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Durability of Lightweight Concrete Containing EPS In Salty Exposure Conditions

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ABSTRACT

The durability of reinforced concrete structures is one of the major problems confronting the construction industry, leading to significant costs of repair and remediation. The factors that are generally associated with high rates of corrosion of steel in concrete are the presence of excessive chloride contamination in the material or penetration of chloride in concretes which are exposed to saltwater. A lot of international investigations are being done in this case, however there still remain many problems that have not been solved yet. Nowadays lightweight concrete is being used for both structural and non-structural applications. As a structural material it should have specific characteristics to meet both the strength and durability for the long term of use. Expanded polystyrene is a stable low density foam of non-absorbent, hydrophobic, closed cell nature that can be used as ultra lightweight aggregate suitable for developing concretes for both structural and non-structural applications by varying its volume percentage in concrete.

INTRODUCTION

Plateau of Iran from earthquake occurrence point of view is one of the most active areas in the world. Occasionally, in our country, a mortar and calamitous earthquake makes soul and financial injuries. One of the structural solutions is to use of light-weight materials and make lighten the structure. In reinforced concrete structures, concrete is the main part of dead load. Hence density abate of used concrete has noticeable advantages, like use of smaller sections and more profitability. Nowadays it is proved that attention to strength as just criterion for concrete mixture for different uses and in different areas can not be responsible for problems that concrete structures in long-time encounter with them [Momtazi et al 1386]. Recently durability of concrete in detector areas attracts engineer's attention. One of the applied lightweight polymer aggregates in concrete mixture is expanded polystyrene (EPS). Polystyrene is a thermostatic polymeric material that is in unexpanded form (UEPS), in usual. This material can be expanded to ideal volume by heating in wet condition. EPS has low specific weight, therefore with changes in its amount in concrete mix design, different kinds of lightweight concretes with different specific weight and different mechanical properties are made, for use in structural or nonstructural aims [Daneti et al. 2004]. On the other hand, available problems in reinforced concrete durability due to decrement in matrix strength and corrosion of reinforced steel bars in corrosive condition, is related to some changes that occurs in structure of concrete and environmental conditions. Due to high effects of corrosion of reinforced steel bars on durability of concrete structures and heavy costs of maintenance and up keeping of structures like bridges, marine structures and so on, there are lots of experimental investigations in international levels is being done, related to this matter. Nonetheless, there are lots of vague points that require more investigations [3]. Use of pozzolans as a partial replacement of cement in concrete mix design is one of the remedies that researchers offer to overcome to this problem. Iron lava slag, fly ash, silica fume, rice husk ash and so on are used with cement in production of concrete. Silica is a very tiny and non-crystalline material which by nature has high pozzolan attribute, modification of strength and durability of concrete is possible by these characteristics [4,5,6]. Also, among agricultural wastage, rice husk ash has maximum amounts of silica. According to researches rice husk can improve strength and durability of concrete, if appropriately being burnt and properly being grinded. Chemical compound of rice husk ash that is burnt and is grinded in proper condition has 85 to 95 percent of silica and some other oxides. Therefore, according to ASTM C 618 standard, rice husk ash can be considered as a artificial pozzolan [6,7,8].

EXPERIMENTAL INVESTIGATIONS:

Cement materials

Portland cement type I-425 is used in this project, produced by Tehran Cement factory, with density of 3.15 g/ , belin area of 3354 /g. Applied silica fume is produced by Frusilis Semnan factory, with density of 2.32 g/ and specific area of 35500 /g. Applied rice husk ash in this project has density of 2.09 g/ and specific area of 9768 /g (produced in Science and Technology Park of Rasht).

Table 1. Chemical analysis of cement, Silica fume and Rice husk ash.

Oxide	Portland cement	Silica fume	rice husk ash
SiO2	21/00	91/10	91/62
Al2O3	4/60	1/55	0/49
Fe2O3	3/20	2/00	0/73
CaO	64/50	2/42	2/51
MgO	2/00	0/06	0/88
SO3	2/90	0/45	-
Na2O + K2O	1/00	-	2/39
LOI	1/50	2/10	-

River aggregates and sands used in this project provided by Piping factory of Shomal. Due to improper gradation, with try and false, we reached to optimum mix composition of aggregates. According to this optimization 55% of mixture consists of course aggregates, 45% sand, that the sand consists of 85% of 0-3 mm sized and the rest contained 3-6 mm sized aggregates. Specific mass of course aggregates is 2.5 g/cm3, water absorption of 2.57%, with maximum size of 12.5 mm for aggregates. Specific mass of mixed aggregates is 2.51 g/ and determined water absorption is 3.5%.

EPS

Expanded polystyrene (EPS) that used in this project supplied from Pars Khazar factory, with maximum aggregates' size of 3.5 mm and specific mass of 0.0257 gr/ .

Super plasticizer

In this investigation GLENIUM 110P super plasticizer is used. This super plasticizer is poly carboxylic dissolved in water. According to manufactured recommendations, appropriate amount of this super plasticizer with concrete mixtures with cement materials mass percentage of 0.5 to 1.5. Also to reach the maximum workability it is recommended that this super plasticizer adds to mixture after adding 50 to 70 percent of mixtures' total water as a dissolved material in remained water (at least 60 minutes after adding it kept on mixing).

Mix design

Mix designs that studied in this investigation, are designed for different percentages of EPS (0%, 15%, 25%, 40%, 55% of concrete volume). Due to survey the effects of Silica fume and Rice husk ash on each one of mentioned percentages, three mix design, first with ordinary cement, and two the others with composite cement materials, contains of 90% of ordinary cement and 10% of Silica fume, 80% of ordinary cement and 20% of Rise husk ash as cement additive, respectively. Because of different results in mix designs, with and without use of Silica fume and Rica husk ash, it is endeavored to have similar fluency in mixtures. Slump of fresh concrete in all mix designs recorded in 50-70 mm range. In replacing aggregates with EPS it is considered to have proper gradation. Details of mix designs are available in table 2.

Table 2. Details of mix designs

No	Cement (kg)	S.F		R.H		W (kg)	W/C	0-3 (kg)	3-6 (kg)	6-12 (kg)	EPS		S.P (kg)	Density (kg/m^3)
		kg	%	kg	%						kg	%		
1	400	0	0	0	0	180	0.45	666	117	957	0	0	1	2322
2	400	0	0	0	0	160	0.4	540	95	777	3.85	15	1	1978
3	400	0	0	0	0	173	0.43	431	76	620	6.42	25	1	1708
4	400	0	0	0	0	165	0.41	294	52	423	10.28	40	1	1346
5	400	0	0	0	0	160	0.4	154	27	222	14.14	55	1	978.5
6	360	40	10	0	0	187	0.47	652	115	938	0	0	1	2293
7	360	40	10	0	0	170	0.43	523	82	753	3.85	15	1	1966
8	360	40	10	0	0	175	0.44	422	74	607	6.42	25	1	1687
9	360	40	10	0	0	170	0.43	282	49	406	10.28	40	1	1319
10	360	40	10	0	0	167	0.42	140	24	202	14.13	55	1	949
11	320	0	0	80	20	210	0.53	623	109	895	0	0	1	2240

12	320	0	0	80	20	220	0.55	468	82	673	3.85	15	1	1850
13	320	0	0	80	20	206	0.52	385	68	554	6.42	25	1	1621
14	320	0	0	80	20	202	0.51	244	43	351	10.28	40	1	1252
15	320	0	0	80	20	200	0.5	101	18	146	14.13	55	1	955

Production of EPS-concrete

At first, cement materials, coarse aggregates, sand and EPS mixed together to reach homogenous mixture. Then 50% of water added to mixture. Finally, super plasticizer dissolved in remained water and gradually added to mixture. This mixture at least 60 seconds mixed with mixer [6].

Curing of specimens

Curing of specimens is done according to ASTM C 192M-95. After placing concrete into molds, specimens covered with wet burlaps for 25 hours. After releasing specimens from molds, the specimens kept in basin with 21 ± 2ºc temperature until testing. Produced specimens for durability test, after 28 days, kept in different environmental conditions;

1. Drinking water condition (water area)
2. Salty exposure condition, consists of 5% of sodium chloride (salty area), this condition simulated to evaluation of destructive salty areas on mechanical strength of EPS-concrete specimens.

EXPERIMENTAL PROGRAM

Slump of fresh concrete measured according to ASTM C 124-1973. Compressive Strength Test for cubic specimens 10cm×10cm done in 28, 90, 150 and 210-days ages, by Multifunctional Control Console set, model of 50-C8222 with maximum loading power of 3000 kN, with loading speed equivalent to 0.25 N/ s. Water-absorption on 10cm×10cm cubic specimens in 28-days ages tested according to ASTM standard, for this, specimens kept in 60ºc temperature to reach constant weight. Although ASTM standard recommends 100-110ºc temperature as a proper range but this range of temperature decreases EPS aggregates volume, changes concrete characteristics and increases unreal water absorption, hence less temperature is used for drying specimens. Then specimens kept in water basin for 72 hours, weight increment of each specimen recorded. Electrical Resistance Test for 8×8×24cm specimens done in 180-days ages. Tests on salty-area specimens shows less corrosion-stochastic of reinforced steel bars, due to less electrical resistance of specimens that were kept in salty water in comparison with specimens that were in drinking water (because of more conductivity of salt-water toward water). This value is safe for certainty.

Table 3. Stochastic estimation of reinforced steel bars (interred in concrete) according to electrical resistance test

Electrical resistance range (K ohm cm)	Corrosion stochastic

<5	extreme
5 to 10	high
10 to 20	Less normal
>20	negligible

CONCLUSIONS

Final water absorption

Final water absorption changes in concretes with different amounts of EPS are shown in figure 1. As seen, final water absorption increases with increment in volume of EPS. Also, water absorption of specimens decreases by adding micro silica. According to results, with the use of micro silica, 7.4% decrement in water absorption occurs, in comparison with specimens that made by ordinary cement materials. On the other hand, adding the rice husk ash to mix design increases the water absorption with average increment of 30.5%, in comparison with ordinary specimens.

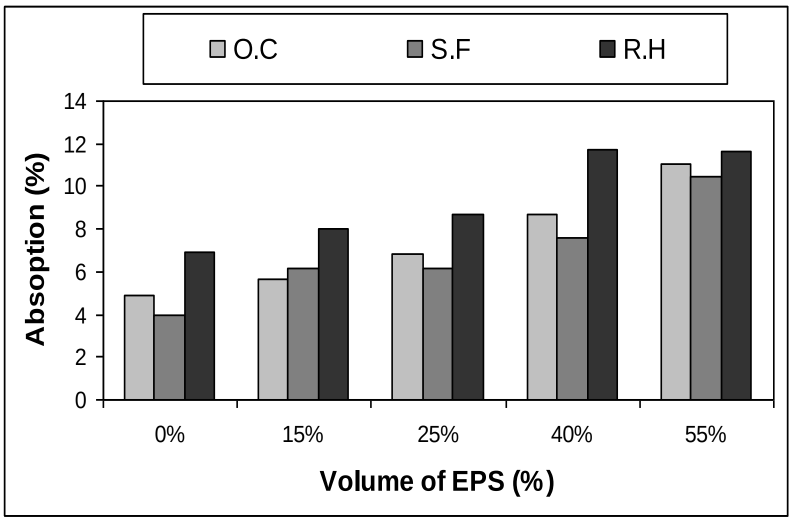

Fig.1. Diagram of changes in final absorption water of concrete specimens contains of different amounts of EPS made by different cement materials

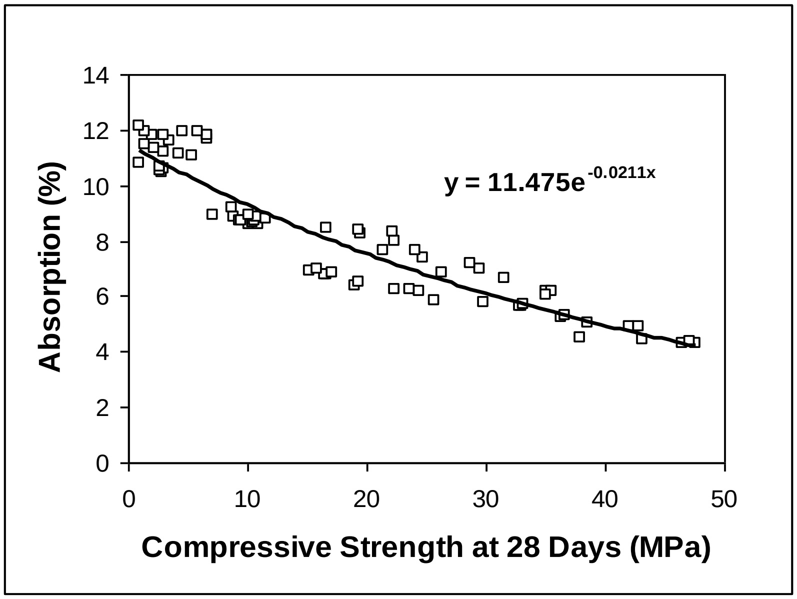

Fig.1. Diagram of water absorption of total specimens surveyed with compressive strength in 28 days age

Increment of water absorption in concrete contains high percentage of EPS, indicates increment in amount of voids that can be result of increment in air bulbs during mixing due to hydrophobia of EPS aggregates. Fig.3 symbolized less juncture between EPS aggregates and cement materials that are made with ordinary cement, engendered voids that may be air bulbs surrounded the EPS grains'. Also this void can be result of depletion in EPS's volume. In concretes with high percentage of EPS, distance between aggregates is less consequently matrix thickness is less. As a result, every reduction in volume of EPS aggregates maybe makes tiny fractions in surrounded matrix. This mater increases the voids and water absorption. Decrement in water absorption due to adding micro silica is related to fineness of ingredients and high pozzolanic attribute of related micro silica, as mentioned previously. High reactional ability of micro silica, rapidly fill voids (with reaction products of pozzolan) and decrease voids, consequently makes less water absorption. On the other hand, results of adding rice husk ash shows increment in amount of absorbed water that may be results of less reactional attribute of rice husk ash. So that, in early days and prime hydration rice husk ash approximately remains inactivate and do not shows reactivation, this mater results more voids and unfilled capillary tubes.

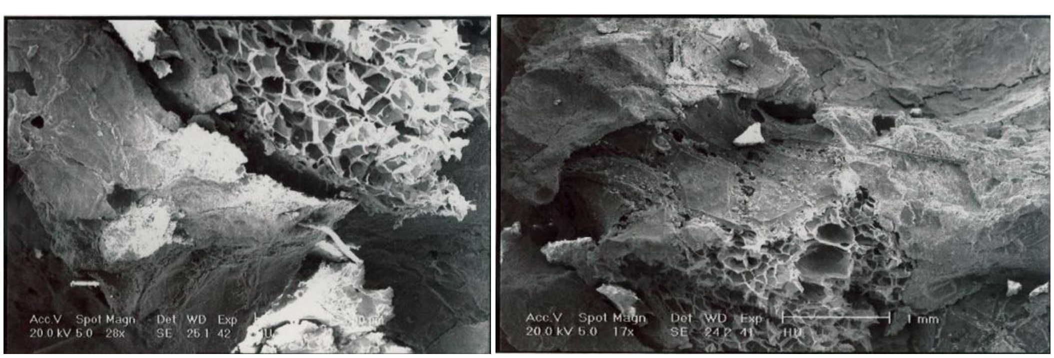

Fig.3. Study on broken surface of concretes contains of ESP, without and with SF, respectively

ELECTRICAL RESISTANCE

According to results, electrical resistance of concrete specimens increases with increment in amount of applied EPS. It means that, corrosion of reinforcing steel bars (interred in concrete) in salty areas decreases with the use of EPS in light weight concrete. On the other hand, results indicates increment of electrically resistance with increment in amount of silica fume and rice husk ash. This increment in silica fume is more. According to results, in structural specimens contains of EPS negligible speed of corrosion in reinforced steel bars is seen, in inactivate areas (similarly to specimens made by micro silica). On the whole, results of investigation on the concrete specimens (kept in salty area) after 210 days show positive effects by using EPS in concrete specimens, for safekeeping the reinforcing steel bars. In spite of voids increment, increment in amount of applied EPS increases electrically resistance of concrete, with, this matter may be results of placing the EPS aggregates (which are electrically insulator) in direction of capillary tubes (size of EPS aggregates is too more than these tube diameters). This placing maybe increase the longitudinal of these tubes or cuts their directions, in both cases electrically resistance of concrete will increase. On the one hand, with previous explanations, by filling voids with reaction products silica fume and rice husk ash have positive effects on concrete, this matter seems to be a good reason for electrically resistance of concrete specimens contains of pozzolan, in comparison with ordinary concrete specimens.

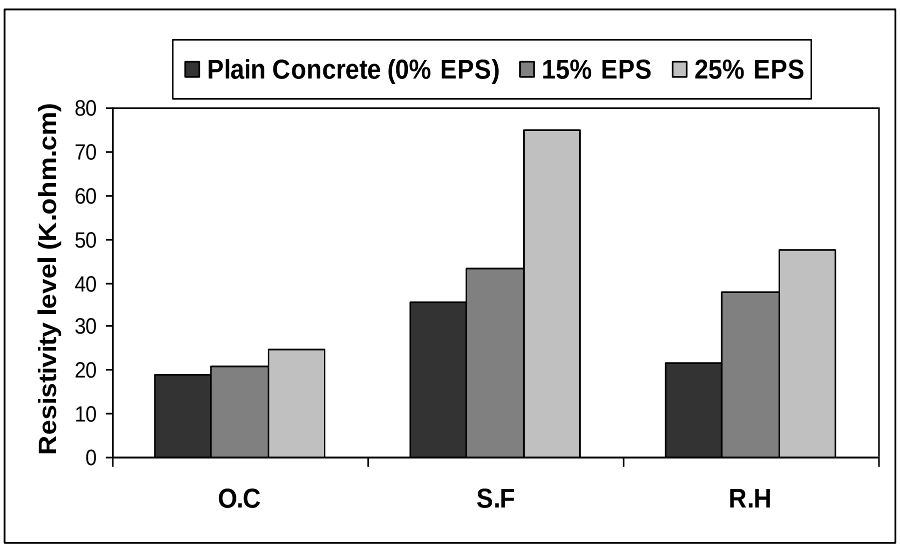

Fig.4. Changes in electrically resistance of concretes contains of different amounts of EPS resulted by using of different cement materials.

SURVEY THE EFFECTS OF SALTY EXPOSURE CONDITION ON MECHANICAL STRENGTH

For survey the effects of salty exposure condition on mechanical strength contains of EPS, compressive strength test done for specimens that were kept in drinking water area and salty area.

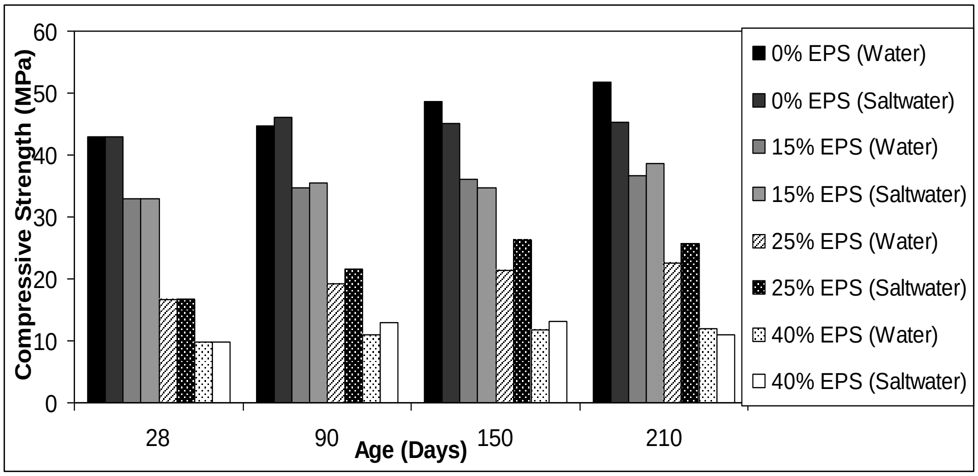

Fig.5. Changes in compressive strengths' of concrete specimens contains of EPS, kept in water and saltwater area

Test results on four mix design indicate increment in compressive strength of specimens contains of EPS in salty destructive area. As regards, it is a long time, theory of: destructive effect of salty area on concrete structures, which results of formation and growth of salt crystals inside voids and finally emerging of internal stresses which make decrement of concrete strength, is made known and some researches emphasized on its accuracy (Kumar Mehta & Monterio, 2006). Nonetheless, some investigations result reversed in all around the world and some researchers are in belief that curing concrete in salty areas makes early strengthening of specimens in prime days [9]. Anyhow, there are different theories about the effects of salty destructive areas on mechanical strengths of concrete specimens, however, previous studies on concrete contains of EPS, indicates high impermeability of it against the chloride ions [10]. Thus, it was prospected that little decrement in compressive strength of EPS-concrete, occurs. While increment in compressive strength of EPS concrete is seen in comparison with specimens that are kept in drinking water.

Effects of using micro silica and rice husk ash on changes of compressive strength in salty destructive area are shown in figure 6.

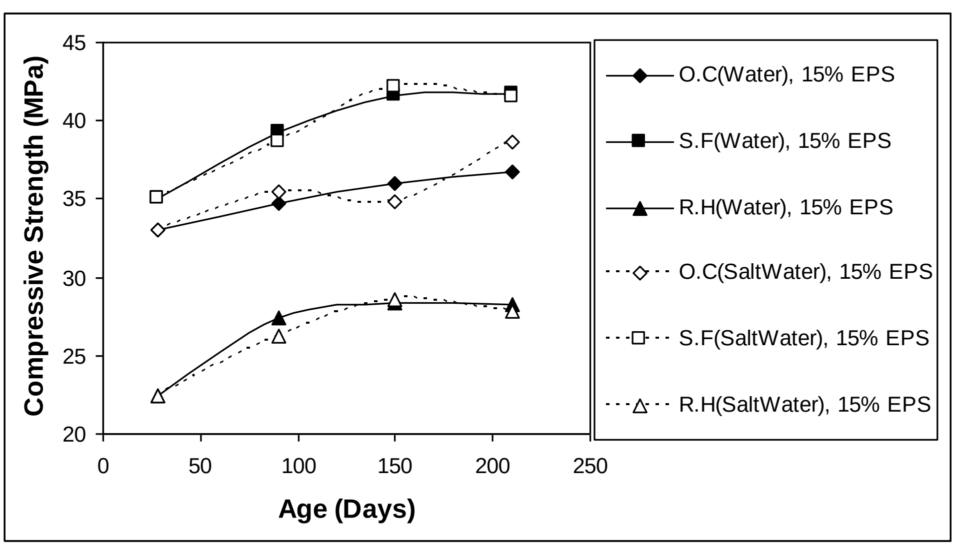

Fig.6. Effects of using pozzolans on changes of compressive strength of concrete specimens contains of EPS in water and salty destructive area

As seen, adding micro silica and rice husk ash to EPS concrete as a partial substitution of cement, changes mechanical strength of EPS-concrete in salty area. In this matter, strength variation due to keeping specimens in salty area is little. This can be result of bounding the chloride ions by use of pozzolans, with increment in amount of A, due to high reactivity of A with radical chloride ions and changing it into effectless salts [11] Indeed, in EPS-concrete with use of pozzolans, due to less effectiveness of salty areas, high increment in compressive strength is not seen.

CONCLUSIONS

The following general conclusions can be drawn from the study provided in the paper:

- Final water absorption test results on concrete specimens in 28 days ages shows increment of this factor with increment of the volume of applied EPS. Also, adding micro silica decrease water absorption of specimens in comparison with concrete specimens made by ordinary cement.
- According to results, increment in amount of applied EPS makes increment in electrically resistance.
- According to electrically resistance test results on specimens made by micro silica and rice husk ash, adding these pozzolans makes increment in electrically resistance of specimens.
- As seen, adding micro silica and rice husk ash to EPS-concrete as a partial substitution of cement, decrease changes in mechanically strength of EPS specimens, in salty area.
- On the whole, results of investigation on the concrete specimens (kept in salty area) after 210 days show positive effects by using EPS in concrete specimens, for safekeeping the reinforcing steel bars. It is clear that for a whole deduction in this case it needs more time.

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