Advances in Concrete Construction, *Vol. 5, No. 5 (2017) 423-436*
DOI: https://doi.org/10.12989/acc.2017.5.5.423

Permeability and mechanical properties of binary and ternary cementitious mixtures

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(Received Ocotber 19, 2016, Revised June 11, 2017, Accepted August 15, 2017)

Abstract. Today, pozzolans are widely used in construction for various reasons such as technical and economic efficiency. In this research, in order to evaluate some of important properties of concrete, silica fume and fly ash have been used as a replacement for cement in different mass percentages. Concrete mixtures were made from a water-cement ratio of (0.45) and cured under similar conditions. The main focus of this study was to evaluate the permeability and mechanical properties of concrete made from binary and ternary cementitious mixtures of fly ash and silica fume. In this study permeability of concrete was studied by evaluating the sorptivity, water absorption, water penetration depth, electrical resistivity and rapid chloride permeability (RCP) tests. Mechanical properties of concrete were evaluated with compressive strength, splitting tensile strength and modulus of elasticity. Scanning electronic microscopy (SEM) was used to characterize the effects of silica fume and fly ash on the pore structure and morphology of concrete with cement based matrix. The results indicated that the incorporation of silica fume and fly ash increased the mechanical strength and improved the permeability of concrete.

Keywords: silica fume; fly ash; permeability; mechanical strength; SEM

1. Introduction

Concrete is a construction composite consisting of aggregate and cementitious binder which is widely used in variety of constructions. Strength and durability are the most important criteria in concrete. Nowadays using additives (mainly pozzolans) as replacement for a part of cement in production of concrete, to enhance its technical and economic efficiency, has become inevitable. Since permeability and shrinkage are key features of concrete in evaluating its long-term behavior and have a close correlation with its durability, use of mineral additives and pozzolanic industrial wastes in order to improve the long-term performance and increase the strength of concrete, has been a subject for experts in this field of research which has led to the wide application of some of

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http://www.techno-press.org/?journal=acc&subpage=7 ISSN: 2287-5301 (Print), 2287-531X (Online)

these materials in industry (Ponikiewski and Gołaszewski 2014, Jalal *et al.* 2015, Raharjo and Subakti 2013, Faleschini *et al.* 2015). Studies have shown that partial replacement of cement with pozzolanic additive materials reduces the hydration heat and cracking caused by it and reduces shrinkage as well. Sustainable construction with the aim of saving energy, resources and costs as well as reducing environmental impacts, incorporates some of the advantages of using these additives. The most commonly used pozzolanic materials are fly ash (FA), ground granulated blast-furnace slag (GGBFS) and silica fume (SF) which are all industrial wastes. Natural mineral additive materials such as volcanic slag and trass are used in the concrete industry (Shaikh *et al.* 2015, Koteng and Chen 2015). Silica fume is an industrial additive material actually the dust of emissions from the chimneys of factories producing silicon or alloys of silicon such as Ferrosilicon in electric arc furnaces. Reaction of silica fume particles with bulking crystals and porous lime, and their conversion to calcium silicate hydrate (C-S-H) gel, brings about an improved bond between the cement paste and aggregates (Chore and Joshi 2015, Patra and Mukharjee 2016).

Bhanja and Sengupta (2013) studied the effect of adding silica fume on tensile strength of concrete. For this purpose, different ratios of water-cement (0.26 to 0.42) and, also replacement of silica fume cement at different amounts (0 to 30%) were considered, results showed that the presence of silica fume in the mixtures leads to a significant increase in both tensile and compression strength. They also found that the optimum replacement percentage of silica fume to have tensile strength is a function of water to cementitious materials rate. The optimum amount of silica fume replacement for tensile strength of 28 days, was between 5 to 10%, and for bending strength the replacement percentage was between 15 to 20%.

Fly ash is a material with very fine particles, a by-product of combustion of coal in thermal power plants. In the research of Elrahman and Hillemeier (2014) the results showed that in dense systems, replacing 25% fine fly ash and 10% silica fume with cement resulted in increasing the compressive strength over 80 MPa and modulus of elasticity up to 45 GPa at water cement ratio of 0.42; Moreover, capillary porosity of all mixtures was reduced in comparison with the control concrete and the porosity of the mixture #8, with water cement ratio of 0.27 was reduced to less than 2%. Grist *et al.* (2003) assessed the increment of Compressive strength of binary and ternary lime–pozzolan mortars. They used different amounts of silica fume and fly ash (15% to 25%) in single form and different combinations. The results showed that adding these materials as a replacement for cement increases compressive strength; The increase in samples containing 25% silica fume and 25% fly ash were remarkable, for example 29.8 and 19.9 MPa of compressive strength at the ages of 90 and 28 days were recorded. Measuring the rate of fluid flow inside concrete, under hydraulic pressure gradient, is a method of measuring the permeability of the concrete. The use of materials as a replacement for cement, such as fly ash and silica fume enhances the microstructure of cement paste of concrete which reduces the permeability of concrete significantly. Knowing the permeability value of concrete for structures exposed to extreme environmental changes such as freezing-thawing and chemical attacks is of significant importance. Thus, molecular and ionic permeability in concrete has a special role in its environmental impressibility and quality of load bearing of the structure in its decades of lifetime. Hooton (1993) studied the permeability of concrete containing silica fume and stated that permeability decreases with addition of silica fume. The permeability of control mixture was 1.8×14-10 m/s while it was less than 1×17-10 m/s for the concrete mixture containing 10% of silica fume.

The electrical resistivity is one of the complex features of concrete which indicates the ability to carry electrical charge in the various components of cement matrix and even the aggregates. It

Table 1 Physical properties and chemical composition

	Physical properties			
	Specific gravity (g/cm^3)	Blain Fineness (cm^2/g)	Initial setting time (min)	Final setting time (min)
Cement	3.15	3120	110	170
Silica fume	2.2	6500	-	-
Fly ash	2.54	3420	-	-

	Chemical composition (% by mass)							
	Fe_2O_3	Al_2O_3	SiO_2	CaO	Na_2O	K_2O	MgO	SO_3
Cement	0.5	0.82	2	3.64	5.36	21.08	64.37	2.1
Silica fume	0	0	2	2	1	90	1.5	0
Fly ash	3.2	-	0.6	4.8	23.4	59.3	8.6	0.1

Table 2 Mix proportions of concrete (Kg/m^3)

Mix	Water	Cement	Silica fume	Fly ash	Aggregate (SSD)	
					Fine	Coarse
Control	180	400	0	0	944	871
F10	180	360	0	40	941	868
F15	180	340	0	60	939	867
F25	180	300	0	100	935	863
S10	180	360	40	0	937	865
S15	180	340	60	0	933	862
S25	180	300	100	0	925	854
S5F5	180	360	20	20	939	867
S5F15	180	320	20	60	935	863
S5F20	180	300	20	80	932	861
S10F15	180	300	40	60	931	859
S15F10	180	300	60	40	929	857

mainly depends on progress of hydration process, geometry and spatial distribution of the pore structure in the volume of concrete, properties of electrochemical compounds in pores and humidity and temperature changes (Ramezanianpour *et al.* 2011). Electrical resistivity can be a measure for comparing the pore structure of the samples, in addition it can be a scale to evaluate the amount and form of connectivity of cement matrix porosity (Afroughsabet 2015, Silva and Birto 2013). Concrete with low electrical resistivity, in which more electrical charges move between the electrodes, compared to high electrical resistivity concrete, will experience a faster and more severe corrosion process.

In this research, in order to evaluate some of the important properties of concrete, silica fume and fly ash have been used as a replacement for cement in different mass percentages. Concrete mixtures were made with a water-cement ratio of (0.45) and cured under similar conditions. The main focus of this study is to evaluate the durability and mechanical properties of concrete made from binary and ternary cementitious mixtures. Durability of concrete was studied by evaluating the sorptivity, water absorption, water penetration depth, electrical resistivity and Rapid Chloride Permeability (RCP) tests. concrete mechanical properties were evaluated by measuring compressive strength, splitting tensile strength and modulus of elasticity. Scanning electronic microscopy (SEM) was used to characterize the effects of silica fume or fly ash on concrete pore structure and morphology.

2. Experimental program

In this study, Portland cement I42.5 conforming to the requirements of ASTM C150, silica fume of Iran Ferrosilicon Company in accordance to ASTM C1240 and fly ash in accordance to the standard ASTM C 618, were used in binary and ternary cementitious mixtures. In Table 1, physical and chemical characteristics are given. Aggregates were composed of natural crushed coarse aggregates with specific gravity 2.69 gr⁄cm^3 and 19-mm nominal maximum size, and sand with specific gravity 2.69 gr⁄cm^3; in accordance to the ASTM C33.

2.1 Mixtures design

In this study, 12 concrete mixtures were made to evaluate the efficacy of supplementary cementitious materials, which are shown in the Table 2. Mixtures with a water-cement ratio of 0.45 in two sections (silica fume/flyash+cement) and (fly ash cement+silica fume) were built. Most of pozzolanic replacement materials in both sections, were 25% which is calculated mass. Method of mix and curing was done in the way that the aggregates saturated with dry surface (SSD) and some water was added into the mixer and mixing. Then cementitious powder materials and some water were added during mixing and the remaining water was gradually added to the mix. Time of mixing was between three and four minutes. In accordance with ASTM C192, after 24 hours of curing in the mold with a layer of plastic sheet, Mixtures were demolded and cured in lime-saturated water at 23±2°C to prevent possible leaching of $Ca(OH)_2$ from the mixtures.

In the Table 2, S is Silica Fume and F indicate Fly ash, and numbers in front of the letters represent the mass percent of them.

2.2 Testing procedure

2.2.1 Mechanical properties

The compressive strength test is the most common test to evaluate samples of concrete. The compressive strength of the concrete samples indicates the process of pozzolanic and cementitious activity and quality of cementitious matrix of concrete and its connection to aggregates. This test was determined on 100 mm cubic specimens at the ages of 7, 28 and 90 days using a loading rate of 0.3 MPa/s. Splitting tensile strength and modulus of elasticity tests were conducted on cylinders with diameter of 150 mm and height of 300 mm at the ages of 28 and 90 days.

2.2.2 Permeability

The water absorption rate was determined in according to ASTM 642 on the 100 mm cubic specimens at the ages of 28 and 90 days. To investigate the effect of silica fume and fly ash on the water penetration into the pores of concrete by capillary, the sorptivity test was carried out in accordance to ASTM C1585 at 28 days. In this test the concrete discs with a diameter of 100 mm and height of 50 mm were used, the bottom of discs was immersed in water about 1 to 3 mm and other surfaces of discs were coated by plastic sheets to prevent evaporation of water during the test. Ultimately, the amount of increase in mass as a result of capillary absorption of water obtained at various time intervals. Prior to weighing, the specimens were removed from the water and the surface was dried using a towel. Each weighing was completed within 30s. The sorptivity was obtained by means of Eq. (1)

$$I = \frac{\Delta m}{A_w \, \rho_w} \tag{1}$$

Where I is the water absorption (mm), Δm is the change in specimen mass at the time t (gr), Aw is the exposed area of the specimen (mm^2) and ρw is the density of the water (g/mm^3).

The water penetration depth under load test was performed on 150 mm cubic samples under stress of 0.5 MPa for 72 hours according to EN 12390-8.

Electrical resistivity test was conducted using two stainless aluminium plates as the electrodes in contact with two parallel sides of the cube, with the dimension 100 mm, water-saturated and applying 60V DC potential. Using Ohm's law, according to Eq. (2), the relation between applied potential and measured current and the electrical resistivity of the sample is obtained.

$$R = \frac{VA}{IL} \tag{2}$$

Where R is electrical resistivity (Ω.m), V stands for voltage (V), I is current passed (A), L is length between two electrodes (height of sample) (m) and A represents surface of electrodes (m2). Measurement was performed at 28 and 90 days so that storage conditions and curing of samples (humidity and temperature) conditions were the same.

Rapid chloride permeability (RCP) test is a common method to evaluate permeability of concrete against Chloride ion that developed late in 1970s by Whiting. In this test based on ASTM C1202 Standard, 3 specimens with a thickness of 50 mm were prepared from a cylindrical concrete with 100 and 200 mm in diameter height, respectively. These samples after being vacuumed and saturated by water, were place in apparatus and were tested. Finally, the net charge of electricity was estimated based on coulomb in 28 and 90 days.

2.2.3 Morphology

In order to investigate the microstructure of cement paste and interfacial zone, fragments with dimensions of about 2×6×6 mm were extracted from the samples center. After preparation of the samples in the lab, they were transferred into the scanning electron microscope (SEM) for imaging.

3. Results and discussion

3.1 Mechanical properties

3.1.1 Compressive strength

According to compressive strength results shown in Table 3, the increasing trend of strength with aging can be observed in all samples. In binary mixtures containing fly ash, compressive strength did not increase at the age of 28 days compared to control mixture. However, compressive strength of mixture F15 at the age of 90 days is 40 MPa which is increased 17.6% compared to

Table 3 Summary result of mechanical properties

Mixture	Compressive strength (MPa)			Tensile strength (MPa)		Elasticity Modulus (GPa)	
	7	28	90	28	90	28	90
ctrl	22	31	34	2.3	2.38	26.4	27.7
F10	20	28	38	2.4	2.72	25.66	30.13
F15	18.5	27	40	2.36	2.6	24.85	30.25
F20	17.5	26	37	2.25	2.45	24.03	28.78
F25	16	23	33	2.2	2.5	23.2	27.78
S10	22	40	42	3.17	3.44	31.3	32.06
S15	21	36	40	3.04	3.22	29.67	31.28
S20	21	35	38	2.68	2.81	29.5	30.7
S25	20	34	37.5	2.5	2.75	28.64	30.07
S5F5	24.5	31.5	43	2.47	3.09	25.8	30.1
S5F15	17.8	28.5	39.5	2.58	3.1	25	29.6
S5F20	20	31	40	2.17	3.16	27	30.8
S10F15	22	33	43	2.57	3.05	28.2	32.2
S15F10	24	32	42	2.66	3.36	28	32

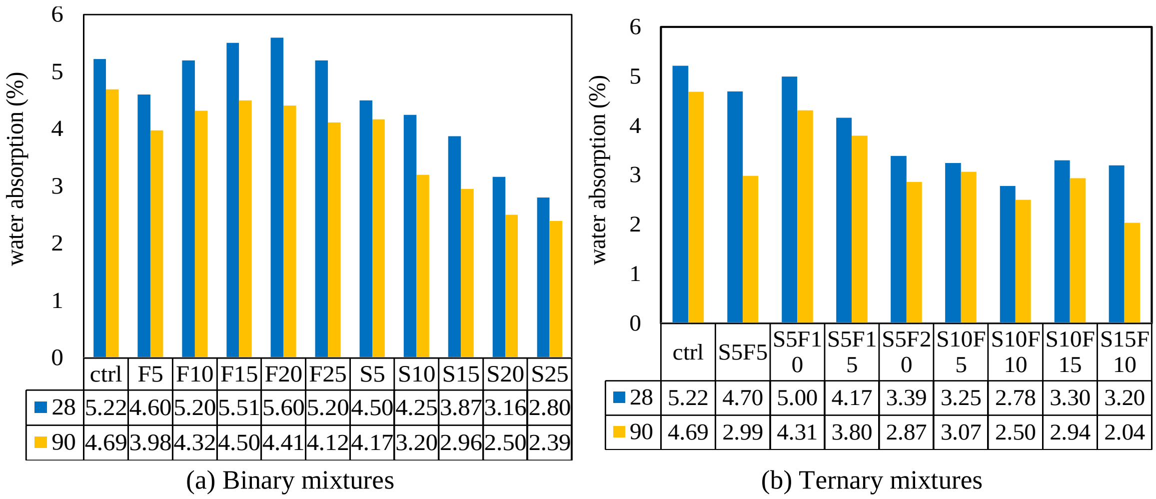


Fig. 1 Water Absorption of concrete mixtures

control. Also at the age of 90 days, all mixtures had higher strength than control mix. At the age of 7 days, it could be seen that existence of silica fume and fly ash reduced the strength and this reduction gets more significant by increasing the value the replacement in the mixtures containing fly ash. In binary mixtures containing silica fume, compressive strength increased drastically at the age of 28 days. This increase was about 29% and belongs to S10. According to studies conducted by some researchers silica fume reacts with calcium hydroxide in the cement paste, generates calcium silicate hydroxide gel, which increases the strength (Sarıdemir 2013). Silica fume is able to improve the microstructure and mechanical strength of concrete. Ultrafine particles of silica fume improve concentration and physical and chemical properties of concrete by filling pores in cement paste. According to the results, in binary blends the rate of increase of compressive strength in mixtures containing fly ash is less compared to mixtures containing silica fume; lower speed of pozzolanic reaction of fly ash can cause this issue.

In ternary mixtures at the age of 7 and 28 days, significant increase of strength was not observed. But by increasing both silica fume and fly ash at the same time, increase of strength was observed. At the age of 90 days all the mixtures had higher strength than control mixtures. The important point is that by increasing the replacement of fly ash at the ages of 7 and 28 days in ternary mixtures any decrease of strength was not observed, but the strength of binary mixtures decreased. This synergistic can be due to silica fume and fly ash act together. In Shaikh and Supit (2015) research, the addition of 8% UFFA, 90 days' compressive strength of ordinary concrete by about 55% and that of HVFA concrete containing 32% fly ash by only about 10%. Also Bagheri *et al.* (2013) reported that combination of 5% silica fume with 15% fly ash has resulted in considerable strength improvement at all ages over the control and the binary mix containing 15% fly ash.

3.1.2 Tensile strength and modulus of elasticity

The results of tensile strength and modulus of elasticity are shown in Table 3. The results of tensile strength indicate that in binary mixtures containing fly ash, the results are close to those of the control mixture, which shows a downtrend in high percentages of replacement. In the mixtures containing silica fume, tensile strength is more than control mixture's at 28 and 90 days which is related to the S10 mixture. It can be seen that by increasing the relative amount of silica fume, tensile strength has a decreasing trend. In ternary mixtures at 28 days tensile strength has not changed much, but at the age of 90 days, tensile strength of control mixture is increased to maximum value of 41.1% which is related to the S15F10 mixture. Also in Modulus of elasticity tests, existence of silica fume and fly ash in the mixture increased strength compared to control mixture. In the ternary mixture at both ages of 28 and 90, Modulus of elasticity was reportedly higher than control mixture's. The results of these experiments entirely agree with the compressive strength and other permeability results.

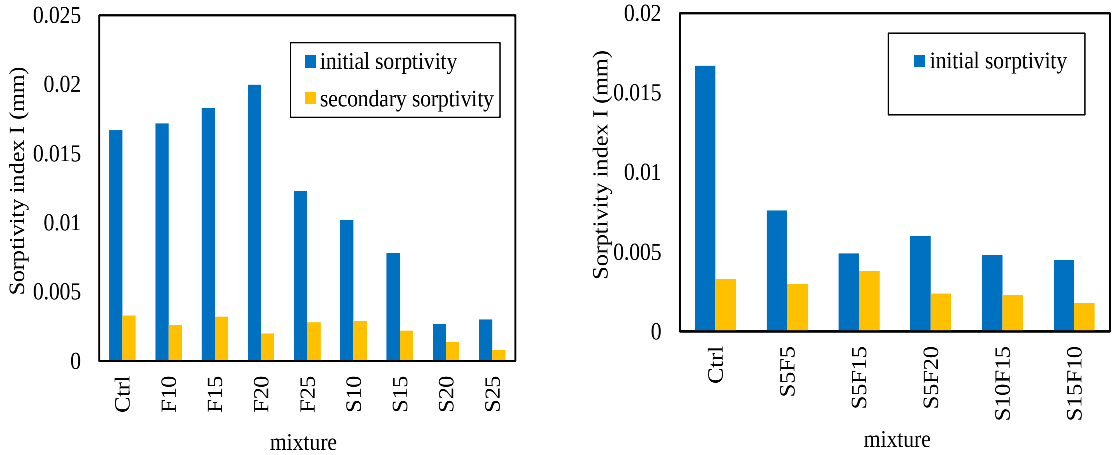
3.2 Permeability

3.2.1 Water absorption

The results of water absorption test are shown in Fig. 1. The results show that with increasing age of mixtures, reduction of water absorption is tangible. Refinement and filling of pores and channels in the concrete mixtures causes it. The Lowest amount of water absorption belongs to of S25 and S15F10 mixtures at 28 and 90 days, decreased 46% and 56% compared to the control mixture respectively. By increasing the relative amount of silica fume, water absorption has a decreasing trend at the ages of 7 and 28 days. Water absorption reduction with presence (enhance) of silica, has been reported in a study conducted by Nili and Afroughsabet (2012). Mixtures containing fly ash have more water absorption at 28 days compared to the control mixture. But going forward until the age of 90 days, the amount of water absorption becomes less than control. Also in ternary mixtures with high amounts of silica fume and fly ash reduction of water absorption seems tangible; these results agree with other results in this study.

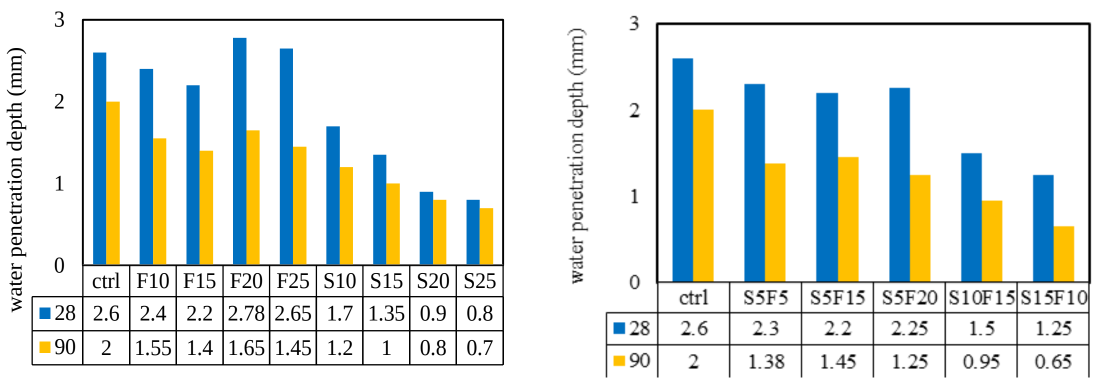
3.2.2 Sorptivity

The results of Sorptivity are shown in Fig. 2. According to the results of binary mixtures



(a) Binary mixture (b) Ternary mixtures

Fig. 2 Sorptivity Index (*I*) of concrete mixtures



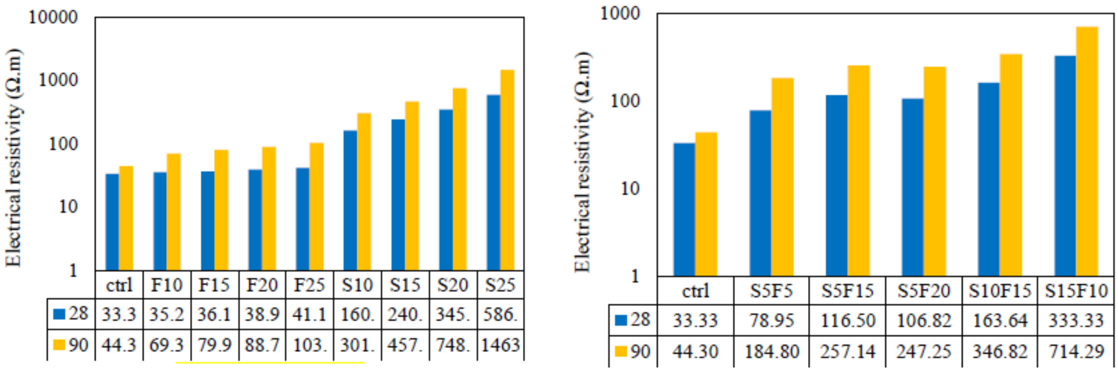
(a) Binary mixtures (b) Ternary mixtures

Fig. 3 Water penetration depth of concrete mixture

containing fly ash, the lowest amount of sorptivity belongs to FA10 mixture. As replacement rate increases the amount of sorptivity index increases too. In binary mixtures of silica fume as the amount of replacement increases index value of sorptivity is reduced. It can be seen that the lowest value of primary and secondary sorptivity belongs to SF25 mixture, and its value relative to the control mixture has decreased 81 and 80 percent respectively. In ternary mixtures by adding silica fume and fly ash, sorptivity index value reduces. The results of sorptivity test are consistent with the results of water absorption. Water capillarity is a function of porosity, diameter of capillary conduit, continuity and complexity of communication pores within the concrete and a meaningful relationship with permeability can be found (Shaikh and Supit 2015). Fine particles of pozzolan have an important role in blocking capillary channels in the cementitious matrix and by creating a more homogenous distribution of the gel C-S-H, they can reduce pores and lower the permeability.

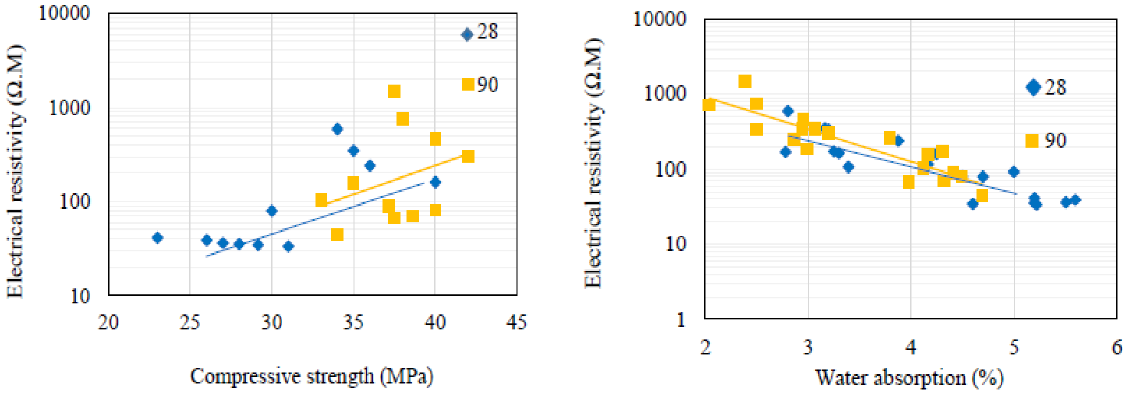
3.2.4 Electrical resistivity

Electrical resistivity of concrete is mainly affected by two fundamental factors, pore structure



(a) Binary mixture (b) Ternary mixtures

Fig. 4 Electrical resistivity of concrete mixtures



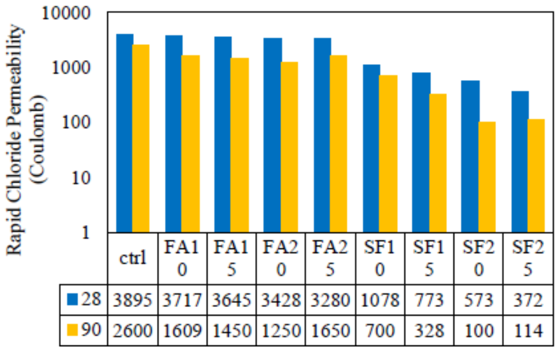
(a) Electrical resistivity-Compressive strength (b) Electrical resistivity-Water absorption

Fig. 5 Electrical resistivity relationship with compressive strength or water absorption

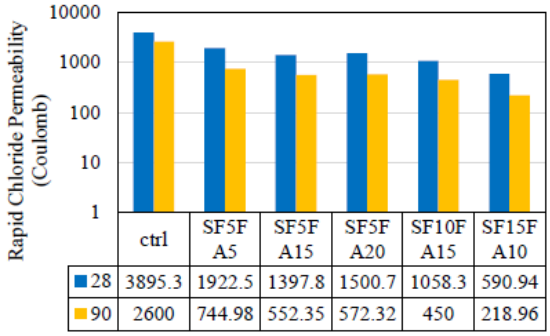
and pore solution which actually represents the mobility of ions in concrete and can be an appropriate criterion for determining the electrical resistivity of concrete against chloride penetration. Also low conductivity of concrete slows ions speed in corrosion process of a rebar, which can be a criterion of corrosion rate (Ramezanianpour *et al.* 2012). Adding pozzolanic material to concrete increases electrical resistivity.

Results of electrical resistivity test are shown in Fig. 4. The results show that by aging, electrical resistivity of mixtures increased. It represents high strength of concrete against corrosion. Existence of silica fume and fly ash in concrete increased the electrical resistivity, due to low reaction rate of pozzolanic mineral materials, electrical resistivity has grown substantially at older ages. Also by increasing the amount of replacing for cement, increase in electrical resistivity can be seen.

In binary mixtures containing fly ash, maximum electrical resistivity compared to the control mixture belongs to FA25 mixture which is increased by 23% and 32% at the ages of 28 and 90 days respectively. In binary mixtures containing silica fume, S25 mixture has the highest electrical resistivity at the ages of 28 and 90 days, increased compared to the control mixture by 17.6% and 33%.



(a) Binary mixture



(b) Ternary mixtures

Fig. 6 Rapid chloride permeability test of concrete mixtures

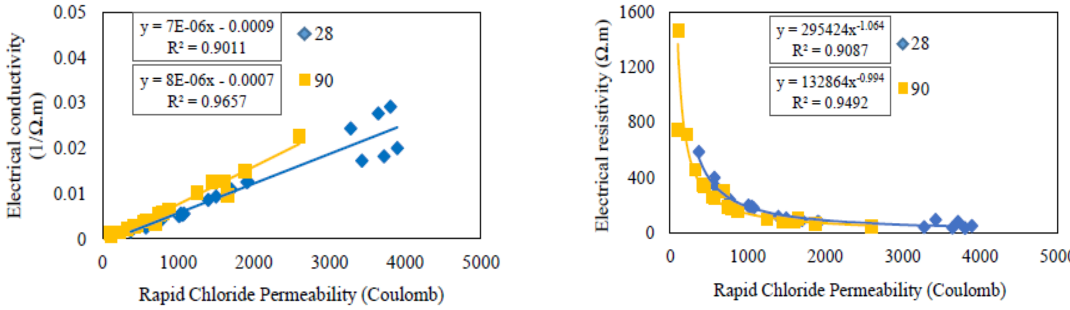
Table 4 Chloride ion permeability and Corrosion probability bar classes according to RCPT and ER

Chloride ion permeability	Rapid chloride permeability (Coulombs) (AASHTO) (2002)	Probability of bar Corrosion	Electrical Resistivity (Ω.m) (ACI 2001)
High	>4000	Very high	50>
Moderate	2000-4000	High	50-100
Low	1000-2000	Low	100-200
Very low	100-1000	Very low	>200
Negligible	<100		

Incorporation of SF has caused considerable increase in electrical resistance of mixes containing FA, showing the clear advantage of ternary mixes over binary mixes containing fly ash alone. Increasing rate of electrical resistivity is higher in silica fume mixtures compared to fly ash mixtures. The use of FA did not significantly improve the 28 days electrical resistivity of concrete mixtures, although at the ages of 90 days with increasing pozzolanic reaction of fly ash, the electrical resistivity of fly ash concretes increased. High pozzolanic reaction of silica fume can be the reason of increased electrical resistivity. By increasing the percentage of cement replacement in other similar pozzolanic additives with ternary mixtures, the increment of electrical resistivity is more tangible. Fig. 5 shows the relationship between electrical resistivity, compressive strength and water absorption. In Fig. 5(a) it is clear that by increasing the electrical resistivity, compressive strength is also increases. In Fig. 5(b) an increase in electrical resistivity by reducing amount of water absorption is observed.

The results of the RCPT test of ternary mixes are presented in Fig. 6(b). In ternary mixtures, penetration of chloride was decreased by 61%. It can be observed, combination of silica fume and fly ash had significantly improved the chloride penetration in comparison with to fly ash containing binary mixtures. By replacement of 5% silica fume, the penetration of chloride was decreased about 48%.

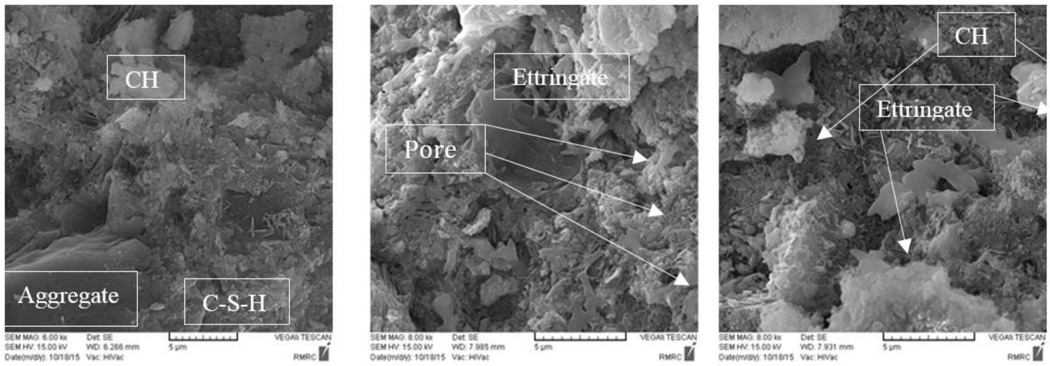
In addition, Table 4 shows classification of Chloride ion penetration and the probability of bar corrosion based on rapid chloride permeability and electrical resistivity, respectively. Electrical conductivity is reversely related with electrical resistivity and directly with penetration. Fig. 7(a) presents the linear relation of electrical conductivity with rapid chloride penetration (RPC) which has the regression coefficient of R=0.9 and R=0.96 in age 28 and 90 days, respectively. Due to



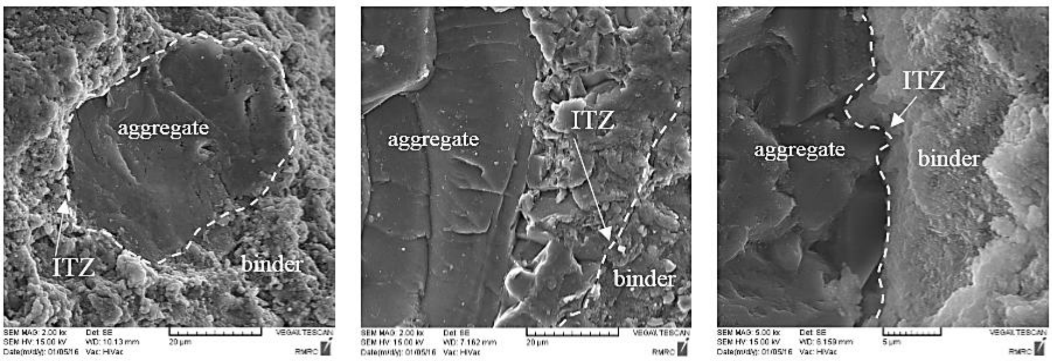
(a) Rapid chloride permeability-electrical conductivity

(b) Rapid chloride permeability- electrical resistivity

Fig. 7 rapid chloride permeability relationship with electrical conductivity or electrical resistivity



(a) (b) (c)



(d) (f) (g)

Fig. 8 Scanning electronic microscopy of the impact of mineral additives materials on microstructure mixture of 90 days, (a) to (f) control mixtures, (e) mixture contain of 15% Flay Ash (F15), (d) mixture contain of 10% silica fumes (S10)

applying the same procedure in different conducted tests, comparing the mixtures performance was carried out based on electrical conductivity. Also, according to the overestimated results obtained from RCP test, its linear relationship with the electrical conductivity can indicate more realistic chloride penetration results.

The relationship between electrical resistivity and penetration of chloride was shown in Fig. 7(b) which is in power type relation with regression coefficient of R=0.9 in 28 days age and R=0.94 in 90 days age. It should be noted that the high voltage that were employed in the chloride penetration test was lead to a significantly increment in temperature. As the strength of concrete against ions penetration decreases, its electrical resistivity also decreases and for a constant voltage, electrical conductivity would increase. Based on this issue, despite these two tests are similar in physical basement, a power relationship was established between them. Regarding the low current in electrical resistivity test, the permeability value in RCP increases compared to electrical resistivity test; Therefore, the relationship between them is usually in a power or exponential form (Ramezanianpour *et al*. 2012).

3.3 Morphology

Scanning electron microscopy (SEM) is an effective way to evaluate the morphology of hydrated cement-based products. According to Fig. 8(a), (b), (c), some of the pores caused by excess lime crystallization and also the growth of ettringate are clearly visible. Because of lack of mineral additives materials, the porosity of the cement paste is obvious and shows that paste matrix has not been completely compacted. In Fig. 8(d), (e), (f) mixtures containing pozzolan have more uniformity, compacting and improved interfacial transition zone (ITZ) in comparison with the control mixture. Mixtures containing 10% silica fume and 15% fly ash, showed more uniform and denser microstructure in the cement matrix.

4. Conclusions

Assessment of permeability and mechanical properties of concrete made from binary and ternary cementitious mixtures of silica fume, fly ash at different curing ages was presented in this paper. From the results obtained in this study, the following conclusions can be drawn:

• At the age of 90 days, all mixtures containing pozzolanic material have more Compressive strength in comparison with the control mixture. Also binary mixtures containing silica fume at the age of 28 days have greater Compressive strength than the control mixture.

• By increasing amount of fly ash in binary mixtures, Compressive strength reduces at the ages of 7 and 28 days, whereas in ternary mixtures, by increasing amount of fly ash and silica fume simultaneously compressive strength increases.

• The simultaneous presence of silica fume and fly ash has a positive effect on tensile strength and modulus of elasticity.

• Adding pozzolanic materials improves durability. In most of cases, reducing water absorption, sorptivity and water penetration depth at the age of 28 days was reported. By increasing age to 90 days the amount of reduction becomes more tangible.

• Duo to high percentage of silica fume as an electrical insulator in silica fume and its significant active role in the reduction of lime and increment of C-S-H and improvement of concrete structure concentration, the silica fume and the simultaneous combination with fly ash, are preferred options to improve the concrete properties.

• The combination of Silica fume and fly ash had a significant influence on reduction of chloride permeability in comparison with other binary combinations containing fly ash. The replacement of 5% silica fume reduced chloride permeability at least 48% in comparison with other binary combinations containing fly ash.

• According to the exponential and linear relationships (with good regression coefficients) generated by results of electrical resistivity test and rapid chloride penetration test, electrical resistivity test can be used as an acceptable non-destructive and low cost method for durability assessment of concrete.

Acknowledgments

The authors are thankful of the staff of concrete and building materials laboratory at University of Guilan who provided support for this research.

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