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A Computerized Study on Mechanical Properties of Concrete Containing Sirjan Pozzolan in Corrosive Environment of Oman Sea

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Abstract: Nowadays, most structures are made of concrete. However, due to violation of construction rules, corrosion would impose high costs on structures even shortly after being completed. The present article seeks to study the reaction of concrete containing Sirjan pozzolan and concrete samples containing Sirjan cement in environment of Oman Sea. Accordingly, concrete samples containing Hormozgan Cement (type II) and 0, 10, 15, 17 and 20% of Sirjan pozzolan replaced for cement with water to cement ratios of 0.40 and 0.35 were studied being exposed submerged and tidal environments of Oman Sea for 3 months. The 7, 28 and 90 days tests of compressive strength were performed on these samples. In the present study, the obtained results of conducted tests on all samples are compared with each other and samples' reactions are investigated regarding their compressive strength loss

Key words: Sirjan pozzolan, Hormozgan cement, compressive strength, optimal percentage, Oman Sea

INTRODUCTION

Concrete has been widely utilized in most structures as a stable and durable material. This material in most cases, acquired the required life span and sufficient strength against the applied loads. In some cases in corrosive environments such as on coasts and under seas, some deterioration is observed in concrete structures before the end of their useful life. In recent few years, durability of concrete has been the center of attention, especially in corrosive environments. However in addition with carbon dioxide small amount of sulfur oxides and nitrogen oxides would also be produced on the process of manufacturing Portland cement which is utilized to make concrete (Lew, 1981). Utilizing natural pozzolan would lead into saving noticeable amount of heat and would prevent large amount of carbon dioxide from being dispersed in environment which is one the major ecological problems (Cavdar and Yetgin, 2007). Figure 1 illustrates failure of a concrete structure, located on Chabahar coast as a result of being exposed to the corrosive environment of Oman Sea (Pardo and Martinez, 2003).

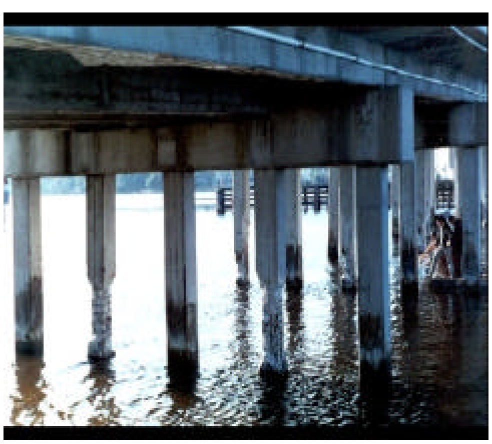

Fig. 1: Structural damage (chabahar harbor)

MATERIALS AND METHODS

Consumed materials: The utilized materials in this study include sand and gravel aggregate, provided from mines located near Chabahar. In order to prevent aggregation change on the process of carrying out the research, all the required materials were primarily prepared and stored. Some tests were also conducted to determine grading graph in the prepared material. Figure 2 and 3, respectively illustrate grading graph of fine and coarse aggregate, compared with the accepted range indicated by ASTM C33. In this project, the utilized cement is Hormozgan cement (type II) and the used water is the potable water of wells located near Chabahar.

According to ASTM C128, absorption of water, sand and gravel are respectively 1.1 and 3.1 and the unit weight of gravel and sand are respectively 2.27 and 2.70. The

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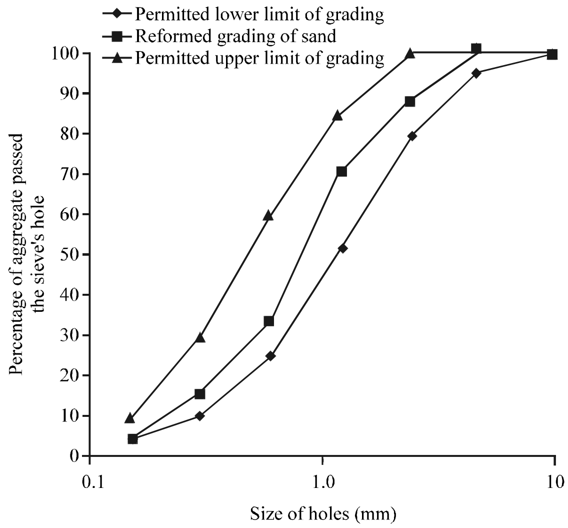

Fig. 2: Aggregation of utilized sand after reformations

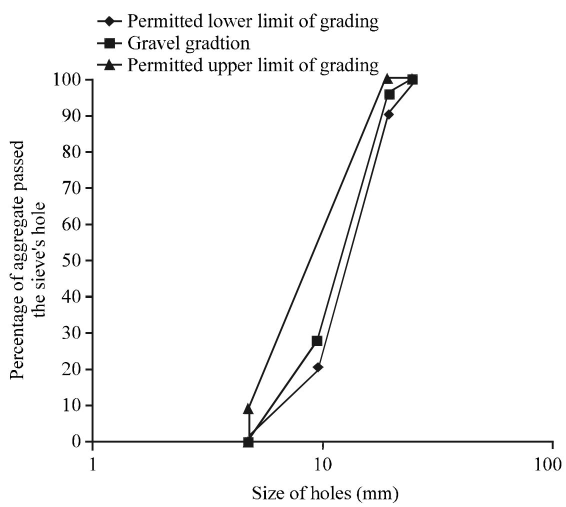

Fig. 3: Aggregation of utilized gravel

fineness modulus of sand equals to 2.96 (according to ACI in the range of 2.3-3.1). The required pozzolan is provided from the mines of Sirjan. This pozzolan is milled and sieved after being transported to cement factory of Kerman. Table 1 indicates the chemical analysis of Sirjan pozzolan and Hormozgan cement (type II).

Construction and maintenance of samples: In this work, 10 mixing designs in the form of 300 cubic samples with the size of 15×15×15 were studied. All of the designs were made of water to cementitious materials ratio of 0.40. The desired slump (about 5 cm) was achieved in all mixes by adding 0.3-0.8 L of Seko- Dense-pc12 per 100 kg of cement.

All mix designs in this study are presented in Table 2. OPC (Ordinary Portland Cement): to prepare these types of samples, only Portland cement is used as adhesive. P (Pozzolan): to produce these types of samples, Portland cement and various percentages of pozzolan are used as adhesives. 35, 40 and 50: the water-cement ratio is 35, 40 and 50%, respectively which are the first numbers after the cementitious material. Percentage of pozzolan replacement: In this study, the percentage of replacement is five. 0, 10, 15, 17 and 20: these numbers indicate the percentage of pozzolan replacement and are the second numbers after the number of water-cement ratio.

After being constructed and molded, all the prepared samples were maintained in shadow for 24 h and their surface was kept wet by the help of hessain. They were extracted from the molds and were kept in the environment (Fig. 4) before being broken. After preparing the samples, equal amounts of each would be placed in three different environments. These environments include:

Table 1: Chemical analysis of Sirjan pozzolan and Hormozgan cement (type II)

Types	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	Loi	C_3S	C_3A
Cement	21.25	4.950	3.75	2.5	1.30	0.40	0.60	2.00	-	55	6.5
Pozzolan	60.48	17.83	3.83	5.8	0.93	1.27	1.23	0.12	4.38	-	-

Table 2: Concrete mix design in this study

Name of the design	Cement	Pozzolan	Gravel	Sand	Water	Super plasticizer CC	Water-cement ratio
OPC400	270.0	-	960	984.0	131.0	810	0.40
P4010	243.0	27.0	960	984.0	131.0	810	0.40
P4015	229.5	40.5	960	984.0	131.0	810	0.40
P4017	224.1	45.9	960	984.0	131.0	810	0.40
P4020	216.0	54.0	960	984.0	131.0	810	0.40
OPC350	270.0	-	960	997.5	117.5	900	0.35
P3510	243.0	27.0	960	997.5	117.5	900	0.35
P3515	229.5	40.5	960	997.5	117.5	900	0.35
P3517	224.1	45.9	960	997.5	117.5	900	0.35
P3520	216.0	54.0	960	997.5	117.5	900	0.35

Table 3: Results of chemical analysis of Oman Sea, Mg/Lit

Types	CL	Ca	SO_2	Na	Mg	K	TDS	PH	Hardness
Chabahar gulf	610.0	480.0	135.9	600	118.6	10.26	35328	7.5	6960
Oman Sea	617.5	20.8	159.8	630	118.8	10.26	35072	8.2	6960

Fig. 4: Curingingsamples in a tidal environment

Regular water: This type of environment includes a pond containing potable water of wells which are located around Chabahar (Teis Koupan village). Samples situated in this pond are considered as control samples.

The dry and the wet (tidal) environment: This type of environment includes two ponds containing Oman Sea water. The water is pumped from one pond to another. This results in creation of dry and wet cycles. Each cycle includes 6 h of dryness and 6 h of wetness which represent two times of tide flowing in each 24 h.

Immersed environment: It is a pond with Oman Sea water while its water can be replaced at intervals of 1 month. It represents the immersed area in Oman Sea water.

Chemical analysis of sea water in Chabahar coastsin two specific areas, i.e., Chabahar Gulf and Oman Sea are presented in Table 3.

RESULTS AND DISCUSSION

Tables 4 and 5 indicate the results of 7, 28 and 90 days compressive strength of concrete samples of this research. Table 6 shows the coefficient of compressive strength growth within 7-28 and 28-90 days in samples containing concrete with different percentages of pozzolan substitute for Portland cement in immersed, tidal, and control environment with water-cementitious materials ratio of 0.50.

Based on Table 6, it can be claimed that in all three prepared designs in the control, immersed and tidal environment, compressive strength increases by augmentation of the curing age. Concrete containing pozzolan in a regular water environment obtained its strength at the age of 28 days and this strength growth also occurs in destructive immersed and tidal environments. Based on the achieved results from Table 6 in the control environment increasing the amount of pozzolan substituted for cement makes coefficient of strength augment more within the ages of 7-28 days and also 28-90 days. Such a behavior can be considered as an advantage for pozzolan, since it leads into successful control of hydration heat. It is worth mentioning that the consequences of this heat such as thermal cracks are among major problems of massive concrete structures like dams. Therefore, the rate of compressive strength growth in concrete containing pozzolan at old ages is more than concrete containing Portland cement. The fact is also consistent with pozzolanic reactions, since at early ages, these reactions are not sufficiently developed. As can be seen in Table 6 in the sample containing 10% of pozzolan within 7-28 and 28-90 days, the compressive strength in the control environment would be respectively about 25.1 and 9.4% in a immersed environment it would respectively be about 15.9 and 7.5% and in a tidal environment about 20.5 and 5.7%. Increasing the amount of consumed pozzolan ends in compressive strength growth within 7-28 and 28-90 days in a way that in samples containing 20% of pozzolan within 7-28 and 28-90 days, growth of compressive strength in regular water (control), would respectively be 35.5 and 19.5 % in a immersed environment about 26.1 and 18.3% and in a tidal environment about 25 and 18.1%. In general, considering the rate of compressive strength growth within the ages of 7-28 and 28-90 days, it would be observed that the highest growth rate belongs respectively to the regula water environment, the immersed environment and the tidal environment.

As a matter of fact, when concrete is exposed to destructive immersed and tidal environments the rate of compressive strength growth decreases in it, due to the presence of sulfate and chloride ions. This happens specifically in tidal environments, where concrete would be continuously gets dry and wet and is effloresence beside of being destroyed by mentioned ions. effloresence (Fig. 5) is the result of salts' leakage out of concrete which leads into concrete's porosity and consequently reduces concrete's strength and rate of strength growth (Ramezanianpuor, 1998). The overall evaluation of the results indicates that the growth rate of

Table 4: Compressive strength test results for W/B = 0.40 (Mpa)

Design numbers	Environment	Names	7 days compressive strength	28 days compressive strength	90 daya compressive strength
1	Regular water	OPC400	18.8	25.1	27.7
2		P4010	16.3	21.8	25.0
3		P4015	13.8	19.7	24.1
4		P4017	12.6	18.4	23.2
5		P4020	10.9	16.9	21.0
6	Immersed	OPC400	19.6	23.3	25.2
7		P4010	16.5	21.2	23.1
8		P4015	15.3	19.3	22.4
9		P4017	13.9	17.9	22.0
10	Tidal	P4020	11.9	16.1	19.7
11		OPC400	18.2	22.9	24.3
12		P4010	17.2	19.6	22.2
13		P4015	14.7	18.7	21.9
14		P4017	13.1	18.4	21.3
15		P4020	11.4	15.2	18.9

Table 5: Compressive strength test results for W/B = 0.35 (Mpa)

Design numbers	Environment	Names	7 days compressive strength	28 days compressive strength	90 days compressive strength
1	Regular Water	OPC350	19.7	25.7	28.9
2		P3510	16.6	22.7	26.1
3		P3515	14.2	20.8	25.2
4		P3517	12.8	19.2	23.7
5		P3520	11.2	17.2	21.3
6	Immersed	OPC350	20.1	24.9	27.1
7		P3510	18.6	22.2	24.6
8		P3515	15.8	20.5	24.2
9		P3517	14.3	19.3	22.6
10		P3520	12.8	17.0	20.2
11	Tidal	OPC350	20.1	24.5	26.0
12		P3510	17.2	21.7	23.7
13		P3515	15.1	20.2	23.4
14		P3517	13.8	18.6	21.8
15		P3520	12.4	15.7	19.5

Table 6: Coefficient of compressive strength growth at the age of 7-28 and 28-90 days in samples containing Sirjan pozzolan with water to cementitious materials ratio of 0.40

	Coefficient of compressive strength growth in control environment (%)		Coefficient of compressive strength growth in immersed environment (%)		Coefficient of compressive strength growth in tidal environment (%)	
Names	7-28 days	28-90 days	7-28 days	28-90 days	7-28 days	28-90 days
OPC400	25.1	9.4	15.9	7.5	20.5	5.7
P4010	25.2	12.8	22.2	8.2	12.2	11.7
P4015	29.9	18.3	20.7	13.8	21.3	14.5
P4017	31.5	20.7	22.3	18.6	28.8	13.6
P4020	35.5	19.5	26.1	18.3	25.0	19.6

compressive strength in samples containing Sirjan pozzolan for water-cementitious materials ratio of 0.35 is similar with that of 0.40 in regular water, immersed and tidal environments (Ghanbari, 2015).

It has been attempted to determine the proper amount of pozzolan Sirjan replacement which results in the lowest 90 days compressive strength reduction in samples exposed to destructive sea water, compared to the control environment. Figure 6 and 7 present 90 days compressive strengths obtained by replacing different amounts of Sirjan pozzolan. Figure 6 and 7 put forward compressive strength values at the age of 90 days achieved by replacing 0, 10, 15, 17 and 20% of Sirjan pozzolan, respectively for water-cementitious materials ratios of 0.40 and 0.35.

Tables 7 and 8 show the coefficient of 90 days compressive strength reduction in concrete containing Sirjan pozzolan in destructive immersed and tidal environments with water to cementitious materials ratios of 0.40 and 0.35, compared with control samples. Considering Fig. 5 in samples containing Sirjan pozzolan with water-cementitious materials ratio of 0.40 and comparing the process of gain in strength in various designs, as it was mentioned previously increasing the amount of Sirjan pozzolan leads in reduction of compressive strength reduction as compared to control sample. In a way that in immersed environment, samples containing 0, 10, 15, 17 and 20% of Sirjan pozzolan had respectively about 9 and 7.6, 7, 5.2 and 6.2% of strength reduction at the age of 90 days, compared with the control

Table 7: Percentage of 90 days compressive strength reduction in concrete containing Sirjan pozzolan in immersed and tidal environments with water to cementitious materials ratio of 0.40, compared to control sample

Names	Compressive strength in control environment (Mpa)	Compressive strength in immersed environment (Mpa)	Compressive strength in tidal environment (Mpa)	Percentage of strength reduction in immersed environment	Percentage of strength reduction in tidal environment
OPC400	27.7	25.2	24.3	9.0	12.3
P4010	25.0	23.1	22.2	7.6	11.2
P4015	24.1	22.4	21.9	7.0	9.1
P4017	23.2	22.0	21.3	5.2	8.2
P4020	21.0	19.7	18.6	6.2	10.0

Table 8: Percentage of 90 days compressive strength reduction in concrete containing Sirjan pozzolan in regular water, immersed and tidal environments with water to cement ratio of 0.35, compared with control sample

Names	Compressive strength in control environment (Mpa)	Compressive strength in immersed environment (Mpa)	Compressive strength in tidal environment (Mpa)	Percentage of strength reduction in immersed environment	Percentage of strength reduction in tidal environment
Opc350	28.9	27.1	26.0	6.2	10.0
P3510	26.1	24.6	23.7	5.7	9.2
P3515	25.2	24.2	23.4	4.0	7.1
P3517	23.7	22.6	21.8	4.6	8.0
P3520	21.3	20.2	19.5	5.2	8.5

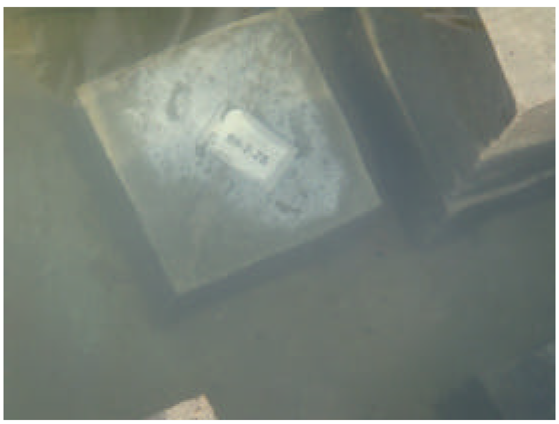

Fig. 5: Efflorescence of samples located in tidal environments

sample. In the tidal environment, samples containing 0, 10, 15, 17 and 20% of Sirjan pozzolan had respectively about 12.3, 11.2, 9.1, 8.2 and 10 percent of loss in comparison with the control sample. In a general review of the results derived from Table 7 it can be concluded that concrete made of water-cement ratio of 0.40 in both immersed and tidal environments, had the greatest reduction in compressive strength of samples without pozzolan (respectively about 9 and 12.3%) and the lowest strength reduction belonged to the sample containing 17% of pozzolan (5.2 and 8.2% respectively in immersed and tidal environments).

As Fig. 6 expresses in sample made with water to cement ratio of 0.35, the same as 0.40 and 0.50 increasing amounts of pozzolan decreases the rate of compressive strength reduction in samples exposed to immersed and tidal environments of Oman Sea. According to Table 8,

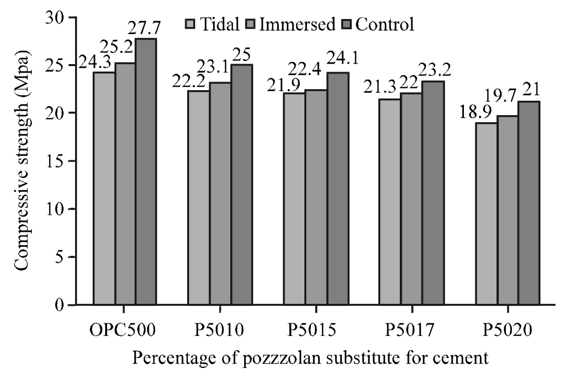

Fig. 6: 90 days compressive strength of various mixtures with water-cement ratio of 0.40

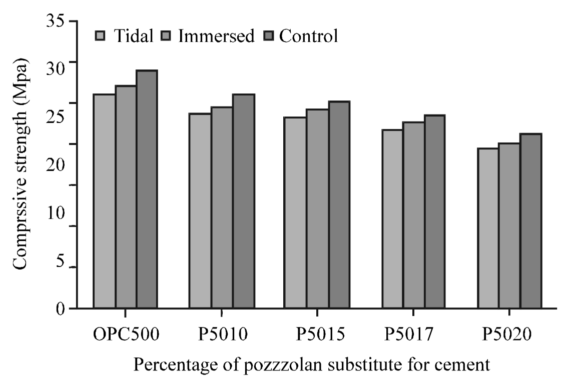

Fig. 7: 90 days compressive strength of various mixtures water-cement ratio of 0.35

samples containing 0, 10, 15, 17 and 20% of Sirjan pozzolan had respectively about 6.2, 5.7, 4, 4.6 and 5.2% of strength reduction in immersed environment, at the age of 90 days. However in a tidal environment, samples containing 0, 10, 15, 17 and 20% of Sirjan pozzolan had respectively about 10, 9.2, 7.1, 8 and 8.5% of strength reduction in comparison with the control sample.

Based on Table 8, it can be claimed that concrete made of water-cement ratio of 0.35 had the maximum level of compressive strength reduction in sample not containing pozzolan in immersed and tidal environment (respectively about 6.2 and 10%) while the minimum level of strength reduction belonged to the sample containing 15% of pozzolan in immersed and tidal environments (respectively about 4 and 7.1%).

CONCLUSION

According to the presence of chloride ion in sea water, the compressive strength of produced concrete of Sirjan pozzolan in submerged and tidal environments was more than the control sample at their early ages (7). Having the same effectiveness at the age of 90 days, compared with early ages, pozzolan Sirjan reduced the compressive strength of concrete at the age of 90 days. Water-cement ratio influences the compressive strength of concrete containing Sirjan pozzolan and decreasing this ratio would lead into increase of compressive strength. Submerged and tidal environments of Oman Sea decrease 28 and 90 days compressive strength of samples containing Sirjan pozzolan, compared with the control sample. At intervals of 7-28 and 28-90 days in both water to cement ratios of 0.40 and 0.35 increasing the unit weight of Sirjan pozzolan would end in growth of the rate of concrete's compressive strength in submerged, tidal, and control environments.

In submerged and tidal environments of Oman Sea, the maximum amount of compressive strength loss belongs to water to cementitious materials ratio of 0.40 and the minimum amount of loss goes respectively to the sample containing 17% of pozzolan and the sample without pozzolan. In water to cementitious materials ratio of 0.35, the least and the most amount of compressive strength loss respectively belongs to the sample containing 15% of pozzolan and the sample not containing it.

REFERENCES

Cavdar, A. and S. Yetgin, 2007. Availability of tuffs from northeast of Turkey as natural pozzolan on cement, some chemical and mechanical relationships. Construct. Build. Materials, 21: 2066-2071.

Ghanbari, M., 2015. Human resources accounting and its role in the establishment of Islamic accounting. J. Sci. Res. Dev., 2: 85-101.

Lew, D.W., 1981. History of slag cements, paper presented at university of Alabama slag cement seminar. Am. Slag Assoc., 186: 72-124.

Pardo, D.V.M. and F.C. Martinez, 2003. Resistance to change: A literatur review and empirical study. Manage. Decis., 41: 148-155.

Ramezanianpuor, A., 1998. Concrete durability and cements, building and housing research center. Sci. Res. J., 2: 48-96.