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USE OF EXPANDED POLYSTYRENE (EPS) BEADS IN SILICA-FUME CONCRETE

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ABSTRACT

Concrete is a good constructional material as it posses enough compressive strength for structural purposes, in spite of that concrete has some dis–advantages, one of these main dis–advantages is its high density (2300-2400) kg/m³ .Many trials were made to minimize its density in different ways. Recently Expanded Polystyrene (EPS) granules (98% air) were added to the concrete for this purpose. In this investigation the concrete density is reduced by adding polystyrene granules to the silica-fume concrete. Silica-fume was added for enhancing the concrete strength and balances the loss in concrete strength due to the inclusion of polystyrene granules .Test results show that the inclusion of silica fume to the concrete improves its strength for both normal concrete and concrete of EPS beads. It is concluded that structural concrete (Strength > 17 MPa) with EPS beads can be manufactured when silica fume is added to concrete.

KEYWORDS: Compressive Strength, Silica Fume, Polystyrene Granules, light weight concrete

1. INTRODUCTION

Concrete is a good constructional material as it posses enough compressive strength for structural purposes, in spite of that concrete has some dis–advantages ,one of these main dis–advantages is its high density (2300-2400) kg/m³ .Many trials were made to minimize its density by manufacturing lightweight concrete. Lightweight concrete was manufactured traditionally by three methods which are;-

A. Using lightweight aggregates like pumice or scoria.

B. Introducing air bubbles in the mortar.

C. Omitting sand from the concrete.

A new technique was used to manufacture lightweight concrete by adding light weight materials (cork and agricultural waste materials) as partially or full replacement of fine or coarse aggregates.

Recently Expanded Polystyrene (EPS) beads and granules which are lighter (98% air) were added to the concrete to minimize it density, herein the review of the researches and investigations about using this material in concrete;-

Bing Chen,Jie Liu and Long-zhu Chen (1) Used the expanded polystyrene beads as totally or partially replacement of the fine or coarse aggregate ,they do that to develop a new lightweight concrete, the beads used were 1,2.5 and 6.3mm size ,also silica fume and polypropylene fibers were used to improve the concrete properties.

Test results show that the silica-fume increases the bond between cement paste and polystyrene beads. Also they concluded that strength of polystyrene concrete decreases linearly with the increase of EPS fraction in concrete.

Hind M. Ewadh and Noorezlin A. Basri (2) studied the effect of using polystyrene beads in concrete on the absorption and workability of concrete. Different ratios of polystyrene beads 25%, 50%, 75%, and 100%) replacement of sand or gravel are used. They concluded that both the workability and absorption of concrete increases with the increasing of polystyrene beads and for 100% aggregate replacement by polystyrene beads the absorption was 82%.

Tengku Fitriani L.Subhan (3) examined the properties (compressive and tensile strength) of lightweight concrete with EPS beads .Their result showed that the polystyrene beads amount in concrete affects the concrete strength inversely, and for the concrete with 15% polystyrene beads, the compressive strength was 86% compared to those of normal concrete.

Loh Wai Kin and Mohd Azreen Mohd Ariffin (4) Studied wall frame composite made from polystyrene beads and cold formed steel. For this purpose they examined three concrete mixes of (1:3.5:2, 1:2.5:3, and 1:3.5:4 (cement sand, polystyrene beads)).

In this study the mix (1:3.5:2) shows the highest compressive strength and therefore it was used in the wall frame composite.

Aman Mulla and Amol Shlake (5) tried to find light weight concrete mix of better properties than the burnt brick (compressive and density),expended polystyrene (EPS)beads were used in concrete as replacement of aggregate (5%, 10%, 15%, 20%, and 25%). Their conclusion indicates that the concrete strength reduces with the increase in amount of the EPS beads; they also concluded that (EPS) beads concrete has only scope of using in non-structural applications.

Roshan Gawale et al.(6) completely replaced the coarse aggregate of concrete by EPS beads and examined the concrete properties .They found that lightweight with EPS beads can be used for the construction of partition walls and bed concretes.

Suhad M Abd et al.(7) replaced the fine aggregate partially(5%, 15%, and 20%) by polystyrene beads and compared it with the normal concrete .They concluded that workability of concrete increases with the increase in polystyrene beads amount ,while the density of concrete decreases with increase in polystyrene beads percent. They also concluded that using polystyrene beads in concrete helps as a solution for polystyrene beads disposal.

Wenbo Shi et al.(8) Produced EPS concrete by mixing expanded polystyrene beads with polymer emulsion and add it to the concrete. EPS was added by volume ratio of 0%, 20%, 30%, and 40% by replacing the matrix or the gravel. They concluded that the compressive strength of the two types of EPS concrete in which the matrix is replaced by EPS or the gravel is replaced by EPS is identical. Another conclusion is that the EPS concrete can be used in some long term of cyclic dynamic load engineering.

Costin Andrei Cadere et al.(9) studied the influence of the inclusion of fly-ash (10%) and polystyrene granules as replacement of aggregate on the density and mechanical properties of concrete (compressive, flexure and splitting tensile strength).

They concluded that the polystyrene granules decreases the concrete density and also decreases all types of concrete strengths except the tensile strength.

Observing the above review it is shown that in the most of researches, one type of the aggregate (sand or gravel) is usually replaced by EPS beads and the researches not deal with the EPS beads as an admixture to be added to the total volume of concrete.

In this investigation a trial was made to reduce the concrete density by adding polystyrene granules to the silica-fume concrete. Silica-fume was added for enhancing the concrete strength (10,11) and it is expected to balance the loss in concrete strength due to the inclusion of polystyrene granules(1,5,9).

In this research it has been deal with the adding materials (silica fume and EPS beads) to the concrete as admixtures as Neville (12) illustrates that admixture is any material other than water, cement, and aggregates that used as an ingredient of concrete.

Experimental Program

A total of 60 cubical specimens were made in three main groups (A, B, and C). Each group consists of 20 specimens. The first group (Group A) includes specimens with EPS beads by concrete volume ratios of (0%, 10%, 15%, 20%, and 25%) with out silica-fume content. .The second group (Group B) includes specimens with EPS beads by concrete volume ratios of (0%, 10%, 15%, 20%, and 25%) with silica-fume content of 5% replaced by cement weight. The third group (Group C) includes specimens with EPS beads by concrete volume ratios of (0%, 10%, 15%, 20%, and 25%) with silica-fume content of 10% replaced by cement weight. The silica fractions (5% and 10%) were chosen according to ASTM C1240-04 (13) advisement which is from (5%-12%).Maximum Expanded polystyrene granules fraction (25%) is controlled by the concrete workability, because the addition of the polystyrene beads reduces the concrete workability and after this ratio the concrete becomes non-workable.

For each variable studied in present investigation, four identical specimens were tested using the same mixing, curing and testing conditions. The details of the parameters or variables which were depended in current experimental investigation are listed in Table (1).

Table (1): Parameters or variables which were studied in current experimental investigation

Group	Mix NO.	Mix Proportions	EPS Beads by Volume%	%Silica-Fume	No. of cubes
Group (A)	Mix 1	1;1.73;2.95;0.5	0%	0%	4
	Mix 2	1;1.73;2.95;0.5	10%	0%	4
	Mix 3	1;1.73;2.95;0.5	20%	0%	4
	Mix 4	1;1.73;2.95;0.5	15%	0%	4
	Mix 5	1;1.73;2.95;0.5	25%	0%	4
Group (B)	Mix 6	1;1.73;2.95;0.5	0%	5%	4
	Mix 7	1;1.73;2.95;0.5	10%	5%	4
	Mix 8	1;1.73;2.95;0.5	15%	5%	4
	Mix 9	1;1.73;2.95;0.5	20%	5%	4
	Mix 10	1;1.73;2.95;0.5	25%	5%	4
Group (C)	Mix 11	1;1.73;2.95;0.5	0%	10%	4
	Mix 12	1;1.73;2.95;0.5	10%	10%	4
	Mix 13	1;1.73;2.95;0.5	15%	10%	4
	Mix 14	1;1.73;2.95;0.5	20%	10%	4
	Mix 15	1;1.73;2.95;0.5	25%	10%	4
Total number of cubes					60

3.1 MATERIALS AND METHOD

3.1Main Materials

The main materials which were used in preparation of the concrete specimens for present investigation are as hereunder:

A. Cement :- Iraqi Ordinary Portland Cement with the specific gravity of 3.10
The cement properties are listed in table(2).

B. Sand :- Iraqi local sand from Al-Khazer area with the fineness modulus of (2.54).
The sand gradation is shown in table(3).

C. Gravel :- Iraqi local rounded gravel from Al-Khazer area with a maximum size of 20 mm. The specific gravity of the gravel is equal to (2.67).

D. Water**:** Potable drinking water is used for mixing and curing .

E. EPS particles are expanded polystyrene Spheres particles with a diameter range of 3–5 mm, white in color. The density of these Polystyrene beads was 28 kg/m³.

F. Silica Fume used is in conformance with the ASTM C 1240 specifications.

Table (2): Physical Properties of cement

Test	Result	Iraqi Specifications NO.(5)1984
Specific gravity	3.1	3-3.25
Initial setting time	167 min.	min.1 hr
Final setting time	3:30 Hours	max. 10 hr
Fineness(surface area)	299 m²/kg	min. 230 m²/kg

Strength at 7 days	29 N/mm²	min.23 N/mm²

Table (3): Sieve Analysis of the sand

Sieve Opening (mm)	% of the Passing	SpecificationB.S882:1992 ZONE (M)
9.5		100
4.75	100	100
2.36	82	65 --- 100
1.18	67	45 --- 100
0.6	56	25 --- 80
0.3	40	5 ---- 48
0.15	0	----
Pan		----

Fig.(1): Polystyrene beads used in the investigation

3.2 Mix Design Principle

According to the test results of the materials used in this research (cement, sand and gravel), concrete mix was designed by DoE method for a minimum strength of 30 MPa at 28 days age. The concrete mix proportions were as follows:- 390:677:1153:195 (Cement, Sand, Gravel, Water) (For one cubic meter) ,in which mix proportions are equal to 1:1.73:2.95:0.5 (Cement, Sand, Gravel, Water).Water to cement ratio was fixed for all the mixes therefore, concrete workability differs from one mix to another depending on percent content of the silica fume and Polystyrene beads.

3.3 Preparation of Specimens

3.3.1 Mixing and Curing Concrete ingredients were mixed according to the designed mix proportions, the EPS beads were added, and finally water is added to form a concrete which was mixed manually. The plastic molds of 100 x

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100 x 100 mm were oiled before filling the concrete. Before casting the concrete in the cubical molds, the internal surfaces of these molds were oiled .The molds were filled by concrete in two layers, and then placed on vibrating table to compact the concrete.

After the compaction has been completed, the excess concrete was removed from the molds with the help of trowel and the surface of concrete is leveled. After 24 hours, concrete cubes were remolded and taken to a water tank to be cured for 28 days.

Fig.(2): Concrete cubes used in current research

3.3.2 Concrete Testing

A. Compressive Strength Test

After removal of concrete cubes from molds, the cubes were allowed to be dried in room temperature for about 5 hours before testing.

Compressive Strength Test was conducted based on BS EN 12390-3:2002. (14). Constant rate of loading, (2.0) MPs/s was applied to concrete cubes during compressive strength test.

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Fig.3. Compression Testing Machine

B. Concrete Density

Concrete cubes with different ratio of EPS beads by concrete volume were weighed at 28-days age. They were taken out of the water tank, dried for 5 hours and then weighed.

As it is mentioned before molds with dimension 100 mm x 100 mm x 100 mm were used for casting concrete; hence the volume of the samples is 0.001 m³.

Concrete density (kg/m³) is determined by dividing the net weight of concrete in kilogram by its volume in cubic meter.

Fig.4. Concrete cube with EPS beads

2. RESULTS AND DISCUSSION

A. Effect of EPS beads on concrete strength

Test results of concrete compressive strength are shown in figures (5, 6, 7, and 8). It is clear that the inclusion of EPS beads to the normal concrete (group A) reduces the concrete strength, this agree with the results of Aman Mulla and Amol Shlake (5). The reduction in strength is due the fact that cement concrete contact zone is stronger than the polystyrene granule material which has the lowest adhesion strength (15).

The inclusion of EPS beads by 10% to the volume of concrete reduces the concrete strength by 51%, while the reduction in strength increases to 70% when the EPS beads increases to 25%. After analyzing the results of (group A) it was shown that the polynomial equation ($Y=0.0352X^2 - 1.7205X + 31.59$ with $R^2=0.9711$) was the best relation between the compressive strength and the EPS beads content.

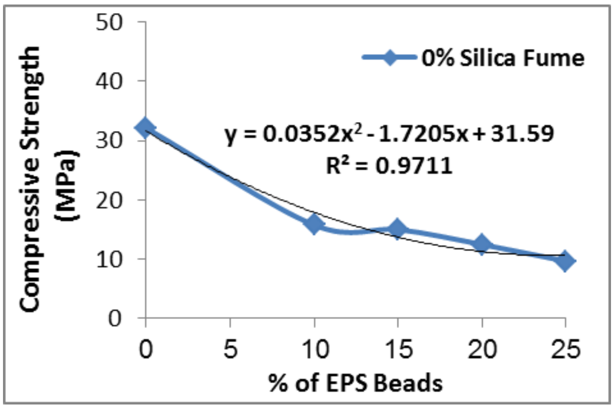

Fig. (5): Variation of concrete strength with EPS beads content (group A)

For the silica fume concrete of 5% silica fume (group B), the inclusion of EPS beads by 10% to the volume of concrete reduces the concrete strength to by 39%. For the same concrete, the reduction in concrete strength increases to 70%, when the EPS beads increases to 25%. After relation between the compressive strength and the EPS beads content. analyzing the results of (group B) it was shown that the polynomial equation ($Y=0.0222X^2 - 1.485X + 36.314$ with $R^2=0.9892$) was the best

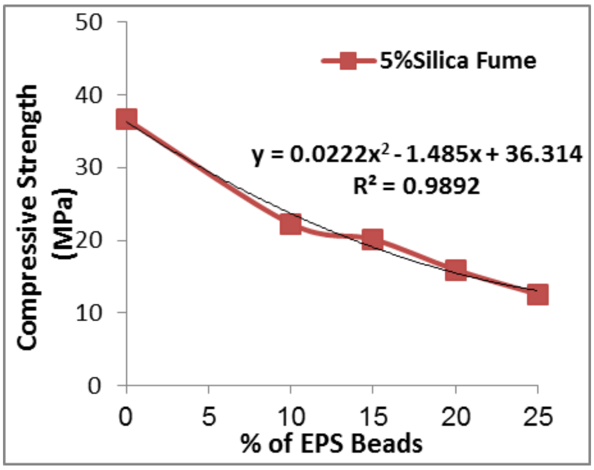

Fig. (6): Variation of concrete strength with EPS beads content (group B)

Test results of silica fume concrete with 10% silica fume shows that the inclusion of 10% EPS beads to the concrete causes a reduction in strength of about 61% with respect to the control one. This reduction in strength increases to 70% when the EPS beads increases to 25%. After analyzing the results of (group C) it was shown that the polynomial equation ($Y=0.042X^2 - 2.3635X + 45.613$ with $R^2=0.9924$) was the best relation between the compressive strength and the EPS beads content

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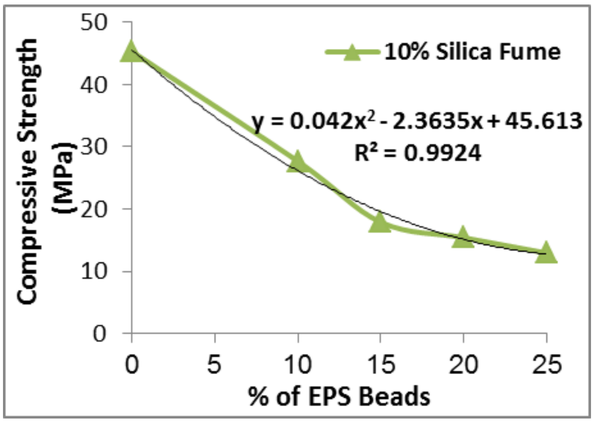

Fig.(7): Variation of concrete strength with EPS beads content (group C)

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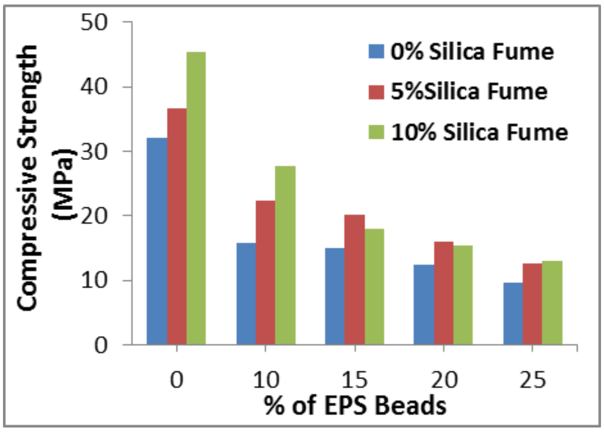

Fig. (8): Variation of concrete compressive strength with EPS beads content

It is concluded that the inclusion of EPS beads to concrete greatly reduces its strength. Also it is included that the reduction in strength follows the same trend for both normal and silica fume concretes.

B. Effect of silica fume on concrete strength

Figure (9) shows the effect of silica fume on concrete strength with respect to non silica fume concrete (Normal concrete).From the figure it is shown that the inclusion of silica fume by 5% replacement of cement, improves the concrete strength. This improvement in the strength of concrete is because of the high pozzolanic nature of the micro silica and its void filling ability in the concrete structure. (13).

The improvement in strength is about 14% for non EPS beads concrete, for this concrete of 10% EPS beads the improvement increases to 41%, and for the concrete of 25% EPS beads the improvement was 30%.

The inclusion of 10% silica fume to the normal concrete improves the concrete strength by 41%.The strength improvement increase to 76% for the concrete of 10% EPS beads, while this improvement decreases to about 34% for concrete of 25% EPS beads.

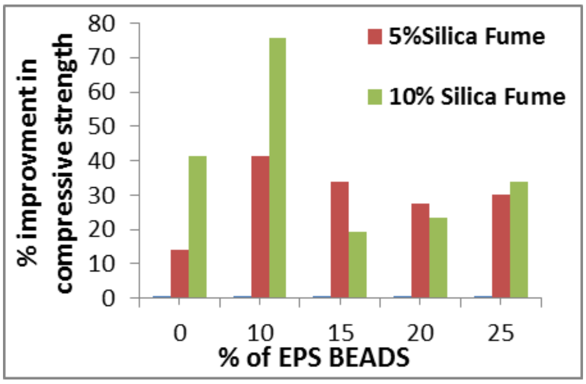

Fig. (9): Variation of % improvement of compressive strength due to Silica –Fume content

It is concluded that the inclusion of silica fume to the concrete improves its strength for both normal concrete and EPS beads concrete.

From the test results it can be shown that the best benefit of adding silica fume to concrete can be taken when added to the concrete of 10% EPS beads by 5 % replacement of cement as the improvement in strength is maximum (41%).

For the concrete of 10% replacement of silica fume instead of cement the best benefit is taken from the silica fume addition when added to the concrete of also10% EPS beads, for which the improvement in strength is about 76%.

For concretes of 25% EPS beads the improvement in strength is 30% and 34% due to the addition of silica fume by 5% and 10% respectively.

It is clear from the test results that structural concrete which is of strength ≥ 17 MPa according to ACI 318 Standard (Section 5.1.1)(16) can be manufactured with an addition of 15% EPS beads to concrete, if the cement is replaced by 5% or 10% silica fume.

For concrete of (10% silica fume replacement of cement) the concrete gets strength of 27 MPa, even when it includes 10% EPS beads.

It is concluded that Structural concrete with EPS beads can be manufactured when silica fume is used in concrete.

This conclusion confirms with the findings of Aman Mulla and Amol Shlake (5) which states that (EPS) beads concrete has only scope of using in non-structural applications.

C. Effect of EPS beads on concrete density

The inclusion of EPS beads to the concrete reduces its density almost by the same percent as its added to concrete as it is shown in figure (10).The inclusion of EPS beads to concrete by 15% causes a reduction of 15.5% in its density. While this reduction in weight become 26.5% when the EPS beads content is 25%.

The little deference between the percent reduction of the density and the percent addition of EPS beads is belonging to two reasons, the first one is the variation in the degree of concrete compaction of the cubes from batch to batch especially for high percent of EPS beads (20% and25%) which belongs to the shrinkage of the beads volume, and the second is the weight of the EPS beads which is about 98% air

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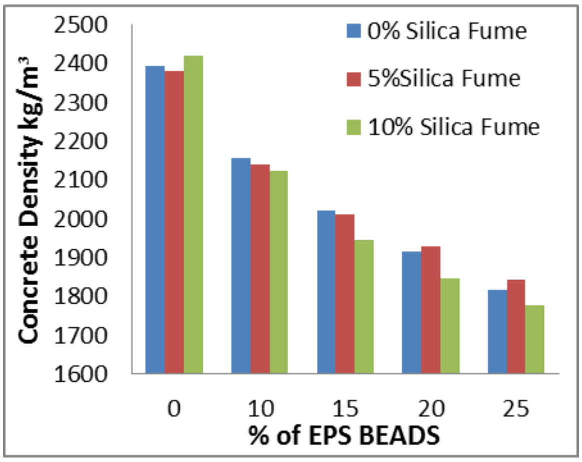

Fig. (10): Variation of concrete density with EPS beads content

CONCLUSIONS

Inclusion of silica fume to the concrete improves its strength for both normal concrete and concrete of EPS beads.

- Inclusion of EPS beads to the concrete greatly reduces the concrete strength.
- The best benefit from silica fume inclusion to the concrete of EPS beads is when the beads percent is 10% by volume of concrete.
- Structural concrete (Strength≥17MPa) with EPS beads can be manufactured when silica fume is used in concrete.
- The inclusion of EPS beads to the concrete reduces its density almost by the same percent as it's added to concrete volume.

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