The effect of water containing sodium sulfate ions on strength of concrete of aquaculture ponds and channels

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Abstract

Aquaculture is among the oldest occupations of human being. Over the past quarter of century, the aquaculture industry has grown rapidly. The effect of water containing sodium sulfate on long term compressive strength of concrete of fishing ponds and channels is investigated in this paper. Aim of this paper was to analyze the strength of concrete channels and of aquaculture which are in direct contact with dissolved sodium sulfate. This is an ongoing laboratory investigation which consisted of 480 standard casting concrete cube mix designs and subjecting them to different curing condition environments. Analyzing laboratory results, it was found that for short period of time, the effect was negligible, but for longer periods up to seven months, EC (electrical conductivity) of water had a low negative effect on compressive strength of concrete, while specimens were placed in waters with different ECs. On the other hand, average compressive strength of concrete was almost 25 kg/cm^2 lower than estimated. However, loading the sample concretes up to failure resulted in strength loss of up to 10%. To solve this problem, designed compressive strength must be considered 10% higher than actual in order to have an acceptable concrete strength for water channels and ponds which are in direct contact with sodium sulfate ions in the water.

Keywords: Aquaculture**,** Compressive strength, Concrete, Sodium sulfate, Electrical conductivity, Ponds and channels.

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Introduction

There are many successful fisheries around the world which are well managed, but preventive maintenance is an important issue which must be considered in order to have more successful business in this field. Numerous environmental factors like pollution, climate change, and acidification are main reasons for collapse of oceans (Jacques, 2015). Fishery as a common-pool resource is a complicated business which has numerous common problems which affect other fishermen's life style (Emery *et al.*, 2015; Katikiroa *et al.*, 2015).

Concrete has a major initial cost in aquaculture pond construction which must be considered by many investors. Coastal fisheries require obeying government regulations in many countries (Jentoft, 2007; Berghofer *et al.*, 2008). But private aquaculture using farms needs less government regulations. Bycatch is a major problem for many fisheries in many countries too (Abbott and Wilen, 2009; Holland and Jannot, 2012). Holland (2010) believed bycatching in fishery is the major problem globally either for individuals or for industry sector. There are also many literatures on fishery policy and management, but there is no research regarding quality of concrete for ponds or channels. Ovando *et al.* (2013) believe that most studies either provide high level theoretical treatments of cooperation or provide detailed, descriptive information for a selected region or type of fishery. Surprisingly, there is no research about effect of different dissolved ions on concrete used in aquaculture construction.

In this study, an attempt was made to study the effects of water with different ECs on compressive strength of concrete (CRT). Concrete is basically a mixture of two components, aggregates and paste. The paste, comprised Portland cement and water, binds the aggregates (sand and gravel or crushed stone) into a rocklike mass (Ksmatka and Panaresa, 1988). In order to study the effects of water with different ECs resulting from sodium sulfate on physical properties of concrete for aquaculture purpose, the compressive strength of concrete should be evaluated in different conditions.

The concrete samples for testing should be placed in water with different ECs. The general assumption is that whether the water with the EC resulting from sulfate has any effect on the strength of concrete in the long run or not. However in practice it can be understood that water with different ECs resulted from sulfate may have effects on the structures, such as ponds or concrete pipes and channels.

The most important parameter in the project was to determine the effect of ECs of water on the compressive strength of concrete. And this requires testing all specimens of concrete in a specific period of time.

One important feature of water is EC. When concrete tanks, ponds, and pipes are in contact with waters with different ECs, the effect of EC on compressive strength should be investigated. However, the ions formed by EC would influence the concrete. The factors affecting EC are anions and cations, CO_3^- HCO_3^-, Cl^- and SO_4^{2-} are anions and Ca^{2+}, Mg^{2+}, Na^+ and K^+ are cations.

In this project, the effect of sodium sulfate existing in water on the compressive strength is studied, in general, the effects of water with different ECs is discussed. The compressive strength is usually measured in periods of 7, 14, 21 and 28 days; however

for this research work, in order to study the long-lasting effect of EC resulted from sodium sulfate more carefully, the concrete specimens were studied for periods of 2, 3, 4, 5 , 6 and 7 months.

Concrete samples were of the same type and quality. For this laboratory research the specimens were placed in water with different ECs for different periods of time. This laboratory research was done in the city of Yazd in central desert part of Iran which is in shortage of water. An amazing method of transferring underground water to the surface was developed by Persians (Iranians) for drinking and agriculture purposes using qanats which are sustainable and green without polluting the environment (Mostafaeipour, 2010). There are many other research works related to using renewable and sustainable energy in Iran for generating clean energy in Iran which could pump underground water to the surface without using fossil fuel for aquaculture purposes (Mostafaeipour, 2010; Mohammadi and Mostafaeipour, 2013; Mostafaeipour *et al*., 2013; Dinpashoh *et al*., 2014; Khorasanizadeh *et al*., 2014; Mohammadi *et al*., 2014; Mostafaeipour *et al*., 2014).

In this study, a total amount of 480 cubic concrete specimens were made with the same mix design and quality of 300kg/cm^3 cement content. Then specimens were placed in waters with eight different ECs, ranging from zero to 18000 micro siemens per centimeter. The cubic CRT specimens were tested for compressive strength in periods of 7, 14, 21 and 28 days. Also for better results, more samples were tested in 2, 3, 4, 5, 6 and 7 months.

Rahman *et al*. (2012a) conducted a study to improve water quality by using duckweed and lime in order to increase fish production. Rahman *et al*. (2012 b) indicated that use of duckweed and lime is economically sustainable.

Reinforced concrete durability is evaluated by testing the capability of concrete cover to protect steel reinforcement from corrosion (Thomas, 1991). It is also reported that concrete's high alkalinity causes chemical protection (Rosenberg *et al*., 1989). Steel reinforcement corrosion is the most common cause of failure in concrete structures (Swamy, 1988; Masuda, 1991). Purpose of this study is to analyze compressive strength on concrete, not steel. Sulfate is the main problem for durability of concrete. Clearly, there are sulfates in soil, ground water, and seawater which reacts with various phases of hydrated cement paste such as C_3A and $Ca(OH)_2$, leading to expansion, cracking, and strength reduction. Sulfate resistance improvement of concrete was studied by many researchers. In order to improve the sulfate resistance of concrete, pozzolans such as fly ash, silica fume, and natural pozzolan can be used (Irassar *et al*., 2000; Thomas and Savva, 2001; Jaturapitakkul *et al*., 2007).

Jaturapitakkul *et al*. (2007) investigation showed that C_3A is not the sole parameter responsible for expansion due to sulfate attack.

Gonzalez and Irassar (1977) studied the attack of sulfate on four cements with low C_3A content (0–1%) and a C_3S content of 40–74%. Their results showed greater expansion for cement mortar with a higher C_3S content. According to some studies, it is found that the type of cement with different C_3A contents does not have much effect on sulfate resistance (Cohen and Bentur, 1988; Al-Amoudi *et al*., 1995; Jaturapitakkul *et al*., 2007). Some works are

conducted on underwater structures or structures in tidal zones under real condition (Sandberg *et al*., 1998; Andrade *et al*., 2000; Tang and Anderson 2000; Meira *et al*., 2007).

Purpose of this study is to determine and evaluate effect of water containing sodium sulfate ions on concrete strength for aquaculture ponds and channels. This paper presents laboratory research work involved in measuring compressive strengths of concrete samples with different properties containing various percentages of sodium sulfates dissolved in the water surrounding concretes for different periods of time.

Materials and methods

Properties of materials
Concrete samples used for this experiment, were made from ordinary Portland cement (Type I), fine aggregate, and coarse aggregate. The maximum size of coarse aggregate was 20 mm and that of fine aggregate was 4.75 mm. Besides, normal tap water (pH= 6.8) was used as mixing water and for curing with ECs of less than 300 micro siemens.

Cement
Portland cement type I was used in this study. The chemical and Bogue compositions calculated according to ASTM C 150 (ASTM, 2001; Jaturapitakkul *et al*., 2007) are given in Table 1.

Table 1: Chemical composition of Portland cement.

Chemical composition (%)	Portland cement type I
Silicon dioxide (SiO_2)	20.4
Aluminum oxide (Al_2O_3)	4.5
Iron oxide (Fe_2O_3)	3.4
Calcium oxide (CaO)	65.2
Magnesium oxide (MgO)	1.4
Sodium oxide (Na_2O)	0.4
Potassium oxide (K_2O)	0.4
Sulfur trioxide (SO_3)	3.1
Loss on ignition (LOI)	1.1

Aggregate
Sand is a major component in concrete mixes. Sand from natural gravel deposits or crushed rocks is a suitable material used as the fine aggregate in concrete production (Al-Harthy *et al*., 2007).

In many desert regions, there is abundance of very fine natural sands known as dune sands (Al-Harthy *et al*., 2007). Banfill and Carr (1987) have studied the effect of very fine sand dredged from river estuaries on concrete mixtures. It was found that as the sand content increases, the water required for a given workability increases. Guettala *et al*. (1997) have compared strength properties of mortar mixes made

with conventional sands and dune sand. Kay *et al*. (1994) also investigated the potential of using dune sand as fine aggregates in concrete. Laquerbe *et al*. (1995) studied the effect of using laterite gravel and dune sand as aggregates for concrete. The researchers reported the use of offshore sand, which is considered as the most viable alternative for river sand, with respect to availability, ease of extraction, environmental impact and cost (NSSSL, 1992; Dias, 2000; Dias *et al*., 2008).

For this work, local river sand with a fineness modulus of 2.82 was used as a fine aggregate. Crushed limestone was used as a coarse aggregate, with a maximum size of

20 mm. The fine and coarse aggregates had specific gravities of 2.48 and 2.52, and water absorption of 0.63 and 0.46%, respectively.

Water
Drinking water with EC of 300 micro siemens was used to make concrete samples. Therefore, all the samples had same properties.

Concrete mixture proportion
Since all concrete specimens were of the same quality, it was concluded that concrete with a compressive strength of 300 kg/cm^2 could be prepared in different ways. The plan according to which the concrete mixture was prepared in the laboratory was as follows:

Table 2: materials used to make 40 cubic samples of CRT.

Material	Amount
Coarse aggregate	750 kg
Fine aggregate	1100 kg
Cement	300 kg
Water	Necessary for slump 10

Curing condition
Ambient atmospheric conditions can adversely influence thermal and moisture structure of freshly poured concrete. If concrete becomes too warm or temperature gradients too large during the first several days after the concrete is poured, or if there is insufficient water in the concrete, the concrete may crack or may not develop its maximum potential strength, reducing its long-term durability (Neville, 1996; Naderi *et al*., 2009).

There existed a lot of barriers to the research, choosing a basin or pond in which specimens could be kept in water with different ECs resulted from sodium sulfate. To solve the problem, the issue was discussed with some concrete manufacturers, but they were unwilling to help. The reason why a laboratory was selected for the research was that the specimens could be placed under the pressure jack at the laboratory immediately.

Therefore, there was a drop in the cost of transportation.

A big problem was removed, but another problem was preparing the water with different ECs which had to be kept for curing of specimens. The employed curing regimes were chosen based upon ACI standards, and all specimens were kept in same physical conditions, they were stationed in the concrete laboratory, and the temperature of the environment was recorded at different periods of time. During the whole curing period, temperature of the room was measured between 14 and 22˚C.

Research methodology
The methodology of this project was designed in a way that the water with ECs resulted from different percentages of sodium sulfate was studied. Water with different percentages of sodium sulfate (Table 4) was divided into 7 groups for this study.

Table 4: properties of water in different containers.

Sample	Electrical conductivity (EC)
1	0-3000
2	3000-6000
3	6000-9000
4	9000-12000
5	12000-15000
6	15000-18000
7	>18000

After water was prepared according to the above – mentioned properties, 800 specimens of concrete of the same properties and qualities were prepared and put in basins full of water with different ECs.

At the end of each period, compressive strength was performed on each capped specimens. Cement, gypsum and sulfur pastes can be used as a capping material as recommended in ASTM C617. Sand paper also can be used at the surface of the specimens too (Topc¸ 1997; Wasserman and Bentur, 1997; Mun, 2007). Capping was not used for cubic samples (15cm × 15 cm × 15cm) in this research work, because it can be used for cylinder shape samples.

The concrete specimens were designed to be cubic, and they were put under the pressure jack for periods of 7, 14, 21 and 28 days according to the standards and their compressive strength were measured. In order to get accurate results, the specimens were tested for longer periods of time such as 3, 4, 5, 6 and 7 months. It should be noted that for each period of time defined according to Table 5, a series of concrete specimens were placed in the water with the EC belonging to the drinking water, and then they were compared with each other.

Table 5: Period for testing the concrete samples.

Period									
Day	7	14	21	28					
Month					2	3	4	5	6	**7**

Water for curing periods

This was the main part of project and eight basins with different ECs were selected according with Table 6. Clearly, aim of this study was to analyze the effect of water with different ECs on compressive strength of cubic CRT specimens. Therefore, there were six different water samples ranging from zero to 18000 EC. There was also one sample with EC of more than 18000 EC. Saturation point for sodium sulfate in water results in EC amount of 18000 for sample of EC7. Drinking water was denoted as EC8 which was mainly for comparison and final analysis of the specimens.

Table 6: Water for curing.

EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8
Zero	3000	6000	9000	12000	15000	More	Drinking
to	to	to	to	to	to	than	Water up to
3000	6000	9000	12000	15000	18000	18000	300

Water composition with different ECs
ECs of water in different barrels were measured. At the beginning, 14 of 160 liter basins full of drinking water with different ECs and one 200-litre basin full of drinking water were selected.

The 160 liter basins were numbered, each one contained water with specific ECs according to Table 8.

No. 1 and 2 contained water with EC ranging from 0 to 3000, each two basins contained water with specific EC, but basin number 15 was filled up with pure drinking water with EC of about 300. Characteristics of water and the number of basins both are mentioned in Table 7.

Table 7: EC of water in different barrels.

Barrel No	1	2	3	4	5	6	7	8	9	10
Min EC	0	0	3000	3000	6000	6000	9000	9000	12000	12000
	To	to	to	to	to	to	to	to	to	to
Max EC	3000	3000	6000	6000	9000	9000	12000	12000	15000	15000

Table 8: EC of water in different barrels (Continue).

Barrel No	11	12	13	14	15
Min EC	15000	15000	18000	18000	
	to	to			300
Max EC	18000	18000			

Followings are different steps for determination of EC and the amount of sodium sulfate needed to add to the water for the purpose of attaining desirable EC ranges:

Stage 1
The initial amount of EC of each basin was measured to be 300.

Stage 2
The amount of sodium sulfate needed to attain different ECs was calculated so the weight of sodium sulfate required for 1 liter of drinking water was measured.

Stage 3

The required sodium sulfate was added to the water, then the ECs of the basins were measured.

Stage 4
The required amount of sodium sulfate was again modified, and finally the amount of required sodium sulfate basin was measured.

Results
The present study was conducted to analyze compressive strength at different periods of time up to seven month.

Analysis of compressive strength at different periods of time

The results indicating the average amount of compressive strength for periods of 7, 14, 21 and 28 days as well as the periods of 2, 3, 4, 5, 6 and 7 months for different ECs were analyzed. It should be noted that the specimens were specified based on the amount of ECs and the following table:

Table 9: EC of water for different barrels.

Specimen No.	Electrical conductivity (EC)
1	0-3000
2	3000-6000
3	6000-9000
4	9000-12000
5	12000-15000
6	15000-18000
7	>18000
8	Max 300

Six concrete specimens were prepared for testing EC of each water sample for each period. Also in order to compare the specimens exposed to the water with different ECs; six specimens were placed in the drinking water for each EC range to be tested in different periods up to 7 months. Average of compressive strength belonging to the concrete specimens in drinking water was also calculated. According to Table 10, there were 7 specimens with different ECs available and sample No. 8 belongs to drinking water. The range of EC belonging to each specimen was specified. Totally 800 specimens of cubic concretes were prepared for analysis in this research work.

Table 10: Average compressive strength of cubic samples at different time.

	EC=1	EC=2	EC=3	EC=4	EC=5	EC=6	EC=7	EC=8
7 Days	102	103	108	118	106	107	108	111
14 Days	195	193	192	190	185	188	180	199
21 Days	215	213	212	211	214	203	208	219
28 Days	221	220	219	211	219	218	217	232
2 Months	270	263	263	260	261	258	251	270
3 Months	292	288	278	282	276	256	256	294
4 Months	297	295	292	290	287	295	280	308
5 Months	314	307	298	301	290	289	283	314
6 Months	318	311	304	304	300	309	302	322
7 Months	319	315	308	308	293	310	305	323

7 days

According to Table 11, the average compressive strength of the specimen number 8 (drinking water) was 111 kg/cm^2 and the average for compressive strength of the other specimens were 107.43 kg/cm^2.

14 Days

The average compressive strength of drinking water was 199 kg/cm^2 and the average compressive strength of the other specimens was 189 kg/cm^2.

21 Days

The average compressive strength of drinking water was 219 kg/cm^2 and the

average compressive strength of the other specimens was 210.86 kg/cm^2.

28 Days
The average compressive strength of drinking water was 232 kg/cm^2 and the average compressive strength of the other specimens was 217.86 kg/cm^2.

2 Months
The average compressive strength of drinking water was 270 kg/cm^2 and the average compressive strength of the other specimens was 260.86 kg/cm^2.

3 Months
The average compressive strength of drinking water was 294 kg/cm^2 and the average compressive strength of the other specimens was 275.29 kg/cm^2.

4 Months
The average compressive strength of drinking water was 308 kg/cm^2 and the average compressive strength of the other specimens was 290.86 kg/cm^2.

5 Months
The average compressive strength of drinking water was 314 kg/cm^2 and the average compressive strength of the other specimens was 297.43 kg/cm^2.

6 Months
The average compressive strength of drinking water was 322 kg/cm^2 and the average compressive strength of the other specimens was 306.86 kg/cm^2.

7 Months
The average compressive strength of drinking water was 323 kg/cm^2 and the

average compressive strength of the other specimens was 308.29 kg/cm^2.

From information presented in Table 10, which is based upon average compressive strength of cubic samples at different times, it is concluded that compressive strength of specimens with different EC at different periods of time was less than that of specimens placed in drinking water. The compressive strength of concrete decreased almost 10% while EC of water increased.

Discussion
Analysis of compressive strength of samples with different ECs
Each chart refers to a particular period of time, the horizontal axis shows different EC and vertical axis the compressive strength based on kg/cm^2. There are eight different charts; each one is related to a specific EC. In other words, the first chart refers to the EC number 1 and all specimens were placed in the water with ECs ranging from 0 to 3000.

Analysis of concrete samples with EC of up to 3000 (EC=1)
All of the samples placed in basins numbered 1 and 2 were analyzed, and the EC of water ranges from 0 to 3000. The horizontal axis indicates the time at which the specimens were tested and the vertical axis shows the compressive strength of specimens in kg/cm^2. Ten periods of time were selected for breaking the specimens, such as periods of 7, 14, 21 and 28 days and the others are arranged at periods of 2, 3, 4, 5, 6 and 7 months.
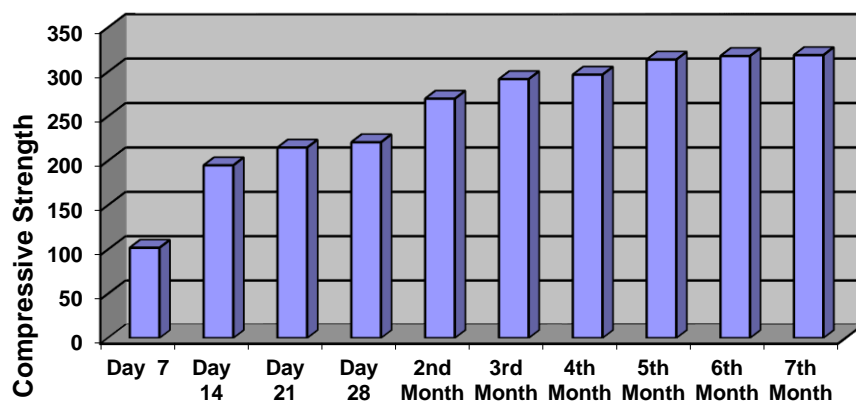
Figure 1: Compressive strengths of samples placed in water with EC from 0 to 3000.

Fig. 1 indicates average of compressive strength in the specified periods of time. The average compressive strength of the specimens placed in the water with the EC ranging from 0 to 3000 was calculated on the seventh days up to period of 7 months (Fig. 1). The results are acceptable because the compressive strength increased and acquires 300 kg/cm^2. After five months, the amount of strength is little more than 300 kg/cm^2, since then the amount becomes somehow constant. The reason why there is delay in the attainment of the final strength is that the temperature at which concrete was preserved was lower than 23 degrees centigrade. Since the study was intended to study the effect of EC on the strength of concrete. Moreover, the EC of water

preserving the concrete doesn't have a lot of effect on the final strength of concrete.

Analysis of concrete samples with EC from 3000 to 6000 (EC=2)

The specimens were placed in the basins 3 and 4 were analyzed. Moreover, the specimens are specified as having EC2 and the EC ranges from 3000 to 6000. The horizontal axis indicates the time at which the specimens were tested and the vertical axis refers to the compressive strength of specimens. Ten periods of times were selected for breaking the concrete samples such as 7, 14, 21 and 28 days, and the rest were arranged at periods of 3, 4, 5, 6 and 7 months.
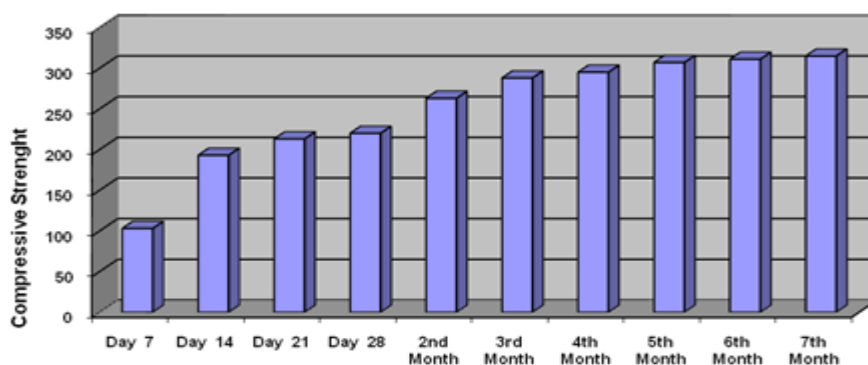

Figure 2: Compressive strengths of samples placed in water with EC from 3000 to 6000.

While concrete specimens were placed in the water with EC ranging from 3000 to 6000, the compressive strength was increasing. The average strength was increasing (Fig. 2) and in the fifth month it remained somehow constant and reaches up to 300kg/cm². Moreover, according to the finding, the EC of water used to preserve the concrete does not have any effect on the strength of concrete.

Analysis of concrete samples with EC from 6000 to 9000 (EC=3)

Basins 5 and 6 were used for analyzing the whole cubic concrete samples. The specimens were specified as having EC3 and the EC ranges from 6000 to 9000. The horizontal axis indicates the time at which the specimens were tested and the vertical axis refers to the compressive strength of specimens. Ten periods of times were selected for breaking the specimens such as 7, 14 , 21 and 28 days, and the rest were arranged at periods of 3, 4, 5, 6 and 7 months. The compressive strength test was done on the concrete specimens placed in the water with EC ranging from 6000 to 9000; the results are shown in Fig 3.
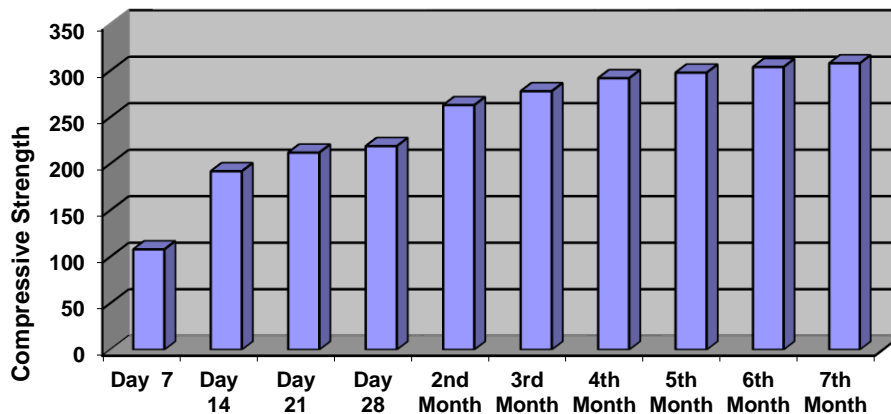
Figure 3: Compressive strengths of samples placed in water with EC from 6000 to 9000.

The final strength has gained its value from the sixth month and since then; it was constant and had the value of almost 300 kg/cm². There was a delay in gaining final strength, because of lower temperature of the environment which the samples were kept. Moreover, according to the finding, the EC of water used to preserve concrete does not have any effect on the strength of concrete.

Analysis of concrete samples with EC from 9000 to 12000 (EC=4)

All the specimens placed in the basins 7 and 8 were analyzed. Moreover, the specimens are specified as having EC4 and the EC ranges from 9000 to 12000.
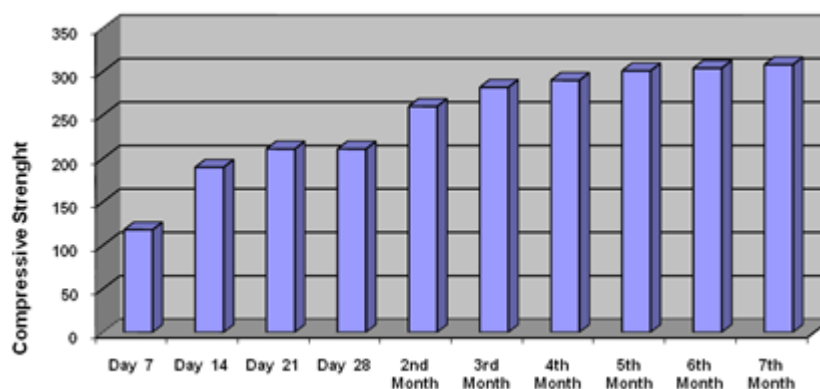
Figure 4: Compressive strengths of samples placed in water with EC from 9000 to 12000.

The final strength has gained its value from the fifth month and since then it was constant and had the value of almost 300 kg/cm^2. There was a delay in gaining final strength, because of lower temperature of the environment which the samples were kept. Moreover, according to the finding, EC of the water used to preserve concrete does not have any effect on the strength of concrete.

Analysis of concrete samples with EC from 12000 to 15000 (EC=5)
All specimens placed in the basins 9 and 10 were analyzed. Moreover, the specimens are specified as having EC5 and the EC ranges from 12000 to 15000. The final strength has not gained its final value of 300 kg/cm^2. But it was almost close to 300 kg/cm^2 in 6th month.
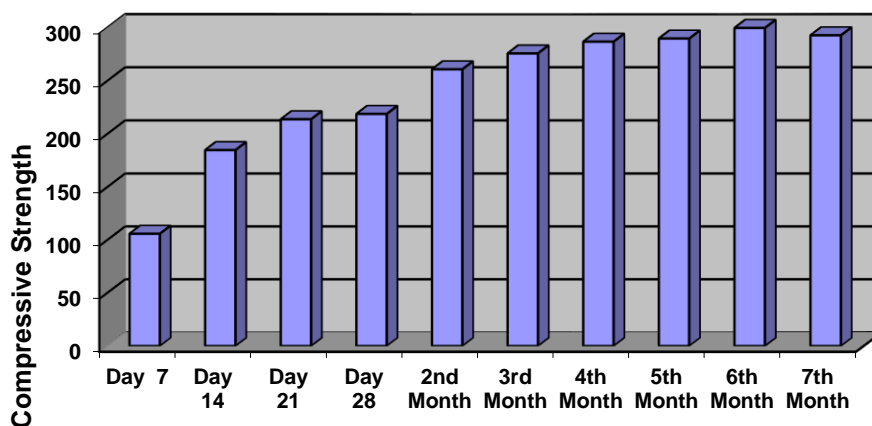

Figure 5: Compressive strengths of samples placed in water with EC from 12000 to 15000.

Analysis of concrete samples with EC from 15000 to 18000 (EC=6)
All specimens placed in the basins 11 and 12 were analyzed. Moreover, the specimens are specified as having EC6 and the EC

ranges from 15000 to 18000. The final strength has not gained its final value of 300 kg/cm^2. But it was almost close to 300 kg/cm^2 in 6th, and 7th month.
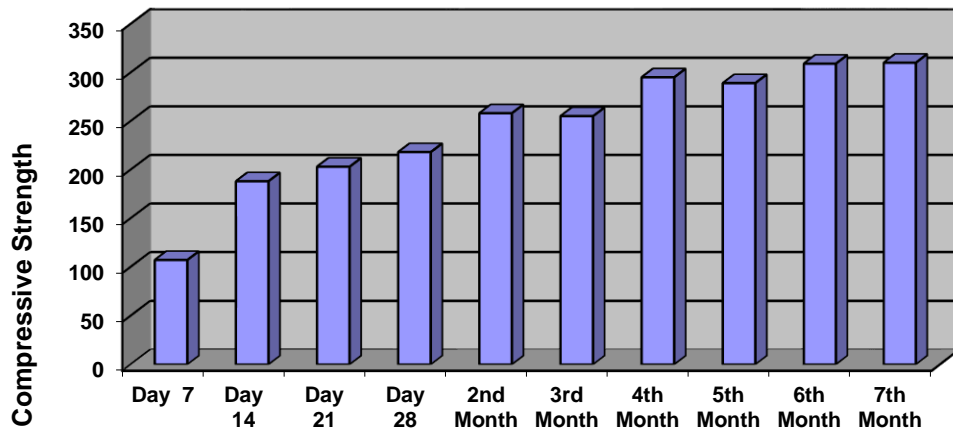
Figure 6: Compressive strengths of samples placed in water with EC from 15000 to 18000.

Analysis of concrete samples with EC from 3000 to 6000 (EC=7)
All specimens placed in the barrels 13 and 14 were analyzed. Moreover, the specimens are specified as having EC7 and the EC of

the water was exactly 18000 or a little bigger. According to the findings, the final strength was gained after 6 months and it was almost same for 7th month.
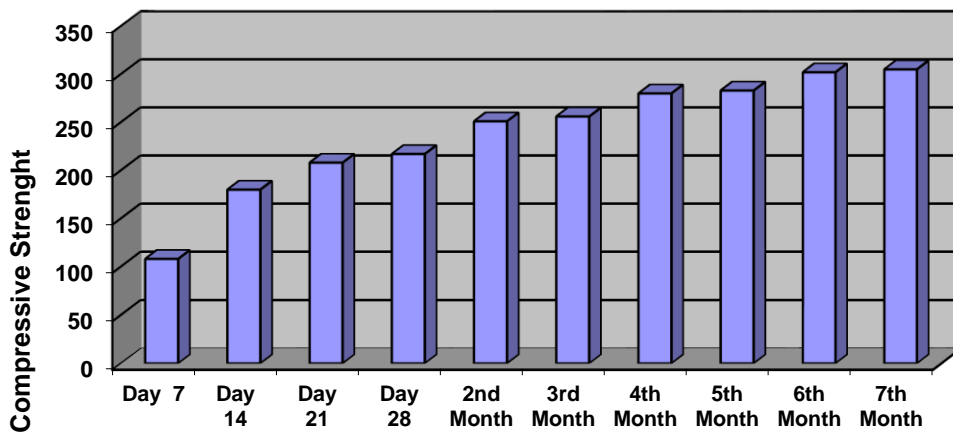

Figure 7: Compressive strengths of samples placed in water with EC equal or more than 18000.

Analysis of concrete samples with EC of up to 300 (EC=8)

All specimens placed in the basin number 15 were analyzed and they were defined as EC8.
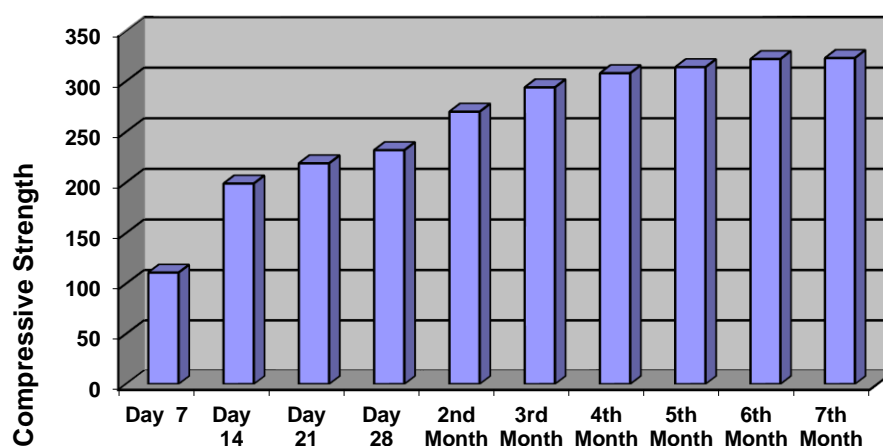
Figure 8: Compressive strengths of samples placed in water with EC of max 300.

The basin contained drinking water was regarded as an index for making a comparison among specimens. The compressive strength increased and it reached up to 308 kg/cm^2 after 4 months and it was 314, 322 and 323 kg/cm^2 accordingly for 5th, 6th and 7th months.

Water in which the specimens were kept was drinking water; it had the EC of 300. Fig. 8 indicates the results obtained from the breakage of concrete specimens. It can be concluded that the concrete samples reached their final compressive strengths after 4 months, which it is acceptable. There is a delay for attainment of the final strength due to the temperature which was below 23˚C since all the specimens were in the same condition.

Compressive strength of the samples at different periods of time
The compressive strengths of the specimens placed in the water with different ECs were analyzed at different periods of time. The compressive strength was increasing and the final strength of all specimens was equal to that of anticipated value that is 300kg /cm^2. The waters with different ECs don't have a lot of effect on final strength of concrete. It should be noted that by increasing EC of the water, the final compressive strength of concretes decrease slightly by almost 10% if we compare all data with the index data of Fig. 8. Fig. 9 clearly shows that EC8 gained the highest compressive strength among other samples. It is true that designed strength was 300 kg/cm^2, but in fact the concrete samples gained more strength than designed. Comparing data of EC8 with other ECs indicate that sodium sulfate has a little negative effect on compressive strength of concrete.
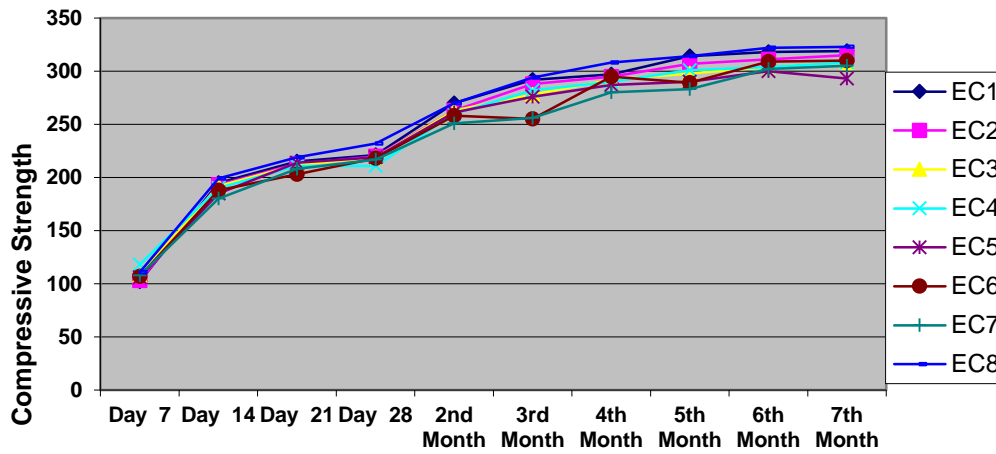
Figure 9: Compressive strength of the samples at different periods of time.

In short periods of time, there was not much difference between average strength of the tested specimens in waters with different ECs and drinking water. In longer periods of time, the differences become more significant, that is, compressive strength of specimens placed in the water with more ECs becomes slower. Even during a period of seven month the strength was under 300 kg/cm^2. In general, EC of the water has a negative effect on compressive strength of concrete, but there is a slight effect. In order to resolve the problem, concrete with higher degree of strength can be made. If concrete with strength of 300 kg/cm^2 is needed, higher strength must be designed to make up for the reduction of the strength. However, there is slight average reduction of strength that is 25 kg/cm^2 and it can be resolved by increasing the design value by 10%.

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