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Experimental Study on Polymer Concrete Containing Expanded Polystyrene Beads and Polyamide 66 Yarns

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The present work is directed towards the performance evaluation of the concrete composites containing different sizes of expanded polystyrene (EPS) beads. Expanded polystyrene concrete is a lightweight material. The study covers the use of three different sizes of EPS beads as lightweight aggregate in concrete. Part of the results were obtained from our earlier study reported on a novel polymer concrete essentially having EPS and polyamide 66 yarns. When largest EPS beads are used, it disintegrates along the contact zone and hence decreases the adhesion strength. The use of polyamide 66 yarns had a significant influence in crack reduction.

Key Words: Polymer matrix, Polymer concrete, Polystyrene beads, Lightweight composite.

INTRODUCTION

Expanded polystyrene (EPS) concrete is a lightweight material with good energy-absorbing characteristics, consisting of discrete air voids in a polymer matrix. However, polystyrene beads are extremely light, with a density of only 12 to 20 kg/m^3, which can easily cause segregation in mixing. Hence some chemical treatment of surface on this hydrophobic material is neded. In our previous report[1], we suggested bonding additives in order to straighten these deficiencies. As it was found from our earlier study[1], the addition of superplasticizers does not affect the phase composition of the cement hydration products to a noticeable extent, but only the physical state and decreased degree of crystallinity of hydratesis formed.

Based on the requirements of density and strength and the reduction of energy consumption in construction, lightweight concrete can be produced by replacing the normal aggregate. Lightweight aggregates are broadly classified into two types: natural and artificial. Adhesion of the composite with the matrix is very important in the process of manufacturing composites[2]. Polymers and organic admixtures interact with the components of Portland cement when coming into contact with water. Expanded polystyrene beads are a type of artificial ultra-lightweight non-absorbent aggregates. It can be used to produce low density concretes which is

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essential for building applications, namely, cladding panes, curtain walls, composite flooring systems, and load-bearing concrete blocks[3]. The present work is a general attempt to study the effect of EPS sizes on the adhesion of beads with concrete.

EXPERIMENTAL

The main chemical composition of the ordinary Portland cement used in this study was found to be $SiO_2 = 20.40\%$, $Al_2O_3 = 6.12\%$, $Fe_2O_3 = 3.051\%$, $CaO = 63.16\%$, $MgO = 2.32\%$, $SO_3 = 2.40\%$.

Three types of commercially available spherical EPS beads were used (Table-1).

TABLE-1
EPS BEAD CHARACTERISTICS

Type	Size (mm)	Bulk density (kg/m^3)	Specific gravity
A	8	12	0.010
B	6	16	0.014
C	3	20	0.029

The particle-size distribution was first carried out, for three types of EPS. The EPS beads were wetted initially with 25% of the mixing water and super plasticizer before adding the remaining materials. A naphthalene-based super plastisized cement paste was prepared. The addition of EPS in place of normal aggregate reduces the weight of the concrete. In order to simplify the mixing process, the estimated component additions were measured by volume. Non-absorbent, hydrophobic and closed cellular aggregates like expanded polystyrene (EPS) beads were mixed in a planetary mixer. Mixing was continued until a uniform and flowing mixture was obtained. The fresh polymer concrete was then poured into molds and compacted by hand firmly. A number of test specimens of different sizes were chosen for investigating the various parameters. In this experimental study, the mixture compacted in the moulds of (100 mm)(100 mm)(100 mm) and cubes of 100 mm for studying the compressive strength. A uniform mixture of materials can be obtained using a horizontal agitator. The samples were kept in the moulds for 3 d and then they were taken out of the mould, immersed in water and then allowed to harden for 3, 7 and 28 days in laboratory environment.

RESULTS AND DISCUSSION

The development of compressive strength gain in 3, 7 and 28 d is presented in Fig. 1-3. The compressive strength of polymer concrete in almost all mixes displayed a continuous increase with age. The rate of strength development increased with a decrease in the EPS bead size for the same mix proportions. Comparison of the strength at 28 d indicated that at these ages, all mixes showed appreciable improvement in compressive strength with age.

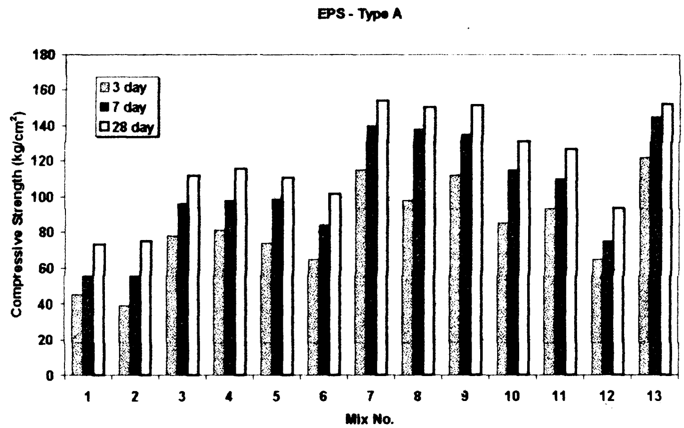

Fig. 1. Development of compressive strength with age (Type A EPS)

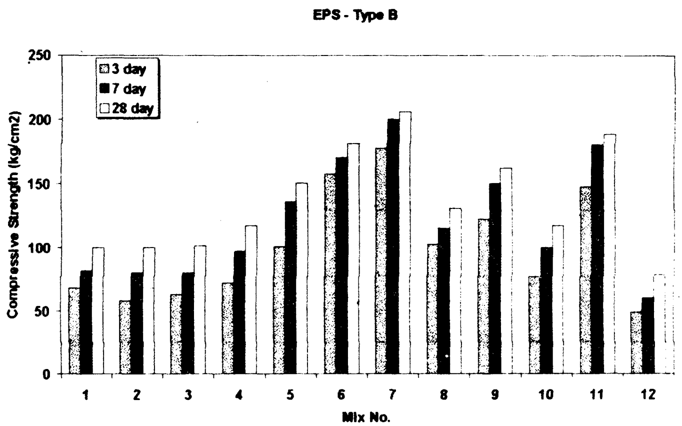

Fig. 2. Development of compressive stength with age (Type B EPS)

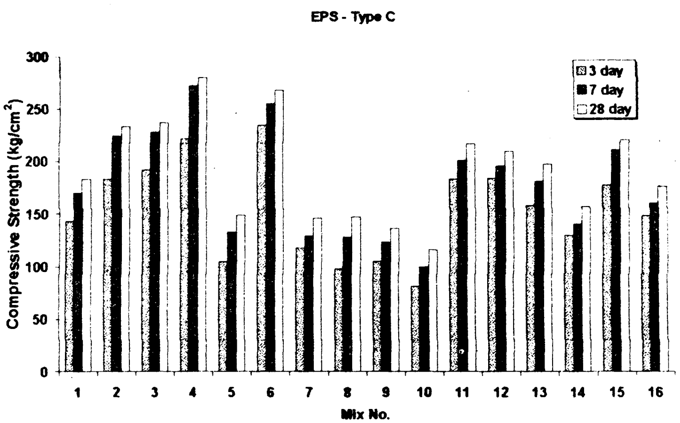

Fig. 3. Development of compressive strength with age (Type C EPS)

This revealed that the strength of polymer concrete marginally increased as the bead size decreased. The highest composite compressive strength is reached when the 3 mm size EPS beads are used (Type C).

However, the dependence of compressive strength values on density, when various types of polystyrene beads are used, is presented in Fig. 4. The strength of polymer concrete appeared to increase linearly with an increase in concrete density. In view of the above, EPS concrete of type C showed the highest increase in compressive strength.

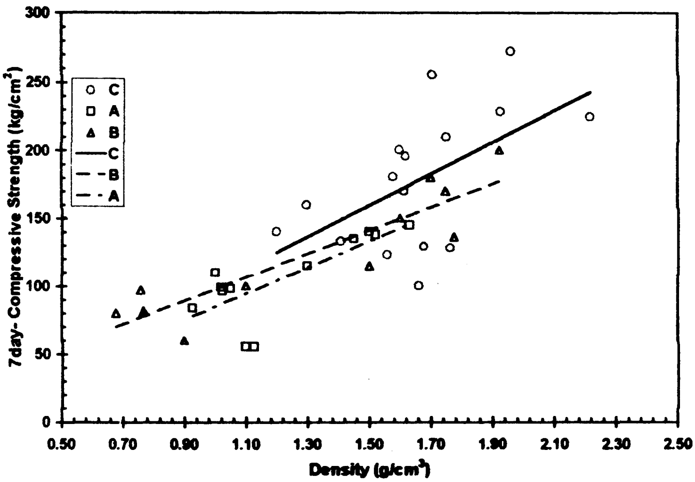

Fig. 4. Variation of strength with density.

Comparison of the composite density for different volume content EPS beads in Fig. 5 showed no appreciable difference. The compressive strength of EPS concrete with different volume content of EPS is presented in Fig. 6. The strength of polymer concrete appeared to increase linearly with a decrease in the EPS volume.

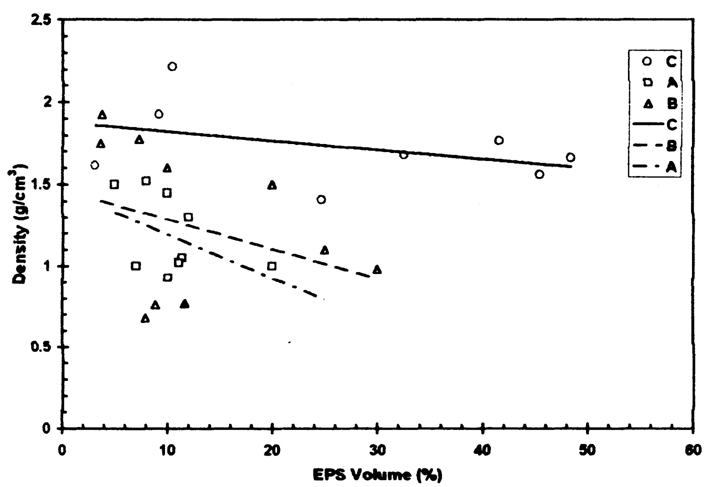

Fig. 5. Variation of composite density with EPS volume

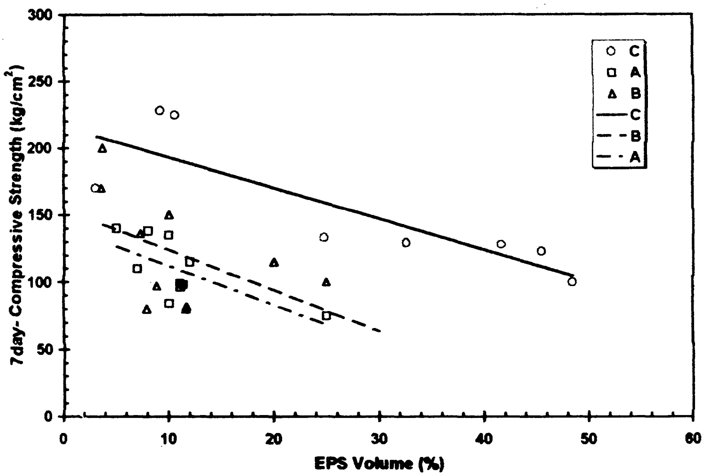

Fig. 6. Effects of EPS % volume on compressive strength

The highest composite strength is reached when type C EPS beads are used. Fig. 7 illustrates the dependence of compressive strength values on density for 28 d polymer concrete. This revealed that the highest increase in strength is reached when the EPS beads of Type C are used.

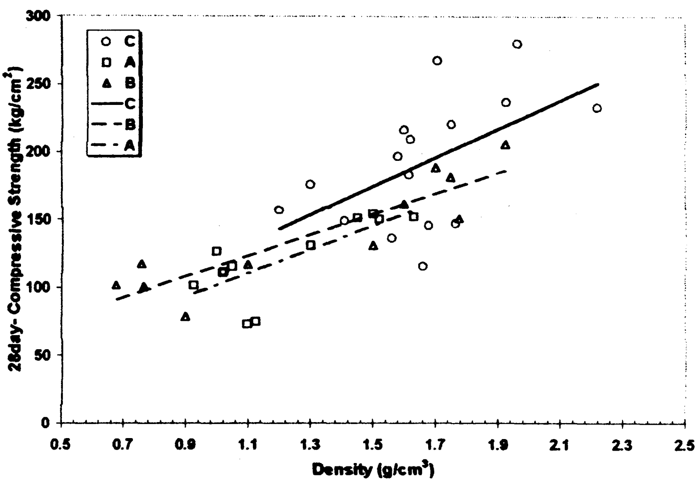

Fig. 7. Variation of strength with density

In view of the above, in Fig. 8 it can be seen that with the same volume content of EPS, 3 mm size beads can significantly increase compressive strength. This can improve the dispersion of EPS in the cement paste. However, with an increasing content of EPS, the increase in strength was reduced.

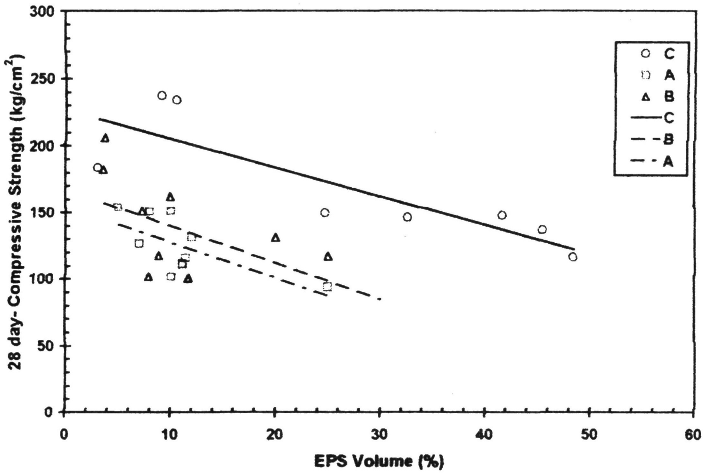

Fig. 8. Effects of EPS % volume on compressive strength

Fig. 9 shows the performance of sample under compressive test. The structure of the interacting polystyrene beads from the surface of the specimen was observed after fracture using electron-scanning microscope (Fig. 10). The micro-structure of the contact zone of EPS beads is free from deep cavities. This reveals that the adhesion strength of fine beads (Type C) is high.

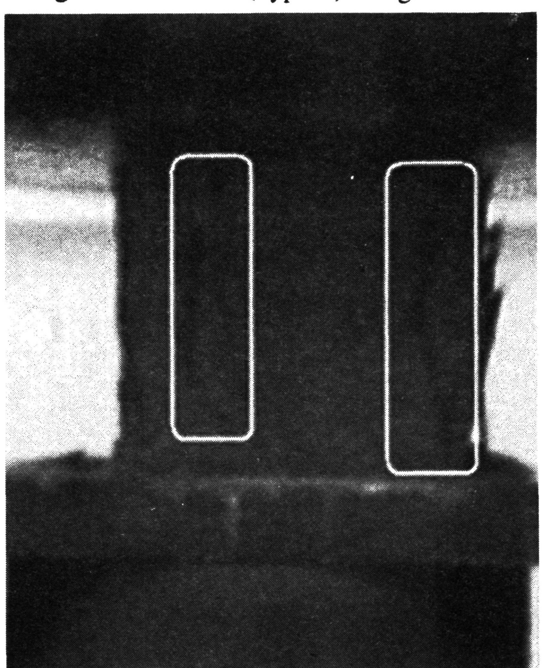

Fig. 9. Compressive strength test and cracks distribution

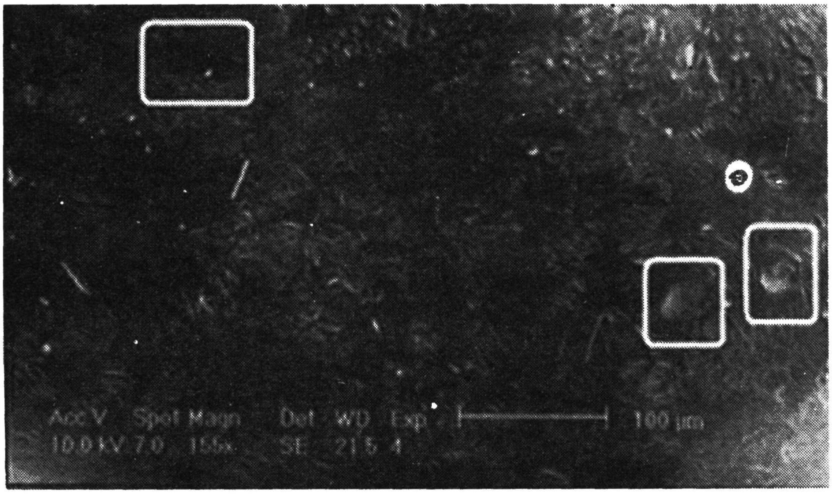

Fig. 10. Microstructure of the contact zone of fine EPS (Type C)

Conculsion

It was found that the strength of the polymer concrete is directly proportional to the concrete density. In general, the behaviour of EPS concretes with smaller bead sizes was much better. This can certainly increase the dispersion of EPS in the cement matrix and then the bonding between EPS beads and cement paste. Although the compressive strength of polymer concrete in almost all mixes displayed a continuous increase with age but the strength of EPS concrete incresased with a decrease in the EPS bead size for the same mix proportions. In view of the above we can conclude that the compressive strength of the investigated material depends on its density and type of EPS beads used. It is shown that the fine EPS beads allow for the highest composite compressive strength, which on average by 45% higher than the largest beads are used. Meanwhile, the application of polyamide 66 yarns had a significant influence in crack reduction.

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