27 and 50 percent in paste absorption and 18, 55 and 155 percent in chloride diffusion values respectively. Despite the adverse effect of foam incorporation on absorption and diffusion characteristic of concrete, it is interesting to note that the structural grade foamed concrete with moderate foam content of 20% and w/c ratio of 0.4, performed better than the base mix. This shows that by reducing the w/c ratio, it is possible to compensate for the negative effects of foam incorporation. The conventional concrete mix however due to its higher w/c ratio had a higher diffusion coefficient compared to the base mix.

4. Conclusions

According to the results of the current study, foam incorporation results in reduced absorption when presented as % by volume of concrete. However, when they are expressed as % by volume of cement paste, which is the penetrable phase, an opposite effect is observed. The results of the rapid chloride migration test also show increased chloride diffusion coefficients with increasing foam contents. It was found that some of the foamed porosity is penetrated by water when foamed concrete is immersed in water which results in increased absorption and diffusion values.

Although foam porosity results in increased absorption and chloride diffusion parameters, structural grade foamed concrete due to its lower w/c ratio and relatively low foam content of 20% achieved similar levels of performance to the base mixture. The performance of the structural grade foam concrete with regards to absorption and diffusion was superior to that of the conventional mix with equal strength value.

5. References

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