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Pozzolans' Effect on Durability of Light Concretes Made of LECA (Light Expanded Clay Aggregate) and Scoria in Corrosive Environments Containing Sulfuric acid

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Abstract

In the recent years numerous structures were made by using light concrete in their structures. The enhancement of resistance of light weight aggregates from one side, and weight loss of lightweight aggregates as well as the possibility of overproduction lead to an impressive increase in building structures by using light weight aggregates. In this research light weight concretes made of light weight aggregates of LECA and scoria containing the pozzolans of silica fume, Metakaolin, rice husk ash, poly propylene fibers with different percentages have been used and examined. After putting light weight concrete samples in acidic places containing sulfuric acid or PH=3, PH=5, PH=7 in the period of 180 days then the effect of this environment on the pushing resistance and the weight of these samples are analyzed. Results show that the concretes containing pozzolans have the better performance in comparison to the concretes which are produced without pozzolans and also the damage to light weighted aggregates concretes in acidic environments is more than regular concretes.

Keywords: light weight concrete, pozzolan, poly propylene fibers, acidic environments

Introduction

In the recent years important steps in the path of light weight structural concrete were taken. Increasing the resistance of light weight aggregates from one side, and weight loss of light weight aggregates and also the possibility of mass produce of them lead to an impressive increase in building structures by using light weight aggregates. Other advantages which lead to the highly acceptance of using these materials are economic advantages and also removal of the weight restrictions of regular concrete. It is obvious that high density of regular concrete is counted as one of its restrictions. Thus, reducing the density by producing light weight concrete could be counted as a huge step in removing this restriction. In addition, light weighted concretes have special engineering features which make them preferred to be used in the construction sector. One of the important factors in designing and building concrete structures is the service life of them. From the effecting parameters on service life of concrete structures it could be referred to environmental conditions and the quality of the concrete (Andiç-Çakır ,2012; A, 1998). Sulfate damage is one of the most serious damages influencing the service life of concrete structures in a way that it reduces the service life (Attiogbe and Rizkalla,1988). Using the cement substitutions such as fly ash, micro silicon and natural pozzolans could be affecting in the improving the resistance of the concrete against the sulfate attacks. The effect of pozzolans in improving the durability of the concrete on sulfate environments is linked to the improvement in the structure of the holes, reducing the permeability and also reducing the amount of calcium hydroxide by the effect of pozzolanic reactions (Cui, Lo, Memonb, Xing, and Shi, 2012; Hossain, Ahmed, & Lachemi, 2011). The attack to the hydrated Portland cement by sulfuric acid occurs in two forms. The first form of attack is the

attack of acid by hydrogen ion. In the second form, sulfuric ions attack the concrete. In this process, forms of salt are created: calcium sulfate from the sulfate ion, calcium hydroxide and Ettringite from the calcium sulfate and calcium aluminate. These salts are expanding salts. The pressure from this expansion during their creation will cause the craters in the concrete, and to demolish the concrete. Sulfuric acid causes more damage in the light aggregate concrete than the regular concrete (Liua, Denga, & Chub, 2006; Shokravi & Heydari, 2011). Studies show that using poly propylene fibers in concrete mixtures will lead to a slight reduce in density and also torsional strength (Sadrmomtazi, and Fasihi, 2010; Tanyildizi, and Çevik, 2010). Silica fume particles are as small as 0.1 micrometers or even smaller. These particles have a high amount of surface energy. In numerous researches it has been shown that the process of hydration is not only limited to primary steps (Wang, et al, 2006) and it continues through the time. Li and his colleagues in a research show that after the primary reactions much of the silica fume stays remained for a week without any reaction. The particles of silica fume surround each particle of cement, condense the cement paste and fill the pores with high resistance products of the hydration. Metakaolin is a highly active pozzolan with specific surface area. For this reason, it can be used as an ingredient particle of cement as a highly cohesive material which can be replaced as a part of the mass of cement. Metakaolin particles are ten times smaller than each particle of cement. Therefore, using them in the concrete mixtures will lead to condensing up the concrete, also, the concrete will attain a higher level of resistance against the water as a result of using Metakaolin and condensing the concrete. Using Metakaolin increases the strength and durability of the concrete against chemical attacks by sulfates (Zadeh and Jalili, 2011).

Rice husk ash should be grinded before usage. This work should be done before mixing the rice husk ash with the cement. Because if the cement is grinded as well as the ash, it will become softer and this will lead to higher consumption of water, finally, the cement mixture or the concrete is not the qualified and expected product.

Specification of consumed materials

Consumed materials in making concrete samples are listed below:

- Cement: Cement type 1 (425 Abyek)
- Lightweight aggregates: LECA & scoria

• LECA: in making the research project lightweight aggregates of LECA (Light Expanded Clay Aggregates) produced by Saveh LECA manufactory have been used

• Scoria: in making the research projects lightweight aggregates of scoria from the Ghorveh mine in Kurdistan province have been used as lightweight aggregates.

- Poly propylene fibers: in this research the amounts of 0.1%, 0.2% and 0.3% of poly propylene fiber have been used.
- Sufuric acid (H_2SO_4): by using the sulfuric acid with the purity of 98% and the PH of 5 and 3 are used to make the acidic environment.

Procedure

After calculating mix designs of the concrete and making concrete samples, finally, optimized mix designs are obtained as below.

In table 1, G, S and L are the symbols of mix designs made with grit, scoria and LECA. Also the numbers 0 is the symbols of volume percentage of poly propylene fibers in the designs. It is noticeable that S comes as the symbol of silica fume, also, M as the symbol of Metakaolin and R as the symbol of rice husk ash.

Making samples

After calculating the measure of water absorption of the aggregates, the set value of water with the aggregates will be entered into the mixer and mixed for fifteen minutes. Gravel and half of the calculated water in the mix design will be added to the mixer. Meanwhile, the plasticizer and then the pozzolan and the cement will be added into the mixer. Then, the remained water will be poured into the mixer. After a while, the concrete mixture is brought out of the mixer and is put into 10cm*10cm*10cm casts. Vibrating operation is done to export the air bulbs from the mixture. Then, concrete samples will be put in the water pool. Compressive strength test were performed in the ages of 7, 28 and 90 days. After 28 days some of samples have been transported to the acid pools with the PH of 3 and 5 and kept for 180 days for further analysis.

Table 1. Details of materials mix design

Row	Design name	Grit (kg)	LECA (Kg)	Scoria (Kg)	Natural gravel (Kg)	Broken gravel (Kg)	Cement (Kg)	Water (Kg)	Silica fume (%)	Metakaolin (%)	Rice husk ash (%)	Poly propylene fibers(%)
1	G0	795			760	190	450	180	0	0	0	0
2	S0			467.5	30.4	7.6	450	202.5	0	0	0	0
3	L0		407.5		30.4	7.6	450	200	0	0	0	0
4	G1	795			30.4	7.6	450	180	0	0	0	0.1
5	S1			467.5	30.4	7.6	450	202.5	0	0	0	0.1
6	L1		407.5		30.4	7.6	450	200	0	0	0	0.1
7	GS0	795			30.4	7.6	420	180	10	0	0	0
8	SS0			467.5	30.4	7.6	420	202.5	10	0	0	0
9	LS0		407.5		30.4	7.6	420	200	10	0	0	0
10	GS1	795			30.4	7.6	420	180	10	0	0	0.1
11	SS1			467.5	30.4	7.6	420	202.5	10	0	0	0.1
12	LS1		407.5		30.4	7.6	420	200	10	0	0	0.1
13	GM0	795			30.4	7.6	420	180	0	10	0	0
14	SM0			467.5	30.4	7.6	420	202.5	0	10	0	0
15	LM0		407.5		30.4	7.6	420	200	0	10	0	0
16	GM1	795			30.4	7.6	420	180	0	10	0	0.1
17	SM1			467.5	30.4	7.6	420	202.5	0	10	0	0.1
18	LM1		407.5		30.4	7.6	420	200	0	10	0	0.1
19	GR0	795			30.4	7.6	360	180	0	0	20	0
20	SR0			467.5	30.4	7.6	360	202.5	0	0	20	0
21	LR0		407.5		30.4	7.6	360	200	0	0	20	0
22	GR1	795			30.4	7.6	360	180	0	0	20	0.1
23	SR1			467.5	30.4	7.6	360	202.5	0	0	20	0.1
24	LR1		407.5		30.4	7.6	360	200	0	0	20	0.1

Results analysis

First we compare primary designs based on weights. As it seems in table 1, samples produced by scoria attain heavier average weight than samples made of LECA. Due to porous surface of scoria, this lightweight aggregate water absorption rate is higher than LECA therefore, samples made by scoria attain higher and heavier weights.

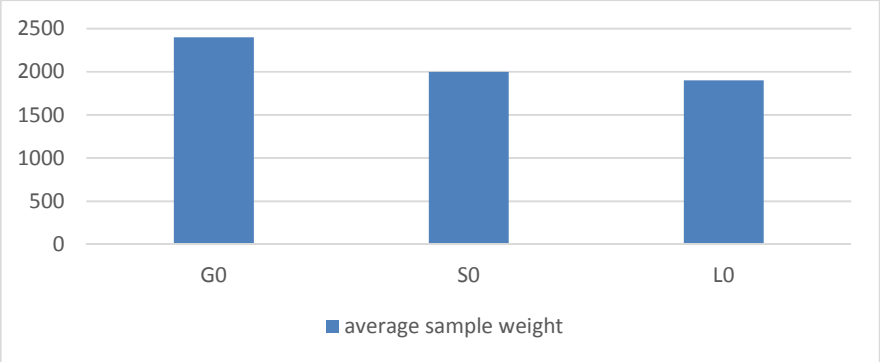

Figure 1. Designs weight based compare (Kg/cm2)

In Figures 2, 3 and 4 compressive strength of samples which are made of grit, scoria and LECA containing the pozzolans of silica fume, Metakaolin and rice husk ash in the presence of poly propylene fibers during the period of 28 days are shown.

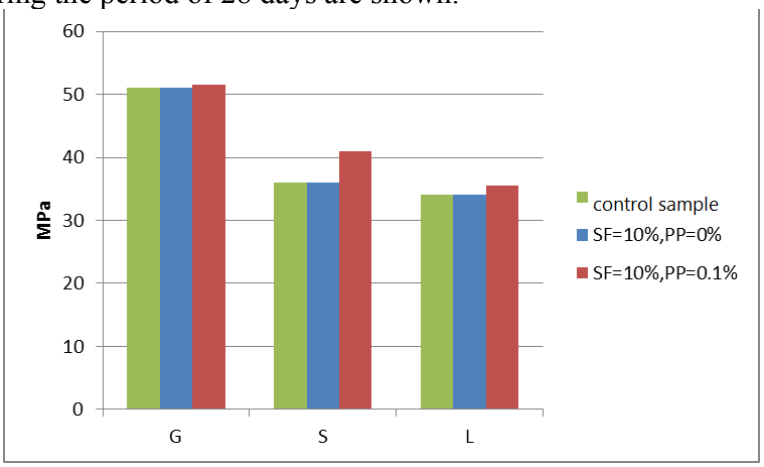

Figure 2. 28 days compressive strength test of control samples containing silica fume and silica fume with poly propylene fibers (MPa)

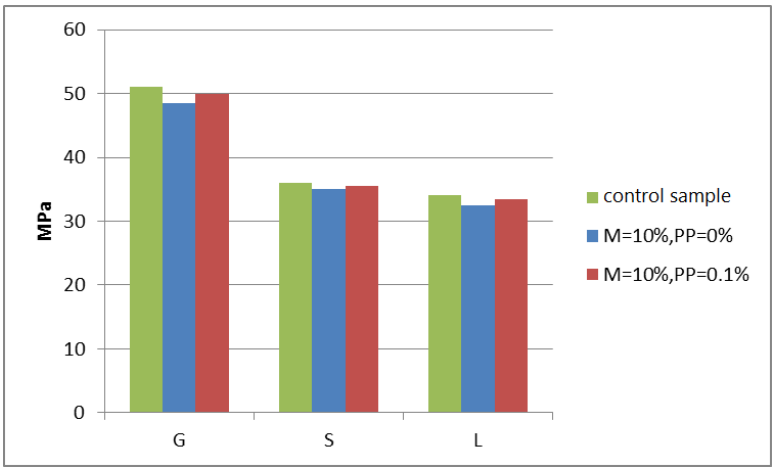

Figure 3. 28 days compressive strength test of control sample containing Metakaolin and Metakaolin with poly propylene fibers (MPa)

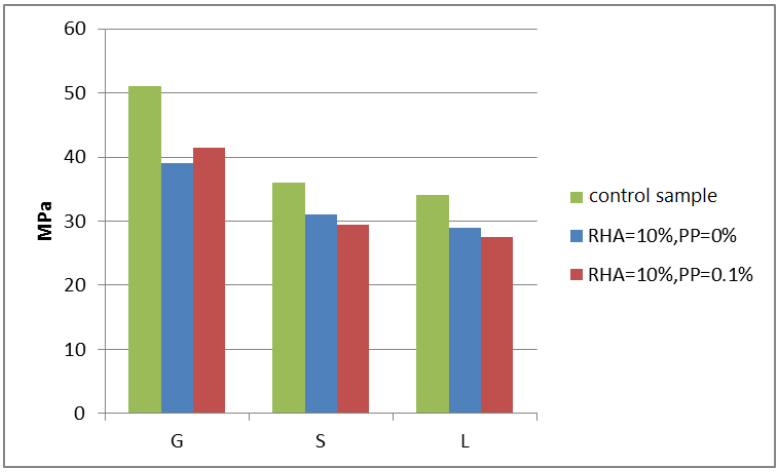

Figure 4. 28 days compressive strength test of control samples containing rice husk ash and rice husk ash with poly propylene fibers (MPa)

After passing 28 days some of the samples were placed separately in two pools of sulfuric acid with the PHs of 5 and 3 for the period of 180 days. The acidic feature of each pond was checked by PH meter on weekly basis in order to keep the PH level of each unchanged.

After 180 days the samples were exported from the ponds. After drying, their weight and compressive strength changes were measured.

In the forms 1, 2 and 3 pictures from the exported samples after 180 days are shown. As it is clear in the pictures, the samples containing light weight aggregates suffered more external damage in comparison with the regular concrete made of grit. Also, it is clear that rice husk ash had more influence on external damage in comparison with two other pozzolans.

Figure 5. Concrete samples made with grit containing silica fume (right), rice husk ash (middle) and Metakaolin (left) after passing 180 days in acidic environment with the PH of 3.

Figure 6. Concrete samples made with scoria containing silica fume (right), rice husk ash (middle) and Metakaolin (left) after passing 180 days in acidic environment with the PH of 3.

Figure 7. Concrete samples made with LECA containing silica fume (right), rice husk ash (middle) and Metakaolin (left) after passing 180 days in acidic environment with the PH of 3.

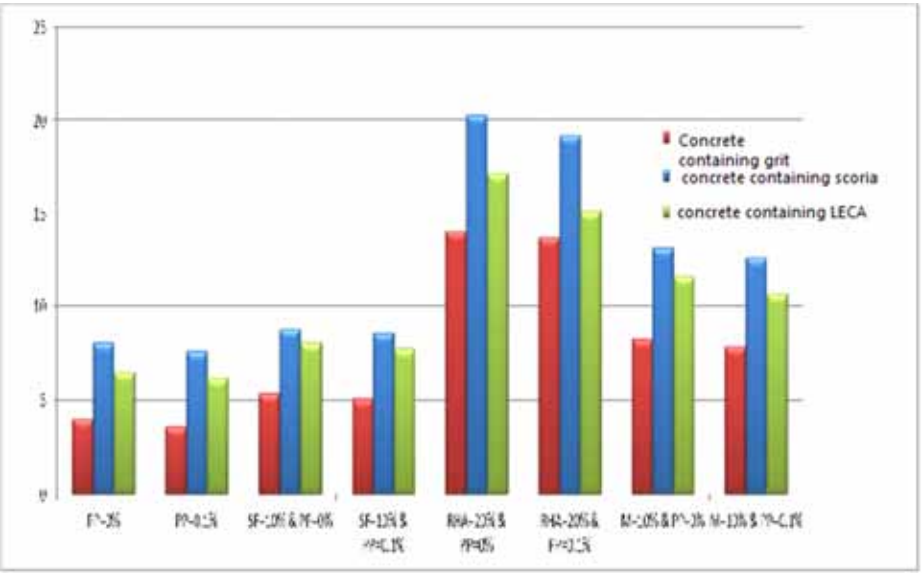

Figure 8. Comparing the weight loss of the samples made with grit, scoria and LECA containing pozzolans and poly propylene fibers after passing 180 days in the vicinity of sulfuric acid with the PH of 3

As it is clear in Figure 8, samples made with lightweight aggregates of LECA and scorias have a higher level of weight loss in comparison with samples made with grit.

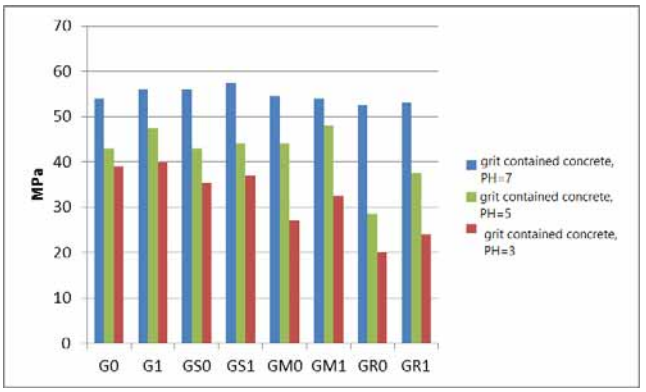

Figure 9. Comparing the compressive strength (MPa) of samples made with grit containing pozzolan and poly propylene fibers in acidic environments with PHs of 7, 5 and 3

This amount in the presence of scoria lightweight aggregates is more than LECA. And also according to the effect of pozzolans on the weight, rice husk ash leads to the highest rate of weight loss in the samples.

On the other side, silica fume pozzolan will lead to the lowest weight loss among the samples. By measuring the weights of the samples which were put in the acidic environment with PH=7 for 180 days only minor changes are observed.

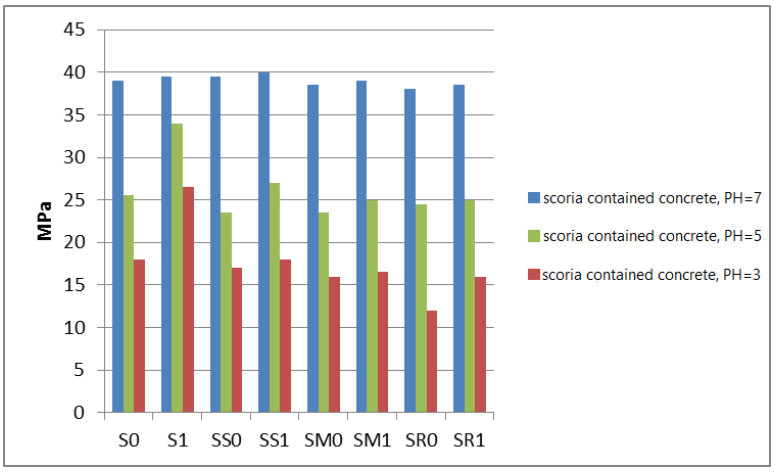

Figure 10. Comparing the compressive strength (MPa) of samples made with scoria containing pozzolan and poly propylene fibers in acidic environments with PHs of 7, 5 and 3.

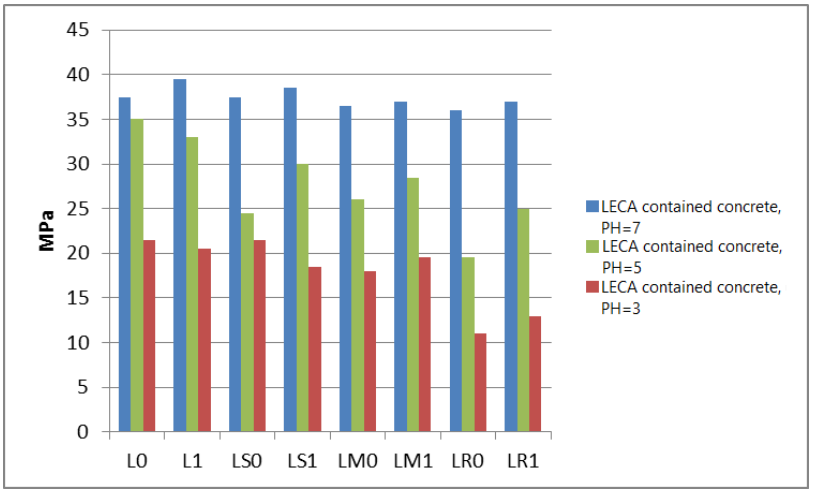

Figure 11. Comparing the compressive strength (MPa) of samples made with LECA containing pozzolan and poly propylene fibers in acidic environments with PHs of 7, 5 and 3

Figure 9, 10 and 11 show the comparison between the results of compressive strength of the samples containing grit, scoria and LECA after 180 days in the environments with PHs of 7, 5 and 3. As it is clear in the Figures, by reducing the PH more intense reduction in the strength is observable. This amount of reduction is variable according to the type of pozzolan. But, it can be seen that in the PH of type 5 of pozzolan has a minor effect on the strength. But, in the PH of 3, rice husk ash has the highest effect on reducing the strength among the samples.

By comparing the compressive strength test results from different samples it can be concluded that concretes containing scoria and LECA lightweight aggregates has higher amount of reduction in acidic environments in comparison with regular concretes. These results show that samples made by scoria has higher amount of reduction in compressive strength test in comparison to LECA samples. Regarding to the pozzolans, it can be concluded that silica fume has the highest effect on increasing compressive strength of the samples. Also, the presence of poly propylene fibers in all the samples leads to a minor increase in the measure of compressive strength which could be related to the effect of fibers in keeping the general integration of the samples under loading pressure.

Results

Concrete samples made with scoria were heavier than samples made by LECA. 28days compressive strength of samples made by scoria was higher than the samples made by LECA and 28 days compressive strength of samples in which 10% of the cement replaced by silica fume was higher than other pozzolans in this test. Samples containing lightweight aggregates suffered higher external damage in comparison with regular concrete. Also, it can be seen that the rice husk ash had higher effect on the external damage of the samples in comparison with other two pozzolans. Samples made with lightweight aggregates had higher weight loss in comparison with samples made by grit.

Regarding to the effect of pozzolans, it can be seen that rice husk ash pozzolan caused the highest weight loss and also, silica fume led to the lowest weight loss among all samples and regarding to the effect of pozzolans on compressive strength of the samples, the minor change occurred in samples made by silica fume and major was linked to the sample made by rice husk ash. Lightweight concrete samples containing poly propylene fibers with the amount of 0.1% had higher compressive strength. Also, these fibers prevented the samples from crushing completely.

Resources

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