An Experimental Study on Concrete Strength and Corrosion Activity by Replacing Potable Water by Sea Water

S.Rajamuniasamy[1], S. Mercy[2], M. A. Raja[3], Praveen[4]

[1]Shri Sapthagiri Institute of Technology, Civil Engineering, Assistant Professor, Tamilnadu, India

[2, 3]Francis Xavier Engineering College, Civil Engineering, Assistant Professor, Tamilnadu, India

[4]Pandian Saraswathi Yadav Engineering College, Civil Engineering, Assistant Professor, Tamilnadu, India

Abstract: ***Several billion tons of water is annually used as mixing, curing and cleaning around the world, in concrete industry. As there is scarcity of fresh drinkable water around the world; so there is a need to save fresh and potable water and hence possibilities of using seawater as mixing as well as curing water should be investigated seriously. Additionally, if use of seawater as concrete material is permitted, it is very convenient and economical in construction; especially in the coastal works. In this project, the effects of mixing and curing concrete with seawater on the compressive, tensile and flexural strengths and corrosion of concrete and reinforcements are experimented. M20 concrete is adopted for this study of concrete behavior and mix design is carried out accordingly. Concrete cubes, cylinders and beams of corresponding dimensions are casted out to investigate the above mentioned properties. On the casted cubes, cylinders and beam specimens' one part is mixed and cured in sea water and the other part is mixed in sea water but cured in potable water to investigate which is better for practical usage. Super plasticizers and Portland Slag Cement (PSC) are adopted for this project so as to reduce the water content and to resist attacks of minerals from sea water respectively. The compressive strength was tested for 7, 14 and 28 days of curing. The flexural strength was tested after 28 days of curing. And the split tension test was carried out after 28 days of curing. The corrosive activity is studied by accelerated corrosion tests carried out on cube specimens with stainless steel reinforcement init. Henceforth the study showed that usage of concrete mixed in sea water and cured in potable water shows aconsistent increase on the compressive strength and flexural strength. And the incorporation of stainless steel for reinforcements shows a very minute amount ofcorrosion.***

Keywords: potable water, compressive strength, accelerated corrosion, modulus of rupture

1. Introduction

The advancement of concrete technology can reduce the consumption of natural resources or use the natural resources in an efficient manner and lessen the pollutants to make the environment eco-friendly. 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. The primary chemical constituents of seawater are the ions of chloride, sodium, magnesium, calcium and potassium. In seawater containing up to 35,000 ppm of dissolved salts, sodium chloride (NaCl) is by far the predominant salt (about 88% by weight of salts). The pH value of seawater varies between 7.4 and 8.4. Corrosion of reinforcing steel occurs below a pH of 11. Therefore, in cases where concrete is subjected to a highly severe environment, the cement must supply alkalinity. The chemical reactions of seawater on concrete are mainly due to the attack by magnesium sulphate ($MgSO_4$). The mode of attack is crystallization. Potassium and magnesium sulphates (K_2SO_4 and $MgSO_4$) 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 (C_2S) and tricalcium silicate (C_3S). The attack of magnesium sulphate ($MgSO_4$) is particularly damaging, forming soluble magnesium hydroxide ($Mg(OH)_2$), which forces the reaction to form gypsum (Swamy1991Swamy, R.N. 1991. *The alkali-silica reaction in concrete*, London: Spon Press).Recent studies showed that composites have ever proved to be resistant to marine environment (Liu *et al*. 2002), and that the level of fine aggregate replacement by ground blast furnace slag and ground basaltic pumice had a beneficial effect on the compressive strength loss due to seawater attack and abrasion value (Binici*et al*. 2008).Further investigation and work is recommended on this subject of using seawater for concrete mixes, as the planet earth is experiencing noticeable shortage of pure clean water sources for future construction work, and the use of seawater to develop durable concrete of lasting performance will be greatlybeneficial.

1.1 Materials used

1) Cement (Portland Slag Cement)
2) Coarseaggregate
3) Fineaggregate
4) Potablewater
5) Seawater
6) Super plasticizer

1.2 Cement

Portland Pozzolanic Cement of 43 grade was purchased from the local supplier and used throughout this project. The properties of cement used in the investigation are presented in table 1.

Table 1: Properties of Cement

S. No	*Property*	*Value*
1	Specific Gravity	3.15
2	Fineness	97.8
3	Initial Setting time	40 min
4	Final Setting Time	485 min
5	Standard Consistency	30%

1.3 Fine aggregate

River sand was used as fine aggregate. The size of the sand used is 4.75 mm and down size. The properties of fine aggregate investigated are presented in table 2.

Table 2: Properties of Fine Aggregate

S.No	*Property*	*Value*
1	Specific Gravity	2.38
2	Fineness Modulus	4.24
3	Surface Texture	Smooth

1.4 Coarse aggregate

Machine crushed granite obtained from a local quarry was used as coarse aggregate. The properties of the coarse aggregate are shown in table 3.

Table 3: Properties of Coarse Aggregate

S. No	*Property*	Value
1	Specific Gravity	2.88
2	Fineness Modulus	4.24
3	Particle Shape	Smooth
4	Particular Shape	Angular
5	Impact Value	28
6	Water Absorption	0.5

1.5 Water

Water used in this project is both potable water and seawater.The properties of sea water are listed below.

Table 4: Properties of sea water

S.No	*Property*	*Value*
1	Total Dissolved Solids	0.0389 gm/ml
2	Total Suspended Solids	0.008 gm/ml
3	Chloride	19.162 g/kg
4	Sodium	10.679 g/kg
5	Magnesium	1.278 g/kg
6	Sulphate	2.680 g/kg
7	Calcium	0.4096 g/kg
8	Potassium	0.3953 g/kg

1.6 Super plasticizer

The super plasticizer used in this project is ENFIIQ superplastic – 400, a water reducing admixture used to reduce the salt water content in the concrete.

2. Methodology

- After collection of materials required, they are mixed as per the mix design obtained for M20. Separate batches of cube mould are prepared for compression tests after 7, 14 and 28 days of curing. For each compression test 3 specimens are used and the average of 3 values is noted.
- Curing condition of the study will be sea water and potable water. 9 cubes are cured in potable water and 9 cubes are cured in sea water. Beams are also casted for flexure test for the same curingconditions.
- Accelerated corrosion tests are carried out to study the corrosion activity. Mild steel will presumably corrode aster in sea water condition, so stainless steel rods of 6 mm diameter are used as reinforcing members on this study.

3. Tests on Hardened Concrete

Compression strength test

3.1 Concrete Mixed In Sea Water & Cured In PotableWater

Table 5: Compressive strength of concrete for 7 days

S. No.	*Specimen*	*Compressive strength of cube (n/mm^2)*	*average compressive strength of cube (n/mm^2)*
1	1	24.889	24.53
2	2	17.778	
3	3	31.112	

Table 6: Compressive strength of concrete for 14days

S. No.	*Specimen*	*Compressive strength of cube (n/mm^2)*	*average compressive strength of cube (n/mm^2)*
1	1	36.444	25.48
2	2	20.889	
3	3	19.112	

Table 7: Compressive strength of concrete for 28 days

S. No.	*Specimen*	*Compressive strength of cube (n/mm^2)*	*average compressive strength of cube (n/mm^2)*
1	1	36.223	34.222
2	2	35.111	
3	3	33.334	

3.2 Concrete Mixed and Cured In SeaWater

Table 8: Compressive strength of concrete for 7 days

S. No.	*Specimen*	*Compressive strength of cube (n/mm^2)*	*average compressive strength of cube (n/mm^2)*
1	1	34.224	33.038
2	2	31.556	
3	3	33.334	

Table 9: Compressive strength of concrete for 14 days

S. No.	*Specimen*	*Compressive strength of cube (n/mm^2)*	*average compressive strength of cube (n/mm^2)*
1	1	33.777	28.444
2	2	19.111	
3	3	32.444	

Table 10: Compressive strength of concrete for 28 days

S. No.	*Specimen*	*Compressive strength of cube (n/mm^2)*	*average compressive strength of cube (n/mm^2)*
1	1	37.334	30.667
2	2	20.445	
3	3	34.223	

4. Flexural Strength Test

The following expression is used for estimation of modulus of rupture: MR = FL/bd^2

Where:
F: ultimate applied load indicated by testingmachine
L: spanlength
b: average width of the specimen at thefracture
d: average depth of the specimen at thefracture

Table 11: Flexural strength of concrete

curing condition	*load (kn)*	*Dimensions (l x b x d)*	*flexural strength (n/mm^2)*
Cured in potable water	19.2	150 x 150x 700	3.982
Cured in sea water	28.8	150 x 150x 700	5.973

5. Accelerated Corrosion Test

Table 12: Classification of corrosivity – Source: NACE standard RP 0775(4)

corrosion rate (mm/year)	*Corrosivity*
<0.025	Low
0.025 – 0.12	Moderate
0.13 – 0.25	High
>0.25	Severe

Table 13: Corrosion test results

curing condition	*Loss of mass (δm) (gm)*	*area of rod (a) mm^2*	*time of exposure (t) (hrs)*	*density of rod – ρ (gm/cm^3)*	*Corrosivity (mm/year)*
Cured in potable water	20	231.66	40	7.48	0.105 (Moderate)
Cured in sea water	40	231.92	40	7.48	0.210 (High)

6. Compression Test Results

Results and Discussions

6.1 Compression test on concrete mixed in sea water and cured in potable water

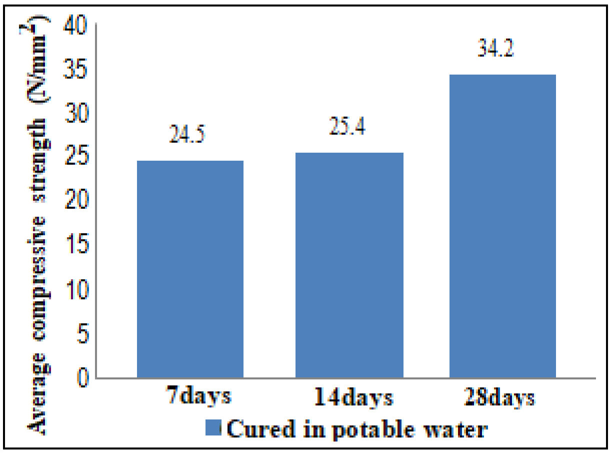

Figure 1: Average compressive strength of concrete mixed in sea water and cured in potable water

Figure 1 shows the average compressive strength of concrete cubes mixed in sea water and cured in potable water. The graph shows that there is a gradual increase on strength from 7 days to 14 days, and then afterwards on 28days the graph shows a drastic increase on the compressive strength. The strength finally attained after 28 days of curing out lasts the target mean strength on the mix design.

6.2 Compressive test results on concrete mixed and cured in sea water

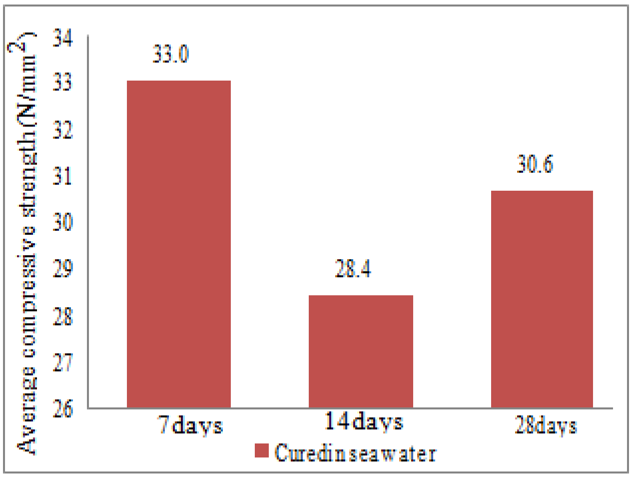

Figure 2: Average compressive strength of concrete mixed and cured in sea water

Figure 2 shows the average compressive strength of concrete cube mixed and cure in sea water. The graph shows the initial inclination on the strength on 7 days of curing. And there is a declination observed on the 14 day strength. On the 28th day test, the results show a further increase on compressive strength from what was observed on 7 days test. Ultimately this graph shows an inconsistency on strength gaining on 7 to 28 days of curing in seawater.

7. Comparison Concrete Mixes

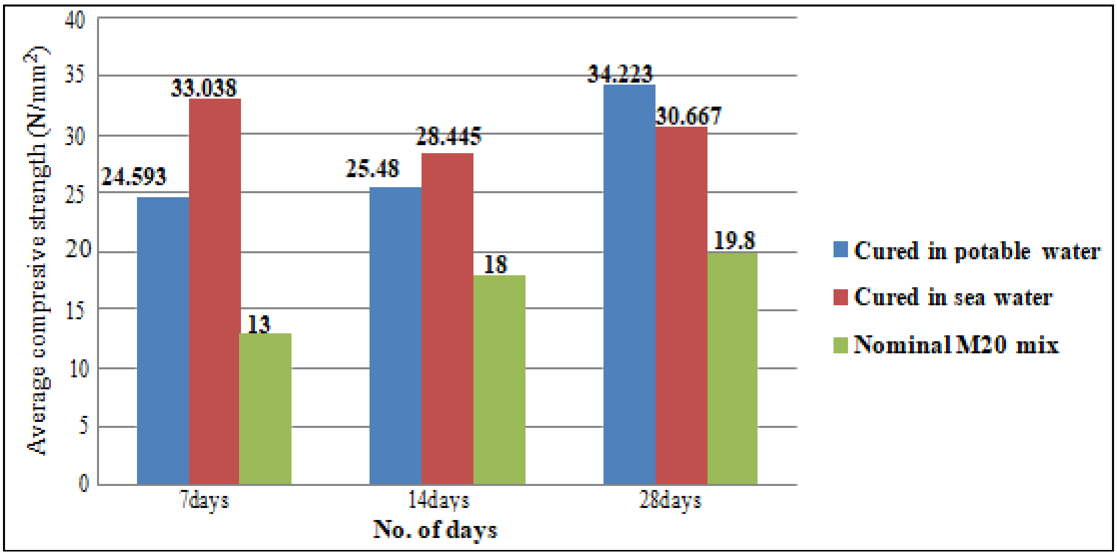

Fig.3showsthecomparisonofaveragecompressivestrengthsofconcretemixedinpotable water&curedinsea water, concrete mixed & cured in sea water and nominal M20 concrete mixed and cured in potable water. There is a consistency seen in increase of strength of concrete mixed in sea water and cured in potable water and concretemixed and cured in potable water. Whereas the strength gained by the latter mix is greater than the former mix. But the initial decline and further incline on the concrete mixed and cured in sea water seems unfit for practicaluse.

1) Flexural strength testresults

The flexural strength of concrete beams mixed in sea water and cured in cured in potable water is 3.982 N/mm^2.And the flexural strength of concrete beams cured and mixed in sea water is 5.973 N/mm^{2}From the above results it can be inferred that the flexural strength of concrete mixed and cured in sea water is high.

2) Accelerated corrosion test results on stainlesssteel

Accelerated corrosion test is carried on stainless steel rods which are inserted on the two respective specimens. Constant DC supply of 20 – 100 mA with a potential of 16 V is maintained for 40 continuous hours. The rate of corrosion or corrosivity is measured by a formula as suggested by NACE standard RP 0775(4).The corrosion observed on the stainless steel on concrete cube mixed in sea water and cured in potable water is 0.105mm/year and the corrosion of steel on concrete mixed an cured in sea water is 0.210mm/year.

8. Conclusion

Concrete mixed in sea water and cured in potable water is seen to be effective on compressive strength than the concrete cured and mixed in seawater.The compressive strength is greater on both the cases than concrete mixed and cured in potablewater.Flexural strength I higher in case of concrete mixed and cured in seawater.Corrosion is less in case of stainless steel rods inserted on concrete mixed in sea water and cured inpotable water.

References

[1] Akinkurolere, O. O., Jiang, C and Shobola O. M. (2007) “The Influence of Salt Water on the Compressive Strength of Concrete”, Journal of Engineering and Applied Sciences, Vol. 2 No. 2, pp. 412 -415.
[2] Akinsola Olufemi Emmanuel., FatokunAjibolaOladipo&OgunsanmiOlabode E., (2012) “Investigation of salinity effect on compressive strength of reinforced Concrete”, Journal of Sustainable Development; Vol. 5, No.6; Published by Canadian Center of Science and Education.
[3] Bella, M., &Fabuss, T. (1989). Properties of Seawater. 1st Edition Academic PressBoston.
[4] Bryant, M. (1964). *Effects of Seawater on Concrete*. Miscellaneous paper no 6-690, U.S. Army Engineers, Waterways experiment station, Corps of Engineers, Vicks berg,Mississippi.
[5] E. M. Mbadike (2011),“Effect of salt water in the production of concrete”, Nigerian Journal of Technology, Vol. 30, No.2
[6] Falah M. Wegian; (2010), “Effects of sea water for mixing and curing on structural concrete Studies”, The IES Journal Part A: Civil & Structural Engineering, Vol .3, No.4, pp 235 –243.

Author Profile

S. Rajamuniasamy, M. E (Structural Engineering), Shri Sapthagiri Institute of Technology, Assistant Professor

S. Mercy, M.E (Construction Engineering & Management), Francis Xavier Engineering College, Assistant Professor

M. A. Raja, M.E (Structural Engineering), Francis Xavier Engineering College, Assistant Professor

K. G. Praveen, M.E (Structural Engineering), Pandian Saraswathi Yadav Engineering, Assistant Professor