

Investigating the effects of using seawater and superabsorbent polymers on the internal curing of self-compacting concrete

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Abstract. Internal Curing in recent years is one of the special topics in achieving optimal mechanical properties and durability in self-compacting concrete. The use of superabsorbent polymers with the ability to absorb and release water in the hydration process in internal curing has fewer performance limitations. Due to environmental considerations and the lack of drinking water in the world, the use of seawater in construction, including concrete Structures and curing of bulk, high-performance and self-compacting concrete has been the subject of recent research. The present study investigates the effect of using superabsorbent polymers and seawater in the internal curing of self-compacting concrete. Two types of superabsorbent polymers with two different amounts have been used in this research. In order to evaluate the mechanical properties and durability of internally cured concrete samples, compressive strength, electrical resistance, water penetration under pressure, freeze-thaw cycles, and microstructure tests were used in this research. The results showed that the compressive strength of samples made and cured with seawater and superabsorbent polymers increased by over 10%. Examining the results of the electrical resistance test on the samples cured using potassium-based super absorbent polymers also shows the greater effect of internal curing in the process of obtaining resistance and completing the hydration. The increase in electrical resistance as a result of internal curing using potassium-based superabsorbent polymer with amounts of 0.2% and 0.3%, compared to sodium, was 25.5% and 19.9%. Internal curing using seawater and potassium-based superabsorbent polymer caused a reduction of over 40% in the test of water penetration compared to sodium-based superabsorbent polymer. Investigation of microstructure results obtained from SEM, XRF, and XRD experiments, showed an increase of 8.1% and 6.2% in final products of the hydration process when using potassium-based superabsorbent polymer.

Keywords: internal curing; microstructure; seawater; self-compacting concrete; SEM; superabsorbent polymers; XRD; XRF

1. Introduction

The construction industry is one of the largest consumers of drinking water. Concrete

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Chemical	NaCl	MgCl ₂	Na ₂ SO ₄	CaCl ₂	KCl	NaHCO ₃	KBr
Concentration (g/L)	24.53	5.20	4.09	1.16	0.695	0.201	0.101

* Chemicals with a concentration level lower than 0.1 g/L are not included in the Table.

Fig. 1 Concentrations of chemicals added to freshwater to simulate seawater

construction requires adequate drinking water and the use of this resource in the world will be limited. Therefore, another resource that is significantly abundant and available seems very necessary and this source is nothing but seawater. Due to the possibility of controlling the effect of chloride ions in seawater on the corrosion of reinforced concrete structures using some additives such as fly ash and the use of special rebar, determining the applicability of seawater in concrete construction requires further studies and research (Lim *et al.* 2015, Otsuki *et al.* 2012).

Otsuki *et al.* (2012) found that due to the shortage of fresh and drinking water, the use of seawater, which is 97% of the total water available on Earth, is absolutely necessary. Even today, in some areas, the use of seawater in concrete is done by observing some criteria.

Freshwater levels in lakes, rivers, and lagoons have been declining since time immemorial, and the likelihood of a shortage of fresh water will be very high in the near future. Based on the prediction, access to fresh water and drinking water will be very difficult. On the other hand, according to the forecasts of the United nations and the world metrological organization, about 5 billion people (about 80% of the planet's population) will even face a shortage of drinking water in the near future. Numerous kinds of research provide new and interesting insights into the behavior of self-compacting concrete (SCC) when using fresh water and undrinkable water in concrete construction and maintenance (Sarfaraz and Bannerjee 2016).

Okamura (1986) first proposed self-compacting concrete (SCC) in Japan. Ozawa (1989) made this type of concrete in the workshop and presented acceptable results in terms of the mechanical properties of concrete.

In another research, Tjaronge *et al.* (2014) found that sand and seawater as components of self-compacting concrete cannot reduce the strength of concrete.

During the research conducted by Erniati *et al.* (2014, 2015a, b) it was found that seawater does not reduce the strength of self-compacting concrete until the age of 90 days. On the other hand, seawater increases concrete strength at an early age. They also found that porosity decreased with the improvement of C-S-H constituents.

Xiao *et al.* (2017) in a study looking for solutions to replace sand, gravel, and water in concrete production, found that the excessive consumption of raw materials, especially river sand and fresh water in concrete production has raised serious environmental concerns.

The importance of water as an essential element in the quality of the final concrete was investigated during the research by Kucche *et al.* (2015). It is generally believed that seawater has an adverse effect on concrete strength due to its high levels of chlorine and sulfate.

The concentration of chemicals in seawater is simulated in accordance with ASTM D1141-98, (2013) shown in Fig. 1.

It is widely accepted that chloride content has a significant effect on the corrosion of ordinary steel in reinforced concrete. Due to the abundance of chloride ions in seawater, many studies have been performed on steel corrosion in concrete adjacent to the sea. Mohammed *et al.* (2004) exposed concrete cylinder specimens to tides for 15 years and found that using seawater instead of freshwater resulted in a large number of corrosion pits with greater depth in steel rods.

However, the results of Otsuki *et al.* (2012) showed that the effect of seawater on steel



Fig. 2 Sodium-base (left) and potassium-base (right) superabsorbent polymers used in this research

corrosion is negligible. After 20 years of exposure to atmospheric and corrosive agents, no obvious difference in the depth of steel corrosion was observed between concrete made with seawater and concrete made with freshwater.

In another study, Lim *et al.* (2014) in addition to investigating the effect of seawater itself, the effect of fly ash has been shown as one of the possible alternatives to cement in concrete made with this type of water.

Over the past four decades, based on research (Afshoon and Sharifi 2014, Sharifi *et al.* 2015) self-compacting concrete (SCC) as a new generation of high-performance concrete, has been recognized as a successful innovation in concrete technology and has been the subject of extensive research studies.

Due to the increasing use of high-strength and high-performance concretes such as self-compacting concrete, the concrete internal curing literature has become the subject of research in recent years. Potentially, several techniques may be used to apply the internal curing method to concrete. In a study conducted by Jensen and Lura (2006), different methods of internal curing and their effects were investigated with emphasis on the use of superabsorbent polymers (SAP). Superabsorbent polymer (SAP) is a polymeric material that is able to absorb a significant amount of liquid from the surrounding environment and can keep the absorbed liquid inside without dissolving. The result of this research shows that in the most extreme case, concrete needs up to 50 kg/m³ of internal water to prevent self-desiccation and self-desiccation shrinkage.

Today, a wide variety of superabsorbent polymers with different chemical compositions are used in research. sodium and potassium-base superabsorbent polymers used in this research are shown in Fig. 2.

Superabsorbent particles and fibers are mainly used to absorb water and aqueous solutions. Buchholz and Graham (1998), found that the maximum amount of water that can be absorbed using existing superabsorbent polymers is 500 times the weight of the polymers. However, the absorption rate of commercially produced superabsorbent polymers is around 50 gr/gr in a dilute salt solution like urine, and in a solution with high-ionic capabilities, such as the liquid in cement paste, the absorption amount is less than 20 gr/gr.

The methods of using SAP for internal curing of concrete are given in the research done by Jensen and Hansen (2002). In the most appropriate method, SAP polymers can be added to the concrete mix design in a dry form and absorb the water they need during mixing.

In another research, Lura *et al.* (2007) stated that internal curing has significant effects on concrete properties. In addition to the effects on hydration and moisture distribution, it also affects concrete characteristics such as strength, shrinkage, cracking, and concrete durability.

Superabsorbent polymers are gradually used in concrete production as an internal curing agent. These polymers, while improving the resistance of concrete against freeze-thaw cycles, effectively

reduce the shrinkage of concrete at early ages and the risk of cracking. Also, it can be stated that the size and amount of SAP components and the water-cement (w/c) ratio of concrete have certain effects on the evaluation of concrete internal-cured with SAP. In the research done by Ding *et al.* (2017) experiments were conducted to investigate the relationship between concrete's w/c ratio, amount of SAP polymers, and size of SAP particles. The main and important criteria affecting concrete strength were identified and formulas were proposed for predicting the strength of concrete made and internal-cured with SAP for the ages of 3, 7, and 28 days. In the aforementioned research, the amount of SAP polymers is suggested to be less than 0.2%, and the results of this research are expected to be the theoretical basis for the rational use of SAP, as a concrete additive.

In another study, regarding the effects of SAP polymers on the self-healing process by Kim and Schlangen (2010) it was stated that Superabsorbent polymer (SAP) is an organic macromolecular material that is gradually used in modern civil engineering as a new internal curing agent. SAP, with a cross-linked three-dimensional network structure, contains carboxyl (-COOH) and hydroxyl (-OH) and other strong hydrophilic groups. These hydrophilic groups rapidly absorb large amounts of water and create hydrogen bonds and gelatinous tissue that improve the hydration process.

Craeye (2006) found that when additional water was added to concrete with amounts of about 30-50 kg/m³, the shrinkage of concrete decreased up to 58 percent. Yao *et al.* (2012) found that SAP polymers reduce the crack width in concrete and consequently reduce concrete shrinkage. Qin *et al.* (2011) predicted the conversion of 0.2-0.3 percent of SAP polymers to gelatinous materials and found that the mechanical properties, deformation characteristics, plastic cracking resistance, and durability of concrete were greatly improved. Huang and Wang (2012) investigate that the compressive and flexural strength of high-performance concrete does not decrease after adding the appropriate amount of SAP.

Venkateswarlu *et al.* (2021) studied the 28-day strength of concrete made and internal-cured with SAP and found that the compressive strength of internally cured SCC mixtures increased to 15-25% at 7 days and 10-19% at 28 days.

In another research, Jeon *et al.* (2021) studied the SAP, SRA, and CSA roles in the strength and shrinkage of concrete. they found that the use of SAP as an additive resulted in a slight decrease in compressive strength. Also, they found that SAP and SRA had greater shrinkage reduction effects on the concrete than CSA clinker.

In recent research by Schrofl *et al.* (2022), the use of superabsorbent polymers and their effects on the rheological properties of concrete, internal curing, autogenous and plastic shrinkage, self-sealing, self-healing of cracks and improving durability and performance in freeze-thaw cycles are approved.

The use of microstructure analysis and porosity measurement of mercury penetration in ultra-high-performance concrete, in the research of Zhihui *et al.* (2022) has shown that internal curing using superabsorbent polymers can improve the pore structure in concrete. The small amount of super-absorbent polymers in high-performance concrete shows a decrease in autogenous shrinkage. with an increased amount of SAP polymers, results show an increase in autogenous shrinkage, this is despite the fact that with the increase of superabsorbent polymers, the drying shrinkage always increases. In this research, the best performance in reducing shrinkage was obtained when using superabsorbent polymers at the rate of 0.15 percent by the weight of cement. In addition, the tensile strength of ultrahigh-performance concrete was also improved by adding small amounts of superabsorbent polymers with the promotion and improvement of hydration and more density and compaction in the concrete microstructure.

Table 1 Self-compacting concrete mix design

Mixing plan	Sand (Kg/m ³)	Gravel (Kg/m ³)	Limestone powder (Kg/m ³)	Super plasticizer%	Silica fume (Kg/m ³)	Cement (Kg/m ³)	Water	W/C%	SAP type	SAP quantity%
#1	668	867	155	1.2	45	450	Seawater	0.35	Sodium	0.2
#2	668	867	155	1.2	45	450	Seawater	0.35	Sodium	0.3
#3	668	867	155	1.2	45	450	Seawater	0.35	Potassium	0.2
#4	668	867	155	1.2	45	450	Seawater	0.35	Potassium	0.3
#CC	668	867	155	1.2	45	450	Seawater	0.35	--	--

Table 2 Ordinary Portland cement specification

composition	weight percent	composition	weight percent	composition	weight percent	Title	quantity
SiO ₂	21.73	MgO	2.48	CaO	62.16	Specific Surface Area cm ² /gr	3250
Al ₂ O ₃	5.07	SO ₃	2.22	Na ₂ O	0.37	Expansion (Autoclave) %	0.1
Fe ₂ O ₃	3.5	K ₂ O	0.64	Cl	0.05	Setting Time (minute)	170-210

Superabsorbent polymers based on alginate and sulfonate, in the research conducted by Tenorio *et al.* (2022), and the use of their different types in cement paste are among other issues raised in recent research. Knowing the chemical compounds and the behavior of these polymers in internal curing helps to choose the appropriate superabsorbent polymer for various applications in cement environments.

In this research, based on experimental and laboratory programs, first, the properties of superabsorbent polymers based on sodium and potassium were investigated, including particle size and water absorption rate in different environments. Then, self-compacting concrete was made and cured using seawater and both types of superabsorbent polymers. In order to investigate the effects of internal curing of self-compacting concrete using seawater and sodium and potassium-based superabsorbent polymers, compressive strength, electrical resistance, freeze-thaw cycles, water permeability, Scanning Electron Microscopy (SEM), X-ray fluorescence (XRF), X-ray diffraction (XRD), were performed and the results were analyzed and compared.

2. Materials and mix proportions

In order to make self-compacting concrete in this research, based on the mixing plan presented by Mazloom *et al.* (2015) shown in Table 1, ordinary Portland cement, with the specifications are given in Table 2, was used. Gravel and sand with continuous granulation, according to the ASTM C136 Standard (2007), were utilized as the aggregates. Silica-fume with specifications presented in Table 3, limestone powder as a neutral filler, polycarboxylate-ether base superplasticizer, and two types of sodium and potassium-based superabsorbent polymers, as shown in Fig. 2 have been used. In this research, to investigate the effects of seawater on concrete properties, Seawater with the specifications shown in Table 4, was used in the construction and internal curing of self-compacting concrete.

Table 3 Silica fume properties

composition	weight percent	composition	weight percent	composition	weight percent	composition	weight percent
SiO ₂	94.55	MgO	0.18	Al ₂ O ₃	1.32	Na ₂ O	0.15
P ₂ O ₅	0.17	S	0.06	K ₂ O	0.21	CaO	0.26
TiO ₂	0.04	Fe ₂ O ₃	0.89	L.O.I	2.17	La&Lu	<1

Table 4 Seawater analysis

Chemical	CL	SO ₃	SO ₄	TDS	Na	K	TSS
Concentration (mg/lit)	22000	2680	3219	30100	14000	450	528

3. Test procedure

In order to know the properties of superabsorbent polymers used in this research, particle size analysis was performed according to ISO 13320 standard (2020). Then the rate of seawater absorption in these polymers was measured in different environments (including cement ions).

After the construction and internal curing of self-compacting concrete samples, the compressive strength test was performed at the ages of 7 and 28 days. The electrical resistance test of the samples was done at the age of 28 days. Evaluation of concrete samples in freeze-thaw cycles and water permeability tests were also done at the age of 28 days. In order to identify and analyze the chemical compounds in the samples, microstructure tests such as SEM, XRD and XRF were also performed at the ages of 28 days.

In this research, cubic samples with dimensions of 150*150*150 mm were used to perform the compressive strength, water permeability, and freeze-thaw cycle tests. Cylindrical samples with dimensions of 200*100 mm were used to conduct the electrical resistance test. In order to perform microstructure tests, crushing of the manufactured samples was used.

It should be noted that in order to eliminate moisture exchange between the concrete samples and the surrounding environment, all samples were completely covered with multiple layers of Nylax and kept at a temperature of about 23°C until the tests were performed.

4. Results and discussion

The results of water absorption and particle size of superabsorbent polymers, compressive strength, electrical resistance, freeze-thaw, water permeability, and concrete microstructure examination along with the analysis of the results are given in this section.

4.1 Water absorption and particle size tests of superabsorbent polymers

Considering that two types of superabsorbent polymers based on sodium and potassium were used in this research, therefore, in order to know the properties of superabsorbent polymers, a particle size test, based on ISO 13320-2020 standard, was first performed to determine the size range of polymer grains and the results are shown in Figs. 3 and 4.

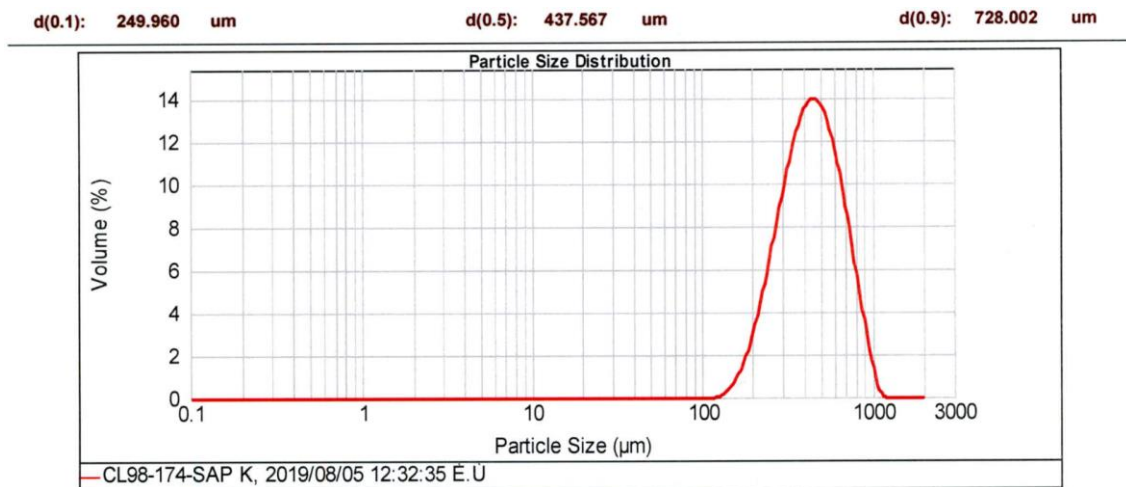


Fig. 3 Particle Size of potassium-base superabsorbent polymer

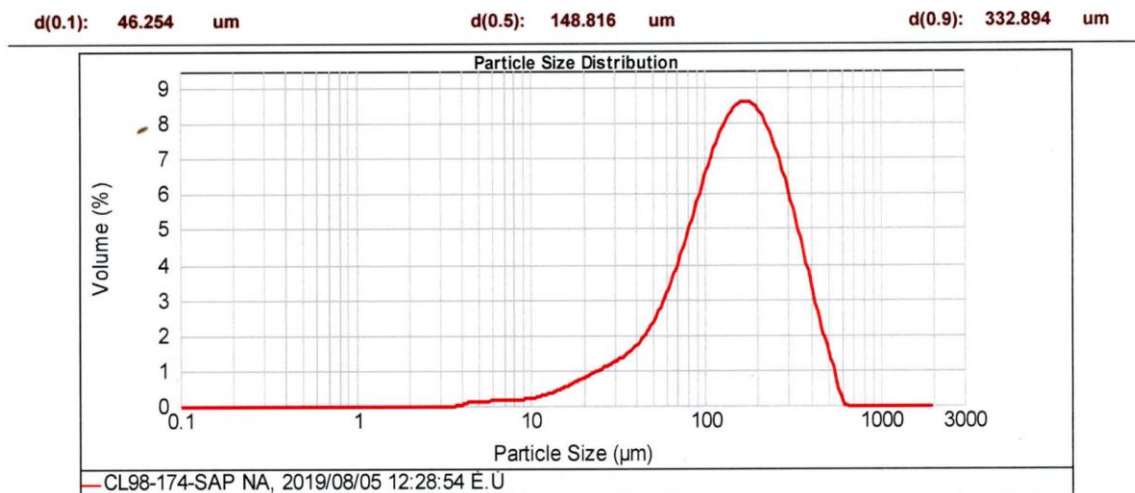


Fig. 4 Particle Size of Sodium-base superabsorbent polymer

Then, the amount and rate of water absorption of SAP polymers were investigated under two different conditions. In the first case, the superabsorbent polymers were simply exposed to seawater. In the second case, in order to simulate cement environments, a seawater solution containing cement ions was prepared from cement paste according to the experiment in Fig. 5, and then the amount and rate of water absorption of superabsorbent polymers in this solution were measured. The obtained results are shown in Figs. 6 and 7.

From the analysis of the results shown in Fig. 6, it can be concluded that the water absorption of superabsorbent polymers against seawater has a decrease of about 2 to 2.9 times. Also, when using a solution containing cement ions, resulting from cement paste, as shown in Fig 7, this reduction is about 2.2 to 3.2 times.

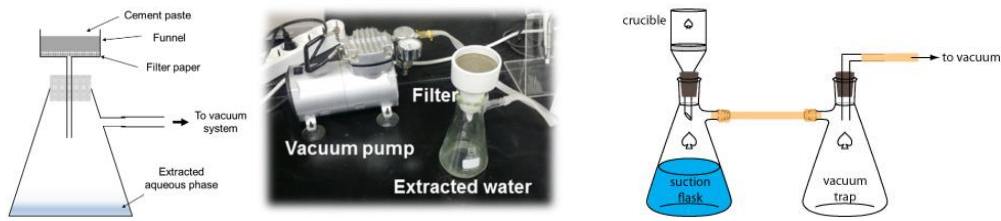


Fig. 5 Extraction of the solution, containing cement ions, from cement paste

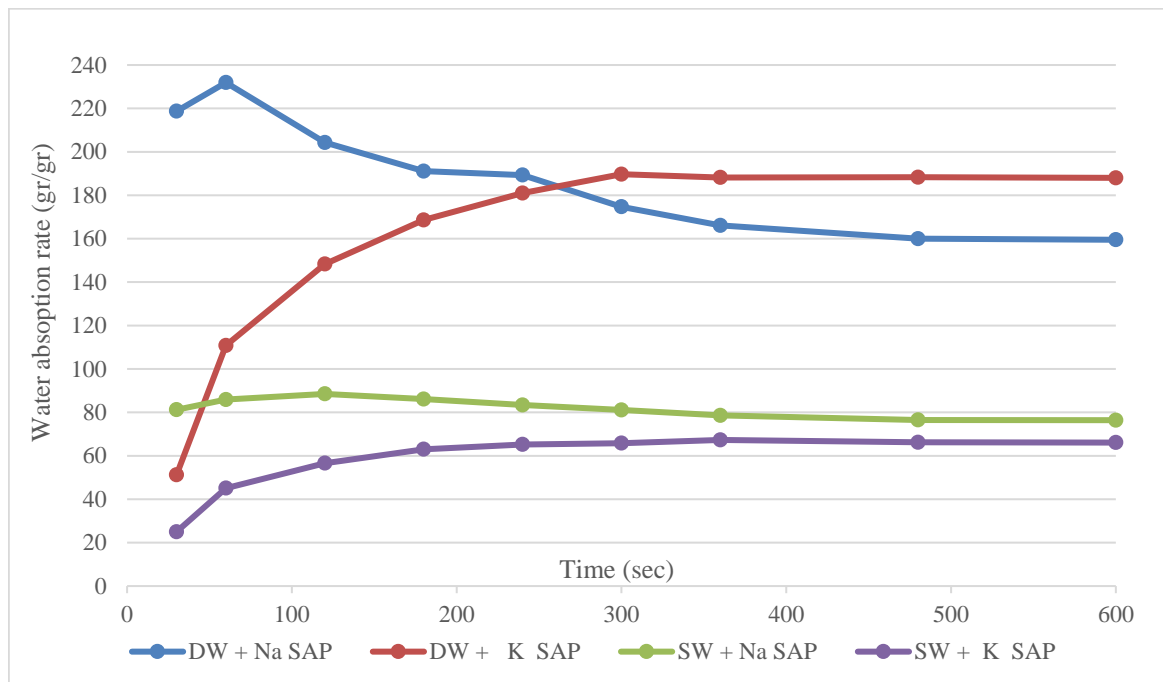


Fig. 6 Seawater absorption rate of super absorbent polymers, used in this research

From the result shown, it is clear that the process of water absorption in sodium-based superabsorbent polymer occurs immediately after exposure to water, but water absorption in potassium-based superabsorbent polymer after exposure to water for a longer period reaches its maximum.

4.2 Compressive strength test

After making the samples, insulating and storing the cubic samples with the dimensions of 15 cm at the temperature of 24 ± 1 °C, testing the compressive strength at the ages of 7 and 28 days according to the standard BS EN 12390-3 was done. The test results are shown in Figs. 8 and 9.

The results of the compressive strength test showed that internal curing with seawater in the presence of potassium superabsorbent polymers with 0.2 percent by the weight of cement had a better performance in the process of gaining strength. The increase in compressive strength, in this

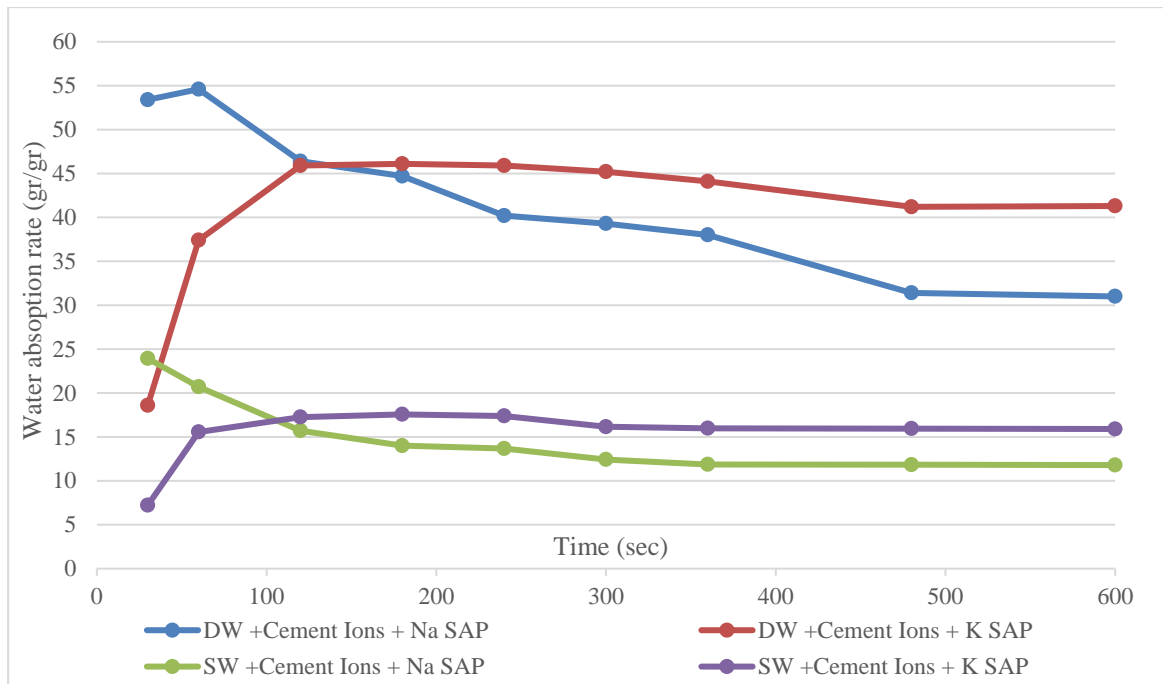


Fig. 7 Seawater absorption rate of used SAP polymers in cement ionized solution

DW: Drinking water, SW: seawater, Na SAP: sodium-based superabsorbent polymer, K SAP: Potassium-based superabsorbent polymer

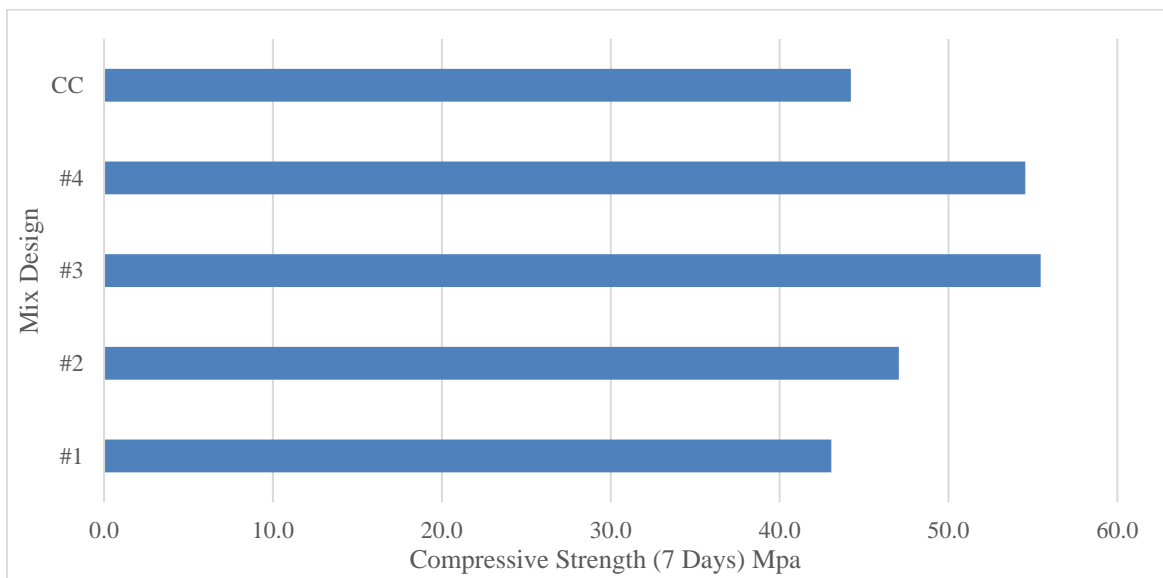


Fig. 8 Compressive strength test results at the age of 7 days

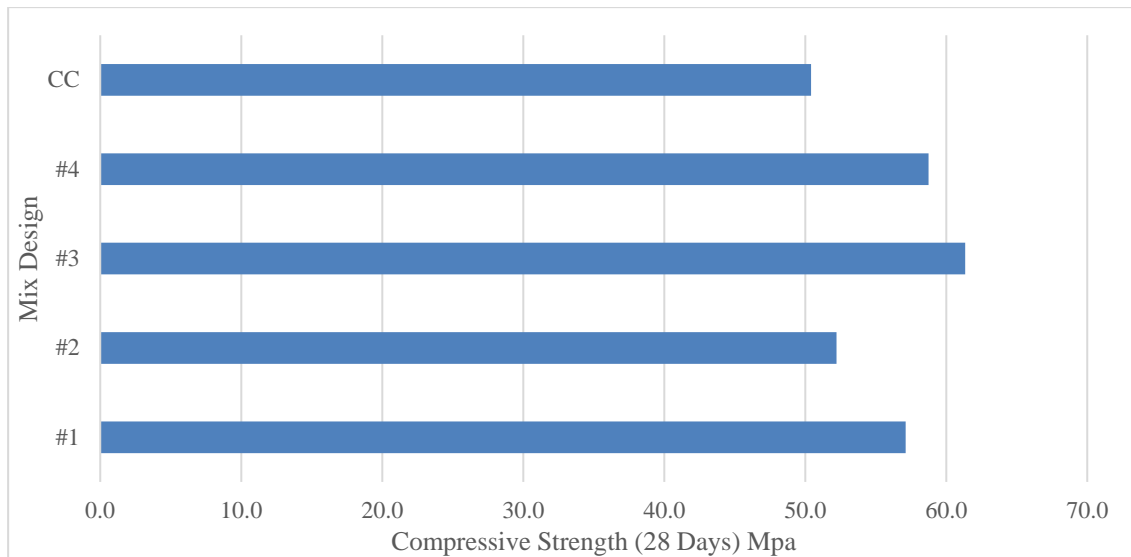


Fig. 9 Compressive strength test results at the age of 28 days



Fig. 10 The device used in this research for evaluating electrical resistance

case, showed an increase of 25% and 7% at the ages of 7 and 28 days compared to the use of sodium-base superabsorbent polymer at the rate of 0.2% by the weight of cement and this increase compared to the control concrete, was 13.1% and 21.6%.

With the amount of 0.3% of potassium superabsorbent polymer in the process of SCC internal curing, the increase in compressive strength compared to the use of sodium-based superabsorbent polymer at the ages of 7, 28 days was 15.9% and 12.5%, this amount of increase compared to the control concrete was 23.3% and 16.5%.

The increase in compressive strength by using superabsorbent polymers based on sodium and potassium in internal curing of SCC, according to other tests conducted in this research, including microstructure tests, is related to the increase in the evolution of the hydration process and the cohesion of the overall structure of self-compacting concrete.

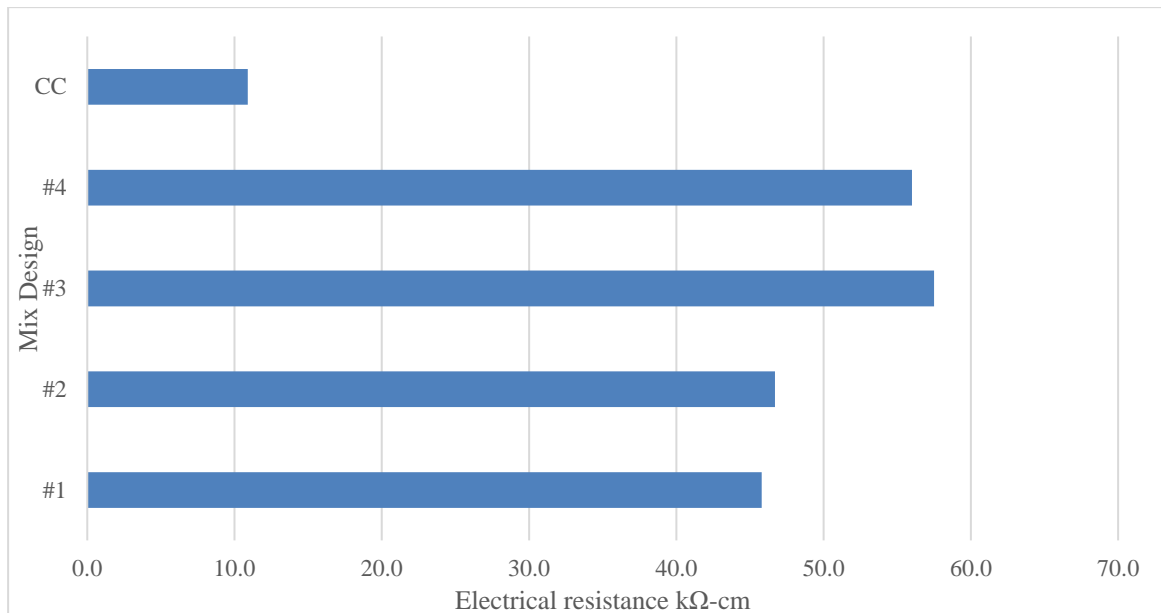


Fig. 11 Electrical resistance test results

4.3 Evaluation of electrical resistance

The measurement of the electrical resistance of cylindrical concrete specimens at the age of 28 days was performed using the device shown in Fig. 10 according to the AASHTO TP95-14 standard. Ohm's law is established in this experiment, therefore, according to the voltage difference between the two inner electrodes and the intensity of the current between the two outer electrodes, by performing four directions, the electrical resistance of the cylindrical concrete sample with the dimensions 10*20 cm was measured in KΩ-cm. the results are shown in Fig. 11.

According to the results of the electrical resistance test, it was observed that cured samples using potassium-based superabsorbent polymer at the rate of 0.2 percent by the weight of cement show more electrical resistance. It has increased by 25.5% compared to the case of using a sodium-base superabsorbent polymer with the same amount of SAP polymer. This rate of increase was 19.9% in the case of using 0.3% potassium-base superabsorbent compared to sodium.

4.4 Freeze-thaw cycles test

Freeze-thaw test in this research was carried out based on the national standard of Iran ISIRI-12728 using the device shown in Fig. 12. The number of freeze-thaw cycles in the mentioned standard is 28 cycles in the temperature range of -20 to 20°C for 168±5 hours. This test was performed on the samples at the age of 28 days. In this method, after preparing the samples according to the standard, the surface of the samples is covered with 3% NaCl solution and subjected to freeze-thaw cycles. Then the materials separated from the concrete surface were collected and weighed. The results are shown in Fig. 13.



Fig. 12 Freeze-Thaw cycles test device used in this research

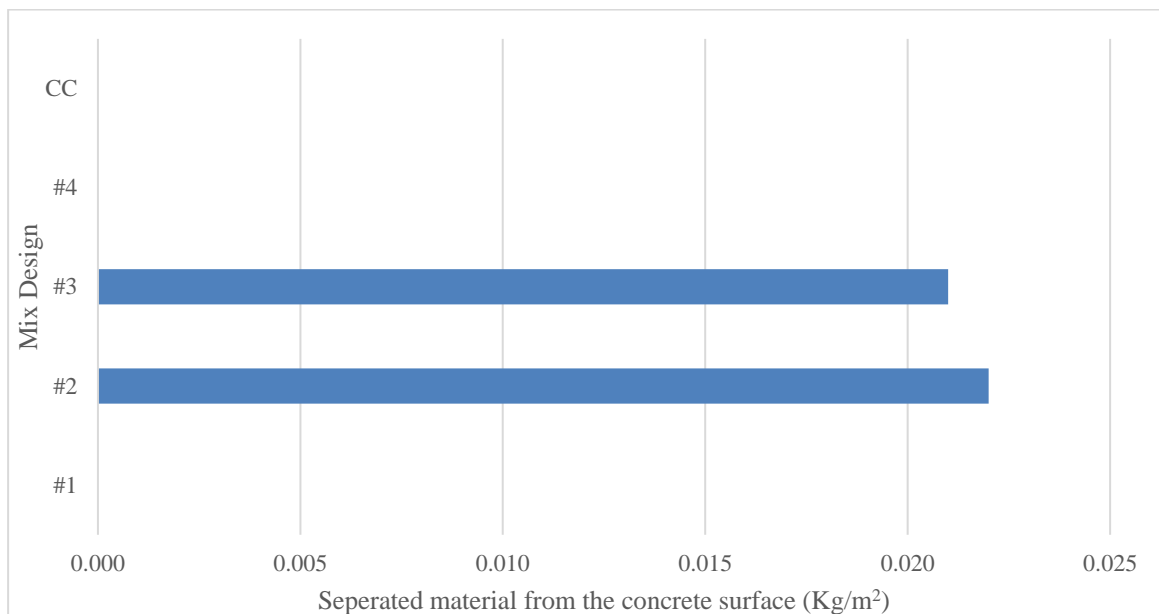


Fig. 13 Freeze-Thaw cycles test results

According to the results of the freeze-thaw cycles test, there was no adverse effect of internal curing using superabsorbent polymers on the durability of concrete in freeze-thaw conditions. Releasing water by superabsorbent polymers to complete the hydration process and leave small bubbles in the concrete, as mentioned in the research results of Bentz *et al.* (2002) and Jensen (2008), increases the resistance of concrete in freeze-thaw conditions. According to the obtained



Fig. 14 Water permeability test device used in this research

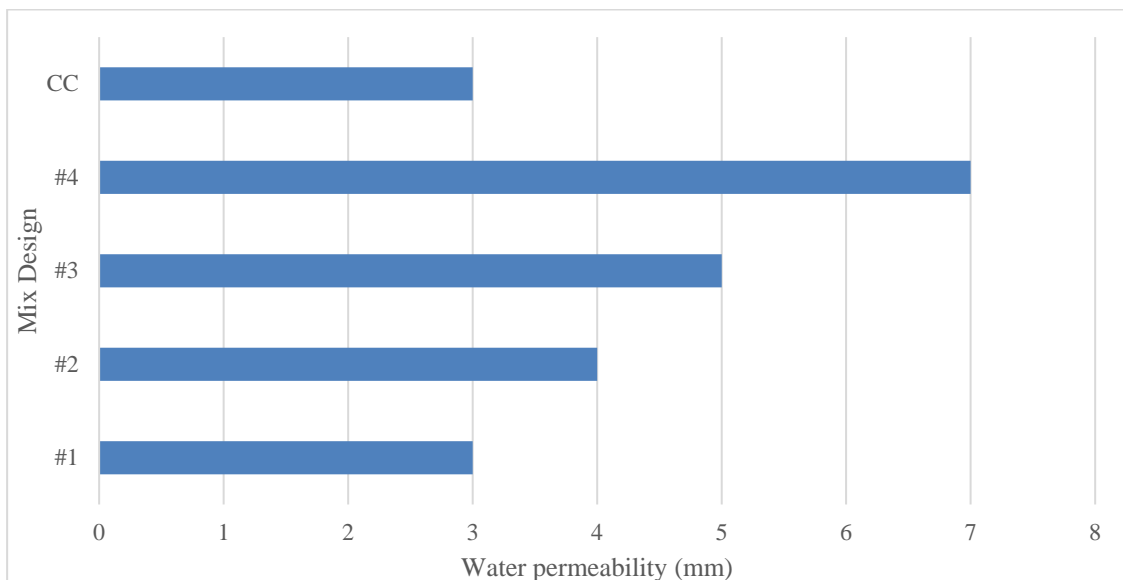


Fig. 15 Water permeability test results

results, investigation and study of the durability of this type of concrete in more severe freeze-thaw conditions can be considered as a subject of future studies.

4.5 Water permeability test

One of the parameters to estimate the durability of concrete and proper curing of concrete is to check the amount of water penetration in concrete. In this research, the amount of water penetration under pressure was measured in SCC samples according to the BS-EN12390-8 standard under 500 Kp pressure and during 72 hours. The device used in this experiment and the results are shown in Figs. 14 and 15.

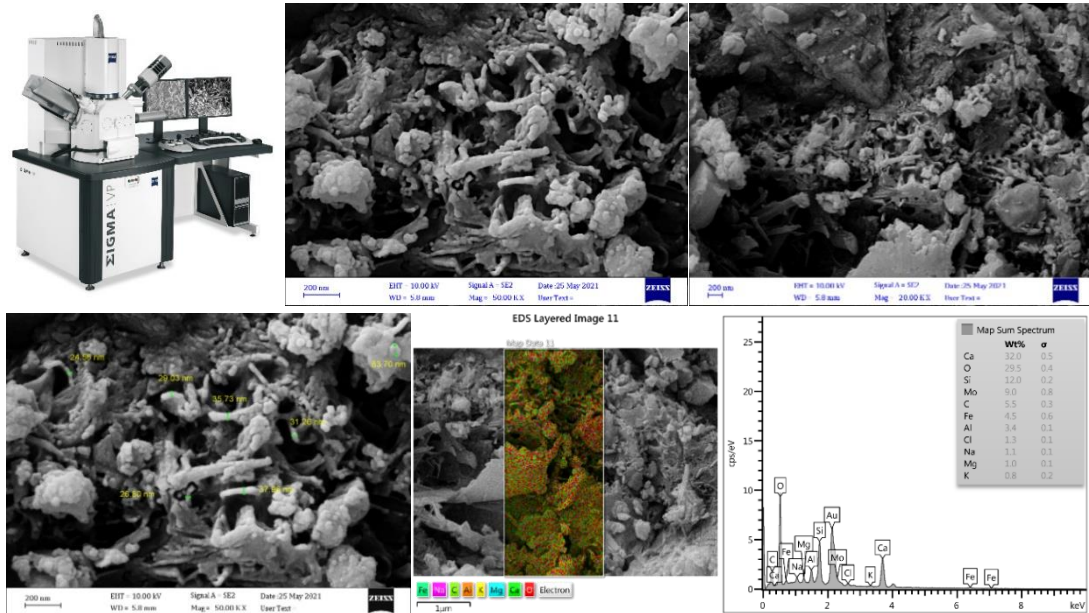
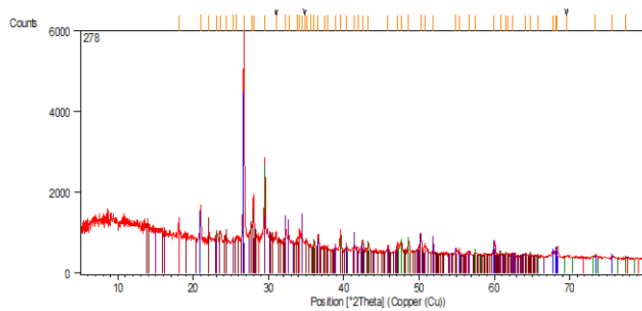


Fig. 16 SEM device and mapping results sample



Pattern List

Visible	Ref.Code	Score	Compound Name	Displ. [°2Th]	Scale Fac.	Chem. Formula
*	98-002-3071	59	Quartz low	0.000	0.623	O2 Si1
*	01-085-0849	52	Calcium Carbonate	0.000	0.304	Ca C O3
*	01-076-0571	30	Calcium Hydroxide	0.000	0.066	Ca (O H)2
*	01-084-0752	22	Sodium Aluminum Si...	0.000	0.131	Na (Al Si3 O8)
*	00-042-0551	29	Calcium Silicate	0.000	0.129	Ca3 Si O5

Fig. 17 XRD device and results sample

By examining the results, it is clear that the samples made and cured using sodium-based superabsorbent polymers in this test show less permeability to water. The amount of reduction compared to potassium based superabsorbent polymers is 40%, 42.9% in the same amount of SAP polymers.

4.6 Microstructure tests

In the conducted research, Scanning Electron Microscopy, SEM, test with EDS, was used for

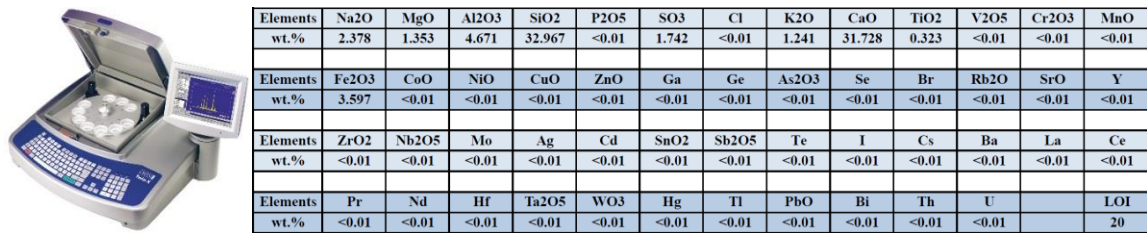


Fig. 18 XRF device and results sample

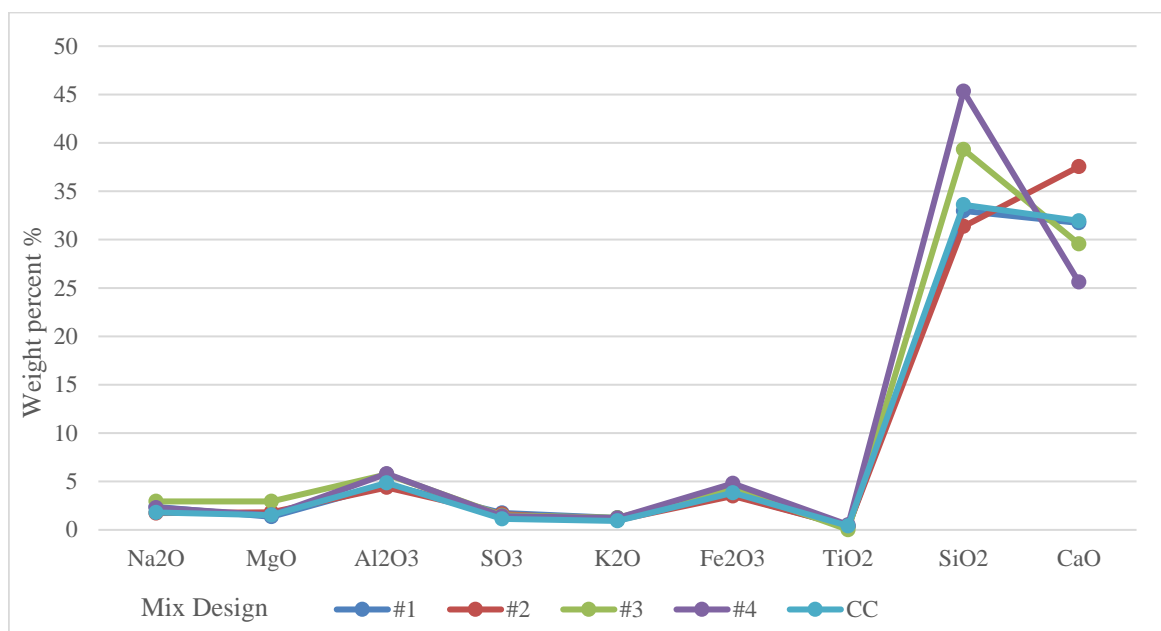


Fig. 19 Effective chemical compounds in concrete to form C-S-H crystal

microscopic imaging of the samples and quantitative analysis of elements. Also X-ray diffraction, XRD, test was used to identify the crystal phase and its characteristics along with X-ray fluorescence spectroscopy, XRF, test to determine the chemical composition in the samples. The SEM, XRD, XRF devices used in this research and the results of the microstructure testing are shown in Figs. 16-18.

Using the information obtained from mapping, the elements, chemical compounds, and their amounts are identified, and based on the important chemical compounds identified in the concrete, the progress of the hydration process is evaluated. Amounts of Effective chemical compounds in the formation of calcium silicate hydrate, C-S-H, crystal structure, such as SiO₂, CaO, Fe₂O₃, and Al₂O₃, have been extracted, analyzed, and compared in Figs. 19 and 20.

Also, equivalent alkalinity based on Na₂O and K₂O compounds have been identified and the results are given in Fig. 21.

Examining the results of microstructure tests showed that the main components of the C-S-H matrix in the samples cured using potassium-based superabsorbent polymers have higher amounts.

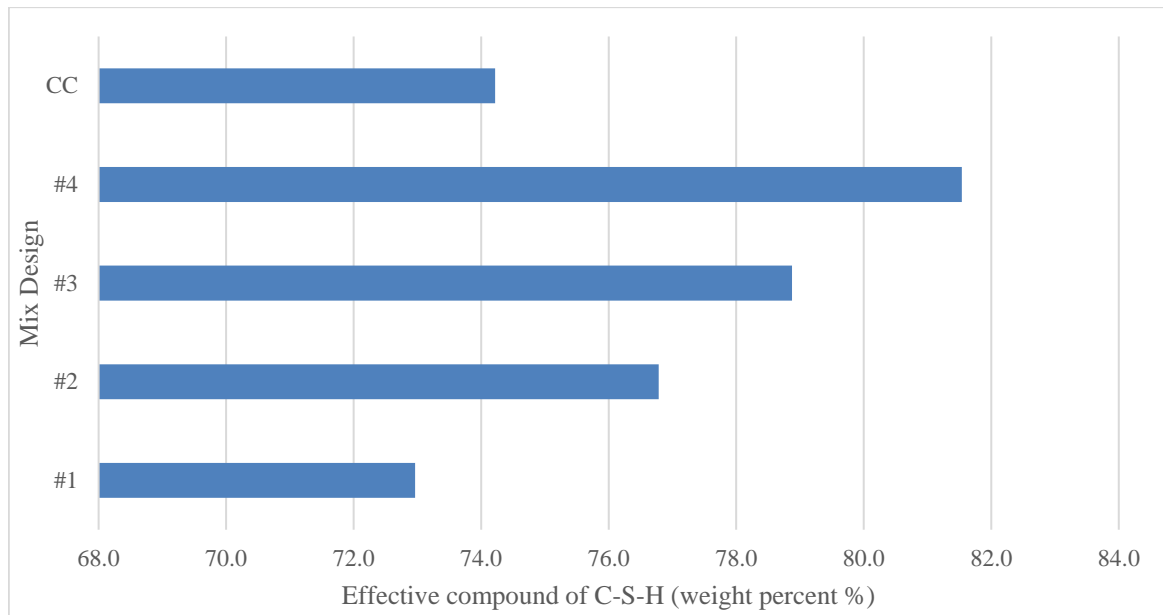


Fig. 20 Effective chemical compounds to form C-S-H crystal

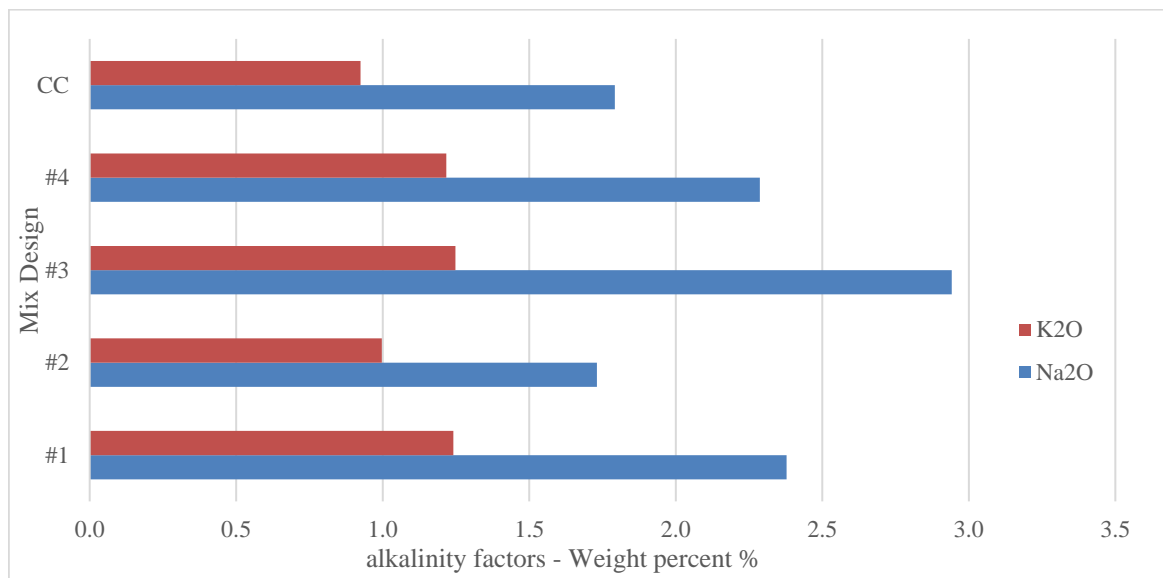


Fig. 21 Amount of equivalent alkalinity factors

This amount increased by 8.1% when using 0.2% potassium-based and 6.1% when using 0.3% sodium-based superabsorbent polymers.

According to the results regarding equivalent alkalinity, it can be seen that by using amounts of 0.2 and 0.3 percent of potassium-based superabsorbent polymers, the effective compounds in

equivalent alkalinity have increased by 17.6 and 29.3 percent compared to sodium-based superabsorbent polymers.

5. Conclusions

The present research was conducted in a laboratory program with the aim of Investigating the effects of using seawater and superabsorbent polymers on the internal curing rate of self-compacting concrete. Internal curing of self-compacting concrete in areas where it is not possible to cure concrete using conventional methods, as well as the possibility of using seawater instead of drinking water as an effective parameter in preserving the environment and fresh or drinking water, are fundamental points of this article and future researchs. After manufacturing, curing, and conducting tests to measure the mechanical, durability, and microstructure parameters of concrete, the main results were obtained as follows:

- Potassium-based superabsorbent polymers, although with coarser graining, have a lower water absorption rate than sodium-based superabsorbent polymers. The maximum amount of water absorption of superabsorbent polymer based on sodium and potassium in drinking water was 231.9 and 189.7 times the weight of the polymer. Meanwhile, these values decrease to 88.5 and 67.3 times when superabsorbent polymers are exposed to seawater. In the ionization solution extracted from cement paste and drinking water, the maximum water absorption of sodium and potassium-based superabsorbent polymers were 54.6 and 46.1 times the weight of the polymers. These values decreased by 23.9 and 17.6 times the weight of polymers by using seawater in cement paste.
- The results of the compressive strength test at the ages of 7, and 28 days show that the internal curing using a potassium-based superabsorbent polymer with 0.2% by the weight of cement had a greater effect on obtaining the compressive strength of concrete. In this case, the increase in compressive strength compared to samples cured using sodium-based superabsorbent polymer at the ages of 7 and 28 days was 15.9% and 12.5%.
- Examining the results of the electrical resistance test on the samples cured using potassium-based superabsorbent polymer also shows the greater effect of internal curing in the process of obtaining resistance and completing the hydration process. The increase in electrical resistance as a result of internal curing using a potassium-based superabsorbent polymer with amounts of 0.2% and 0.3%, compared to sodium, was 25.5% and 19.9%.
- Observation and analysis of freeze-thaw cycles test results show that internal curing of self-compacting concrete using seawater and superabsorbent polymers will not cause a defect in concrete's resistance in freeze-thaw conditions.
- The results of the water permeability test in the samples cured using sodium-based superabsorbent polymer compared to potassium-based polymer, with 0.2% and 0.3% by the weight of cement, have shown a decrease of 40% and 42.9%, respectively.
- Examining the results of microstructure tests and analysis of chemical compounds identified as effective in the structure of C-S-H shows that the hydration process is more evolved using potassium-based superabsorbent polymer. This amount of increase with the use of 0.2% and 0.3% of the potassium-based superabsorbent polymer was 8.1% and 6.2% compared to the sodium-based superabsorbent polymer.

- According to the equivalent alkalinity, based on the identification of Na₂O and K₂O compounds, it is recommended to use low-alkalinity cement to make SCC and conduct an alkaline reactivity test of aggregates.

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