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Compressive Strength of Concrete Mixed and Cured with Different Ratios of Fresh and sea Water

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Abstract: **By 2025, there will be insufficient drinking water according to a report of the world meteorological organization (WMO). In order to provide drinking water it was found that the use of seawater in the concrete industry was necessary. Researchers in the last decade's findings have revealed some very important facts, but still it remains to be a dynamic subject for further study about the chemical deterioration of concrete for sea water used. This research presents an experimental study of the effect of sea water in concrete mixture, Totally 57 specimens (27cubes, 18cylinders, 12columns) where tested. The concrete cubes were going to be cured for 7, 28 and 96 days. The cubes were divided into three groups, group (A) concrete is mixed and cured in fresh water (FF). Group (B) was mixed and cured in seawater (SS), while group (C) mixed in fresh water and sea water (FS) by 50%. From the experimental results it was found that, The compressive strength in concrete mix B (SS) was higher than concrete which mix A (FF) and mix C (FS) by 31% and 7% at age 7 days, but at age 28 days the compressive strength in concrete mix A (FF) was higher than concrete which mix B (SS) and mix C (FS) by 4% and 10%, and at 96 days the compressive strength in concrete mix A (FF) was higher than concrete which mix B (SS) and mix C (FS) by 13% and 18%, due to the chloride contains tends to accelerate the setting of cement and may be due to salt crystallisation formation facing the strength gain.**

Keywords: **Columns; Sea water; Fresh water; GFRP-reinforced concrete; Fire, Compression behaviour.**

1. INTRODUCTION

Concrete has an excellent structural performance and durability, but is affected by early deterioration when subjected to a marine environment. The most common cause of deterioration is corrosion of the steel reinforcement, with subsequent sapling of concrete. Therefore the selection of materials, mix design, and proper detailing of reinforcement are essential parameters in producing a durable marine structure concrete. Construction engineering in coastal areas are facing the challenge of shortage of fresh water for mixing and curing. The quality of water places an important role in the setting and strength development of concrete structures. At least sea water can be adopted in the construction industry as an alternative ingredient to potable water particularly in the coastal region may be the construction exposed to seawater. But Combining of seawater in the concrete mixing of the concrete columns and reinforced with glass fiber polymer (GFRP) gained wide acceptance as an alternative material for steel in applications where steel is subjected to high risk of corrosion, Several products of FRP are commercially available in worldwide for the use in different civil engineering applications. A variety of fiber-reinforced polymers (FRP), Glass, Aramid and Carbon are now available in form of bars. Glass fiber reinforced polymer (GFRP) bars with many advantageous characteristics, GFRP is of high strength and high chemical resistance and it is relatively low cost when compared to other fiber-reinforced polymers such as carbon FRP, Adequate mechanical characteristics and superb corrosion resistance.

The weight of FRP bars is about one-fourth that of conventional steel, the tensile stress-strain relationship of GFRP bars is linear elastic up to failure. GFRP bars possess higher tensile strength but lower modulus of elasticity and ultimate tensile strain when compared to steel bars. The high temperature levels initially influence the concrete and then the reinforcement bars. Appropriate design of each concrete part may improve concrete behavior against high temperature effects. The action of FRP rebar reinforced concrete is very distinct from traditional reinforced concrete under fire exposure. The chemical reactions of seawater on concrete are mainly due to the attack by magnesium sulphate (MgSO4). The mode of attack is crystallisation. Potassium and magnesium sulphates (K2SO4 and MgSO4) present in salt water can cause sulphate attack on concrete because they can initially react with calcium hydroxide Ca(OH)2, which is present in the set cement formed by the hydration of dicalcium silicate (C2S) and tricalcium silicate (C3S). The attack of magnesium sulphate (MgSO4) is particularly damaging, forming soluble magnesium hydroxide (Mg(OH)2), which forces the reaction to form gypsum.

2. PREVIOUS RESEARCH

Olutoge, F. Adeyemi and Amusan (2014) [(1)] studied the effect of sea water on the compressive strength of concrete, mixed and curing sea and fresh water, they studied the compressive strength in case of sea and fresh water. A number of 140 concrete sample cubes of 150mm * 150mm * 150mm, All the mixes were prepared using constant water cement ratio (w/c) of 0.6 by weight. The cubes specimens were cured in fresh water and sea water for 7, 14, 21, 28, and 90 days, at 7 days the maximum compressive strength was represented in case of SF, at 14 days test the maximum compressive strength in case of SS, at 21 days test the maximum compressive strength in case SS, at 28 days test the maximum compressive strength in case SS, at 90 days test the maximum compressive strength in case SS, they showed that concrete strength casted and cured with seawater increases gradually. **Falah M. Wegian (2010)** [(2)] studied using seawater for mixing and curing on structural concrete, sixteen concrete mixes, six groups mixed and cured with fresh water and other six group mixed and curing with seawater, the last four groups mixed with fresh and cured by seawater. Slandered cubes 150mm * 150mm * 150mm used for compressive strength and also the cylinder 150mm * 300mm was used for split and flexural, to split test they used high tensile steel bar with 30mm diameter, The results suggest that aggregates should have a good grading and must be resistant against strong chloride solutions and alkali aggregate reactions since deleterious aggregates can react to the penetrating saltions if the paste does not provide protection against the diffusion of chlorides and the alkali aggregate reaction, They showed that at 7, 14 days concretes mixed and cured in seawater have higher compressive, tensile, flexural and bond strengths than concretes mixed and cured in fresh water, the strengths after 28 and 90 days for concrete mixes mixed and cured in fresh water increase in gradual manner, The reduction in strength increase in exposure time may be due to salt crystallization. **B.Sathish kumar1, P.Samuthirapandiyan2 (2018)** [(3)] studied the effect of sea water on the strength of concrete as compressive, flexural, and splitting tensile strength. Total of specimens 27 was divided to 9 cubes are 150mm * 150 mm * 150mm for compressive tests, 9 cylinders are 150mm * 300mm for split tensile tests and 9 beams are 100 mm * 100mm * 500mm for flexural tests. Casted and cured with seawater. Experimented at the ages of 7, 14, and 28 days, They showed that the concrete mixed and cured in fresh water have higher compressive, tensile, and flexural than concretes mixed and cured in sea water **Qingyong Guo and Wensong Zhang (2018)** [(4)] studied the effect of mixed and curing sea water on strength of concrete at different ages, total of specimens 192 cubes are 100mm * 100mm * 100mm were used for the determination of the compressive strength, The specimens classified into four groups (A, B, C, D) named (FF – FS – SS – SF) They showed the concrete specimens casted and cured with sea water (SS) increases at the early strength (that at age 7 days) due to the chloride percentage tends to accelerate the setting of cement but ultimately decrease the strength (14, 28, 90 days) due to leaching out of soft hydration product or the sulphates contains in sea water that retard the setting of cement. **Prof. Sagar Gawande1, Prof. Yogesh Deshmukh2 (2017)** [(5)] Studied a comparative between salt water and fresh water on concrete strength according compressive, flexural, and split tensile strength. Total of Specimens 72 divided into 24 cubes are 150mm * 150 mm * 150mm for Compressive tests, 24 cylinders are 150mm * 300mm for split tensile tests and 24 beams are 100 mm * 100mm * 500mm for flexural tests. Casted and cured with sea and fresh water, exposed to 7, 28 days period of curing, there is a higher in the strength of concrete specimen casted & cured with salt water as compared to those of cast & cured in fresh water. The rate of the strength gained in fresh water cubes is slow as compared with salt water; we can conclude that there is no reduction in the strength if we use salt water in casting & curing the concrete. This concept can be used for the regions having more salty water, rural area having salty bore water. **S. Khatibmasjedi, F. De Caso, and A. Nanni (2019)** [(6)] Early-age strength performance of seawater concrete was somewhat greater than that of freshwater-mixed counterpart until Day 7, followed by a strength performance that was 7–10 % lower to freshwater concrete after 28 days or later. In addition, seawater concrete shrank slightly more than freshwater concrete, with a difference of 5% recorded after 56 days of mixing. **Younis, A., Ebead, U., Suraneni, P., & Nanni, A. (2018)** [(7)] Seawater is currently forbidden from being used in concrete mixtures due to its high chloride concentration, which promotes reinforcing steel corrosion. The average total salinity of seawater is 3.5 percent, with sodium chloride (NaCl) accounting for roughly 78 percent. Despite the popular perception that seawater is unsuitable for structural concrete, seawater concrete (seawater-mixed concrete and seawater concrete are used interchangeably in the text) was successfully employed to construct some structures during the last century or even earlier. This can be viewed as intuitive proof for the use of seawater in the production of long-lasting concrete. Steel corrosion can be avoided by employing seawater in non-reinforced concrete applications or by reinforcing concrete structures with non-corrosive materials such as Rebar reinforced polymer (FRP).FRP bars, in addition to being lightweight and strong, can resist corrosion, and as a result, good durability performance has been observed for FRP-reinforced concrete exposed to seawater. **Preeti Tiwari 1 , Rajiv Chandak 2 , R.K. Yadav 3 (2014)**[8] they studied the effect of salt water on compressive strength of concrete aimed at Half of concrete cubes were cast and cured with fresh water and remaining half cubes were cast and cured with salt water. The concrete cubes were cured for 7, 14 and 28 days respectively. The result of the average compressive strength of concrete, From the results it is clear that, there was an marginal increase in the of concrete cubes which were casted and cured with salt water as compared with the concrete cubes cast and cured with fresh water. The rate of the strength gain in fresh water cubes is slow as compared with the salt water cubes. At 28 days, the rate of strength gain is still increasing in all the concrete cubes. The fresh water cubes also recorded its maximum strength at 28 days. Although, the compressive strength of the salt water concrete cubes was slightly higher than that of the fresh water concrete cubes.

3. SIGNIFICANT OF STUDY

The lack of understanding in this research identified from the above literature survey the study of the effect of fire on columns in which seawater is used and reinforced with FRP in case of HSC.

4. EXPERIMENTAL WORK

4.1 Sample Descriptions and Test Matrix:

Totally 57 specimens (27cubes, 18cylinders, 12columns) where tested. The concrete cubes were going to be cured for 7, 28 and 96 days. The columns and cubes were divided into three groups, group (A) concrete is mixed and cured in fresh water (FF). Group (B) was mixed and cured in seawater (SS), while group (C) mixed in fresh water and sea water (FS) by 50%. Twelve reinforced concrete columns for concrete compressive strength. All of columns are square section 200*200 mm and height 1000 mm as the shown figure (1), the columns consist of three groups the first is mixed by freshwater and second by seawater and third mixed by mixed water 50% equal.

4.2 Materials

The test specimens used in this program were made from local materials, Coarse and fine aggregate was composed of ordinary sand and gravel of good quality and was clean from injurious materials, The cement used in all specimens was Ordinary Portland Cement, Glass fiber bars, Normal mild steel and high tensile steel reinforcement bars locally produced were used, Tests to determine the properties of these materials were carried out according to the Egyptian Standard Specifications, GFRP bars and Mild steel reinforcement was used as shear stirrups. The following sections present the characteristics of used materials.

a- Concrete

The tested columns were cast using one batch of normal strength concrete (NSC); the physical and mechanical properties of the material contents used to form the batches are discussed in this section.

b- Fine and Coarse Aggregate

natural sand and small gravel as aggregate, the maximum nominal size of aggregate was 20mm, the specific gravity of gravel was about 2.6 and the volume weight was 1690kg/m3, The specific gravity of sand was about 2.65 and the volume weight was 1650kg/m3, It was cleaned and free organic material in Figure (2).

c- Cement

Ordinary Portland cement used was provided from the Helwan factory, the usual analysis, as well as the physical properties of the sina cement batches used in this work as determined by the laboratory tests, show its suitability for concrete works. Tests carried out on different cement batches provided for the tests of this research work gave more or less similar results, this proves the uniformity of cement batches used. It complies with the Egyptian specifications

d- Water

Clean fresh drinking water was added and mixed and then clean seawater was added and mixed thoroughly. Mixing operation was continued after adding water until a uniform color was obtained, some conduct as shown in the following Tables (2) and (3).

e- Casting and compaction

The reinforcement was placed in its right location in the form and strain gauges fixed at specified points on the reinforcement rebars, Just after mixing, the concrete was cast in the form and compacted using a vibrator, The quantity of concrete in each batch was enough to cast only one specimen.

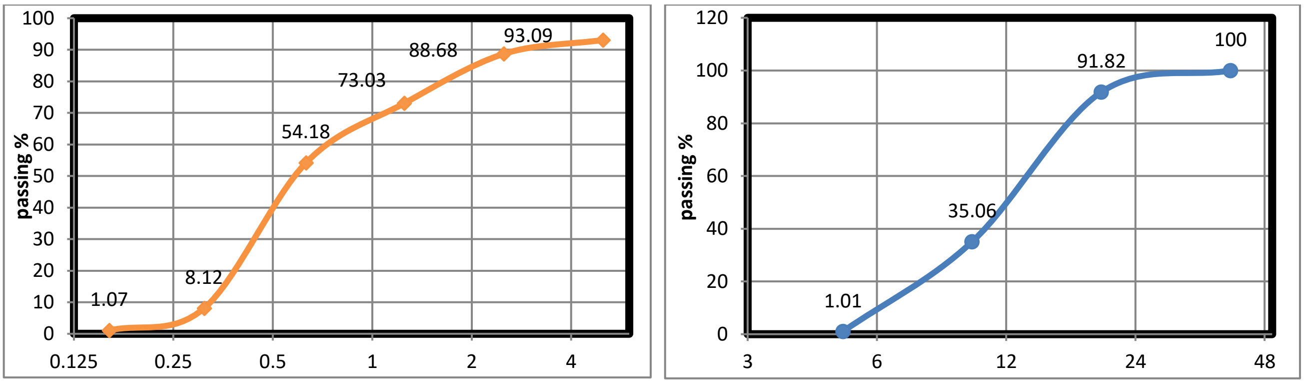
Three test cubs of 15 cm side length were taken during casting of each column, then concrete was placed after mixing in three layers each layer compacted using a standard rod with 25 blows for cubes and the vibrator.

f- Curing

All columns test specimens were cured after 24 hours from casting, they were cured using fresh and sea water and covering with sheets until the date of testing. The cubes were submerged into potable water until they were tested.

g- Formwork

Ordinary wooden forms were used for concreting all the columns specimen. The clear dimensions of the forms were 20 x 20 x100 cm.



(a) **(b)**

Figure (2) Sieve Analysis of (a) Fine Aggregate and (b) Coarse Aggregate.

Table (2): Chemical Analysis for Fresh Water Sample.

parameter	Results	Allowed limits
PH	7.1	6.5-8.5
Electrical conductivity (EC), µS/cm	544.0	
Total dissolve solids (TDS) ,mg/l	335.0	1000
Calcium, mg/l	52.0	
Magnesium, mg/l	19.0	
Sodium, mg/l	33.0	200
Potassium, mg/l	6.0	
Carbonate, mg/l	Nil	
Bicarbonate, mg/l	174.5	
Sulphate, mg/l	98.0	250
Chloride, mg/l	40.0	250

Table (3): Chemical Analysis for Sea Water Sample

Parameter	**Results**
PH	7.7
Electrical conductivity (EC), µS/cm	68800.0
Total dissolve solids (TDS), mg/l	41369.0
Calcium, mg/l	624.0
Magnesium, mg/l	2098.0
Sodium, mg/l	11600.0
Potassium, mg/l	455
Carbonate, mg/l	27.3
Bicarbonate, mg/l	150.7
Sulphate, mg/l	3989.0
Chloride, mg/l	22500.0

h- Mix design of concrete:

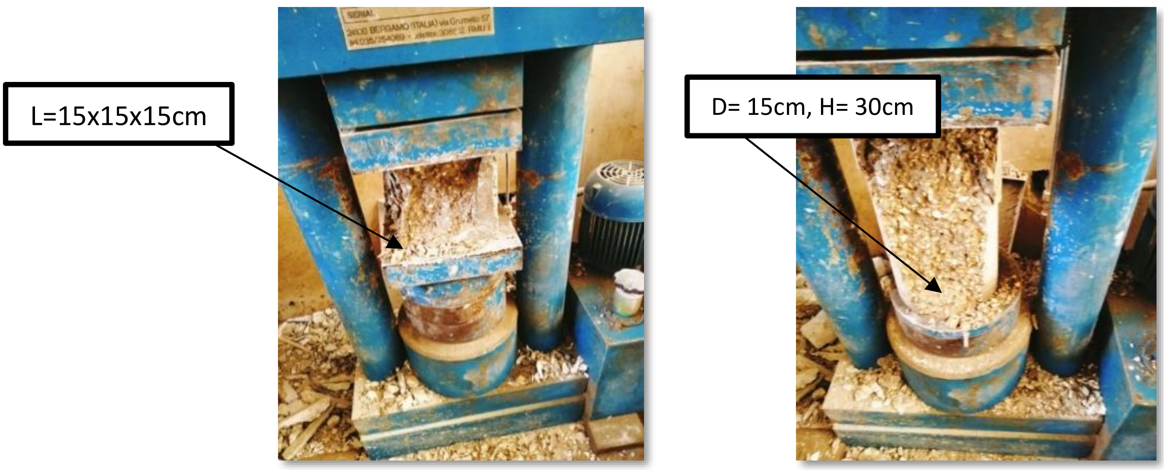
The mix properties for the studied concrete are listed in Table (4)

Table (4): Mix proportions for the studied concrete

Fine aggregate (kg/m^3)	590
coarse aggregate(kg/m^3)	1080
Water (kg/m^3)	180
(W/C)	0.52
OPC cement	350

4.3 Materials Test

The experiment was carried out on three different types of concrete mixes that were mixed and cured in fresh water and seawater. Mixes A, B and C were made with fresh water and cured in fresh water, whereas Mixes B were made with sea water and cured in sea water, Mix C were made with sea water and fresh water with 50% and cured in sea water and fresh water with 50%. Compression strength was measured on all combinations at 7, 28, and 96 days. Compressive strength was determined by using Compression Testing Machine. See Figure (4) and Table (5) and (6).



(a) (b)

Figure (4): concrete test - Compression test of cubes (a) and cylinders (b).

Table (5): Compressive strength for cubes after 7- and 4-months days and 96 days

Cubes (KN)									
Mix No / Days	7 days			28 days			96 days		
No of Samples	1	2	3	1	2	3	1	2	3
Load of mix A (FF) (KN)	377	382	387	668	559	608	776.5	680.4	677.1
Average load for mix A (FF) (KN)	382.00			611.67			711.33		
A (FF) (N/mm^2)	**16.96**			**27.16**			**31.58**		
Load of mix B (SS) (KN)	608	518	535	438	679	643	619.6	624.9	604.3
Average load for mix B (SS) (KN)	553.67			586.67			616.27		
B (SS) (N/mm^2)	**24.58**			**26.07**			**27.36**		
Load of mix C (FS) (KN)	513	533	500	639	584	420	621.3	543.2	583.3
Average load for mix C (FS) (KN)	515.33			547.67			582.60		
C (FS) (N/mm^2)	**22.88**			**24.32**			**25.87**		

(a)

Table (6): Compression strength for cylinders after 7- and 4-months days

Cylinders (KN)						
Mix No / Days	7 (KN)			28 (KN)		
No of Samples	1	2	3	1	2	3
Load of mix A (FF) (KN)	192	213	166	544	447	516
Average load for mix A (FF) (KN)	190.33			502.33		
A (FF) (N/mm^2)	**10.77**			**28.43**		
Load of mix B (SS) (KN)	344	278	375	445	491	535
Average load for mix B (SS) (KN)	332.33			490.33		
B (SS) (N/mm^2)	**18.81**			**27.75**		
Load of mix C (FS) (KN)	249	213	225	468	449	452
Average load for mix C (FS) (KN)	229.00			456.33		
C (FS) (N/mm^2)	**12.96**			**25.83**		

(b)

4.4 Test setup:

The test was conducted in the reinforced concrete laboratory in faculty of engineering at Helwan University. The test setup for testing the specimens includes a steel frame, two steel plates, loading cell and hydraulic jack used for axial compression; each cubic specimen was capped at its top and bottom with a steel capping to avoid the concentration of stresses and ensure load transfer among the cubic.

5. TEST RESULTS

5.1 Concrete mix test results

As shown in Figure (8), for cubes:-

For cubic at 7 day the compressive strength in concrete mix B (SS) was higher than concrete which mix A (FF) and mix C (FS) by 31% and 7%, but at 28 days the compressive strength in concrete mix A (FF) was higher than concrete which mix B (SS) and mix C (FS) by 4% and 10%, and at 96 days the compressive strength in concrete mix A (FF) was higher than concrete which mix B (SS) and mix C (FS) by 13% and 18%.

As shown in Figure (9), for cylinder:-

At 7 day the compressive strength in concrete mix B (SS) was higher than concrete which mix A (FF) and mix C (FS) by 42% and 31%, but at 28 days the compressive strength in concrete mix A (FF) was higher than concrete which mix B (SS) and mix C (FS) by 3% and 9%.

We deduced that, the concrete specimens casted and cured with sea water (SS) increases at the early strength (that at age 7 days) due to the chloride contains tends to accelerate the setting of cement but ultimately decrease the strength (28, 90 days) due to leaching out of soft hydration product or the sulphates contains in sea water that retard the setting of cement, and may be due to salt crystallisation formation facing the strength gain.

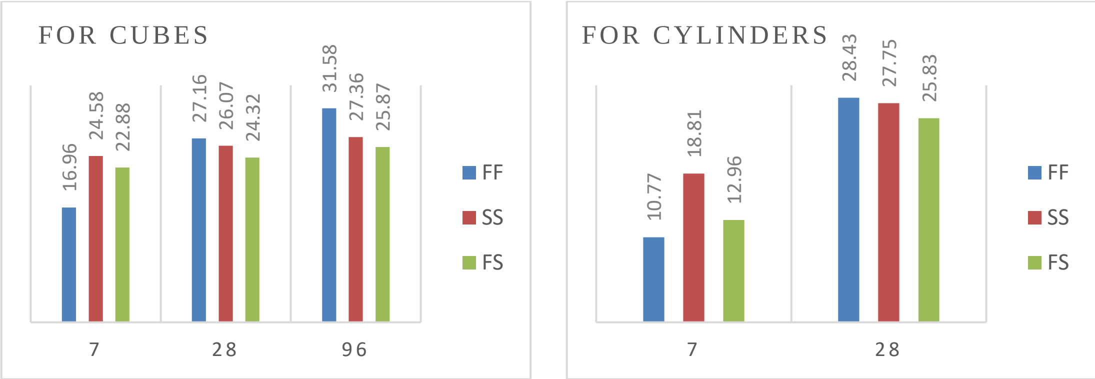


Figure (8, 9): Compressive strength for A, B and C (a) after 7 days, 28 days and 96 days for cubes.

6. CONCLUSION

Based on this study, the following conclusions may be drawn:-

1- For cubes the compressive strength in concrete mix B (SS) was higher than concrete which mix A (FF) and mix C (FS) by 31% and 7% at age 7 days, but at age 28 days the compressive strength in concrete mix A (FF) was higher than concrete which mix B (SS) and mix C (FS) by 4% and 10%, and at 96 days the compressive strength in concrete mix A (FF) was higher than concrete which mix B (SS) and mix C (FS) by 13% and 18%.

2- For cylinder At 7 day the compressive strength in concrete mix B (SS) was higher than concrete which mix A (FF) and mix C (FS) by 42% and 31%, but at 28 days the compressive strength in concrete mix A (FF) was higher than concrete which mix B (SS) and mix C (FS) by 3% and 9%.

3- The concrete specimens casted and cured with sea water (SS) increases at the early strength (that at age 7 days) due to the chloride contains tends to accelerate the setting of cement but ultimately decrease the strength (28, 90 days) due to leaching out of soft hydration product or the sulphates contains in sea water that retard the setting of cement, and may be due to salt crystallisation formation facing the strength gain.

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