An Investigation on Strengths of Concrete for Marine Works using OPC and Sea Water

P. Krishnam Raju[1], V. Ravindra[2] & M. Bhanusingh[3]

[1](Research Scholar, Dept. of Civil Engineering, Jawaharlal Nehru Technological University Kakinada, India)
[2](Professor, Dept. of Civil Engineering, Jawaharlal Nehru Technological University Kakinada, India)
[3](M.Tech Student, Dept. of Civil Engineering, Jawaharlal Nehru Technological University Kakinada, India)

ABSTRACT : *The investigation aimed to adopt sea water both for mixing and curing of concrete as the potable water is a scarce commodity on the planet Earth. At least sea water can be adopted in the construction industry as an alternative ingredient to potable water. Two concrete mixes viz, M30 and M35 using ordinary Portland cement (OPC) of 53 Grade as per the Guide lines of concrete mix proportioning with a slump of 100 to 150mm were considered. The mixes were prepared with "Potable water mixing and Sea water curing" & "Sea water mixing and Sea water curing". A total specimen of 54 cubes, 54 cylinders and 54 beams including specimens for reference concrete were cast for both the mixes and exposed to 7days, 28days and 90days period of curing. The compressive strength behaviour, modulus of rupture and flexural strengths were investigated. The reference concrete was prepared with OPC using only potable water both for mixing and curing. The study reveals that there is no considerable reduction in compressive strength due to mixing of sea water and also due to mixing and curing with sea water compared to its target strength.*

Keywords - *compressive strength, curing, potable water, sea water, target strength.*

I. INTRODUCTION

Most of the developments in construction were taken place with concrete due to its versatility. Water is one of the important ingredients in making concrete. It was estimated that world's fresh water bodies is only 2.5 percent and balance constitutes sea water. UN predicted 5 billion people will be in short of drinking water. Day by day the water levels are in depleting trend due to its abnormal usage and other environmental effects. Potable water is a scarce commodity on the planet earth. It may be true that a stage may be reached and potable water may not be available to a common man even for drinking purpose. Probably more than 50% of people are habituated procurement of water regularly for their drinking needs. It is warranted, to explore various alternative means to Potable water in the Construction Industry. Possibility of usage of sea water in concrete is to be studied. Lot of marine infra-structure is going to establish along the coast, where sea water is available at least cost. The types of structures built in marine environment are break waters, berths, buildings and jetties etc., which are directly in contact with or subjected to sea water. Some studies were already done internationally on concrete by mixing and curing of sea water. The results indicated that there is a gain in strength initially and decrease of strength for longer period. Most of the studies were done for nominal concrete mixes with low strength.

In the present study, concrete with Ordinary Portland cement, 53 Grade is adopted. "Concrete grades of M30 and M35 design mixes with a slump in between 100 to 150mm were considered in the study. Two exposure conditions for each of these grades were studied. The exposure conditions are "Potable water mixing and sea water curing (PM&SC)" and "Sea water mixing and sea water curing (SM&SC)". A reference concrete mix for all the above two grades were also done for comparison of the compressive strength behaviour, modulus of rupture and flexural strength behaviour. The specimens required for the above experimental study were cast for 7days, 28days and 90days strength so as to study the performance.

Sea water, as its abundant availability along the coastal regions may be adopted for construction both for mixing and curing of concrete as a replacement to potable water. According to IS 456:2000, mixing or curing of concrete with sea water is not recommended because of presence of harmful salts. Under unavoidable circumstances sea water may be used for mixing or curing in plain concrete with no embedded steel after having given due consideration to possible disadvantages and precautions including use of appropriate cement system. The same publication also specified the minimum grades of plain concrete and reinforced concrete to be adopted as M20 and M30 respectively when the concrete is used in sea water or exposed directly along the sea coast. Hence concretes of M30 and M35 are adopted for the present study.

The estimates show that the damage to marine structures is only 20% due to chemical attack. The plain concrete exposed to sea water would be subjected to chemical attack. Action of carbon dioxide causes the formation of calcium carbonate and reducing the alkalinity of the concrete, action of sulphates causes formation of Ettringite and gypsum resulting physical expansion and leaching and chlorides would affect reduction in alkalinity of concrete and leaching.

II. LITERATURE REVIEW

Studies were conducted during past on effect of mixing and curing of sea water in concrete. An investigation of salinity effect was conducted by Akinsola Olufemi Emmanuel et al (2012) on compressive strength of reinforced concrete and reported that the sample cast and cured with ocean and lagoon water slowly increases in its strength but lower when compared with fresh water reinforced concrete element and recommended rich mix other than 1:3:6 and 1:3:5. Falah M.Wegian (2010) investigated the effects of mixing and curing concrete with sea water on the compressive, tensile, flexural and bond strengths and reported that there are increases of strengths of concrete mixed and cured in sea water at early ages and a definite decrease for ages more than 28 days and up to 90 days. Influence of salt water on compressive strength of concrete was studied by O.O.Akinkurolere et al (2007) and reported that the mixing and curing concrete with salt water increases the compressive strength rapidly and the strength was still increasing at 28 days. Md. Moinul Islam et al (2012) reported that the compressive strength loss of about 10% when the concrete specimens made and cured with sea water compared to plain water mixed and cured concrete. M.I.Retno Susilorini et al (2005) reported on the performance of early age concrete with sea water curing of 7 days and 14 days is higher than those cured by plain water in respect of its compressive strength. E.M.Mbadike et al (2011) investigated the effect of salt water in the production of concrete and reported 8% strength reduction.

III. EXPERIMENTAL WORK

Two design mixes viz; M30 & M35 using Ordinary Portland cement were carried out for the study as per "Concrete mix proportioning – Guidelines". Specimens cast using potable water and also sea water was cured in sea water for a period of 7, 28 and 90 days before testing its compressive strength, split tensile strength and flexural strength. Concrete cubes of 150 X 150 X 150 mm³ of standard size were used for compressive strength (fc) study. Concrete cylinders of 150 X 300 mm² and concrete beams of 150 X 150 X 700 mm³ were adopted for the study of split tensile strength (fs) and flexural strength (fb) respectively.

Ordinary Portland cement, with 53 Grade standard brands confirming to IS: 12269:1987 with a specific gravity of 3.15 and at normal consistency of 29% was used for the study. The fine aggregate used in the study was of natural river sand conforming to grading zone-II of IS: 383:1970. Graded granite metal coarse aggregate of nominal maximum size of 20mm was adopted in the study. Potable water or drinking water as available in the laboratory and sea water obtained nearby source in Kakinada were taken in the study. An admixture of standard make conforming to IS: 9103:1999 was used in order to make concrete to achieve required slump. A standard deviation value of 5 was assumed to calculate target compressive strength at 28 days. Necessary trail mixes were carried out to achieve the required slumps etc.

The concrete mix proportions as adopted are tabulated in Table-1. The same mix proportions were used for concrete cast with sea water also since the specific gravity of sea water is very close to the potable water. The mix designations and number of specimens cast for various strengths are presented in Table-2.

Table – 1: Concrete Mix Proportions

Content (per cu.m)	Concrete Grade	
Design Mix	M30	M35
W/C ratio	0.43	0.41
Water (lit)	182.47	182.47
Cement (Kg)	424.42	445.21
Fine aggregate (Kg)	640.56	627.23
Coarse aggregate (Kg)	1200.27	1195.87
Admixture (lit)	2.12	2.23

Table – 2: Mix Designations

Mix Designa-tion	Mixing water	Curing water	No. of specimens for		
			fc	fs	fb
M30 (PM&PC)	Potable	Potable	3 X 3	3 X 3	3 X 3
M30 (PM&SC)	Potable	Sea	3 X 3	3 X 3	3 X 3
M30 (SM&SC)	Sea	Sea	3 X 3	3 X 3	3 X 3
M35 (PM&PC)	Potable	Potable	3 X 3	3 X 3	3 X 3

M35 (PM&SC)	Potable	Sea	3 X 3	3 X 3	3 X 3
M35 (SM&SC)	Sea	Sea	3 X 3	3 X 3	3 X 3
			54	54	54

IV. RESULTS AND DISCUSSION

Before casting the concrete specimens, the slump and compaction factors were observed for various mixes and same are reported in Table-3. The degree of workability is high for the observed slumps or compaction factors and the same is suitable for pumping and tremie placing as in the case of installation of marine piles and diaphragm walls.

Table – 3: Slump & compaction factor observations

Mix Designation	Slump (mm)	Compaction Factor
M30(PM & PC)	140	0.91
M30(PM & SC)	140	0.91
M30(SM & SC)	135	0.90
M35(PM & PC)	135	0.90
M35(PM & SC)	135	0.92
M35(SM & SC)	130	0.88

The required specimens were cast for various mixes and demould them on next day. The specimens were cured for 7, 28 and 90 days period in masonry / PVC water containers and tested them for various strengths after elapsed period of curing. The test results of compressive strength, split tensile strength and flexural strength are tabulated in Table - 4, 5 and 6 respectively.

Table – 4: Compressive strength test results

Mix Designation	Compressive Strength (N/mm^2)		
	7 days	28 days	90 days
M30(PM & PC)	41.27	47.37	49.26
M30(PM & SC)	44.90	45.78	43.45
M30(SM & SC)	37.35	40.98	40.55
M35(PM & PC)	44.57	45.49	47.37
M35(PM & SC)	45.92	47.37	46.65
M35(SM & SC)	37.50	42.14	41.17

Table – 5: Split tensile strength test results

Mix Designation	Split Tensile Strength (N/mm^2)		
	7 days	28 days	90 days
M30(PM & PC)	2.57	3.24	3.63
M30(PM & SC)	3.03	2.87	2.82
M30(SM & SC)	2.64	2.78	2.78
M35(PM & PC)	2.89	3.11	3.32
M35(PM & SC)	2.96	3.05	2.91
M35(SM & SC)	2.73	2.96	2.82

Table – 6: Flexural strength test results

Mix Designation	Flexural Strength (N/mm^2)		
	7 days	28 days	90 days
M30(PM & PC)	5.11	6.54	7.05
M30(PM & SC)	6.10	6.40	6.37
M30(SM & SC)	5.21	6.00	5.90
M35(PM & PC)	5.69	6.64	7.14
M35(PM & SC)	6.78	6.48	6.64
M35(SM & SC)	5.67	6.56	6.64

COMPRESSIVE STRENGTH

It was observed that the average compressive strength arrived for all the three designated concretes of M30 are more than the target strength except a small reduction by 2.35% in case of 7days when sea water is used both for mixing and curing. Reduction in strength was also observed in case of M35 concrete for the same exposure in all the ages of concrete. It was also observed that the 7days compressive strength is higher for both M30 & M35 concrete in case of potable water mixing and sea water curing than the reference concrete. “Fig.1&2” shows the comparison of compressive strength results.

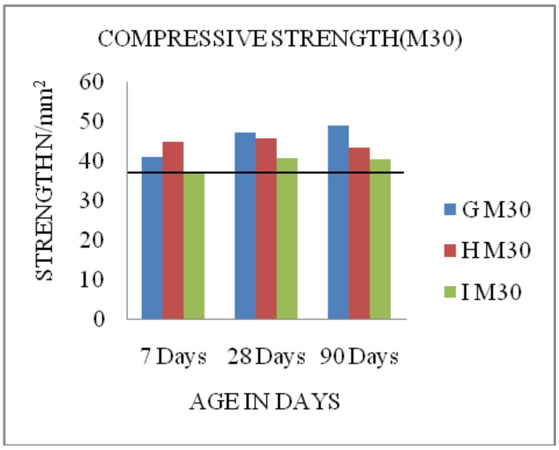

Fig.1. Compressive strength of M30 Grade concrete and Age in number of days

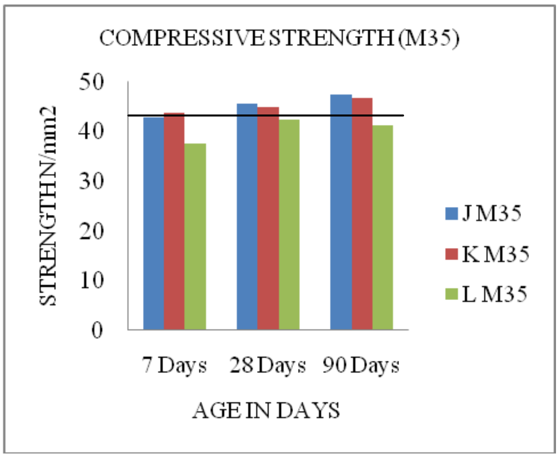

Fig.2. Compressive strength of M35 Grade concrete and Age in number of days

SPLIT TENSILE STRENGTH

The split tensile strength is in increasing order from 7days to 28days, and by 90days the strength increases gradually in case of M30 & M35 reference concrete. The 7days split tensile strength for M30 concrete for potable water mixing and sea water curing is more than the strength of 28days and 90days where as for M35 concrete under the same conditions the strength is increased marginally at 28days and reduced marginally at 90days. The results of split tensile strengths are shown in "Fig. 3 & 4".

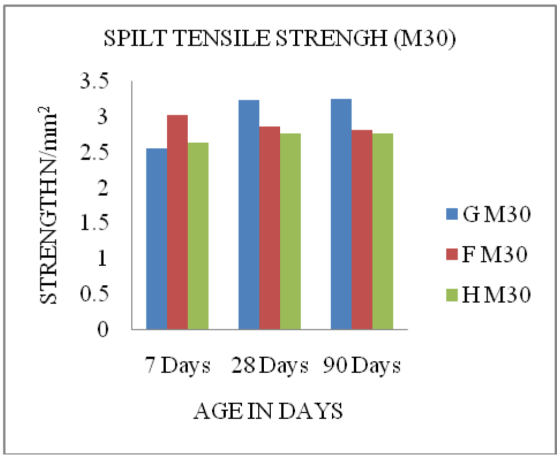

Fig.3. Tensile strength of M30 Grade concrete and Age in number of days

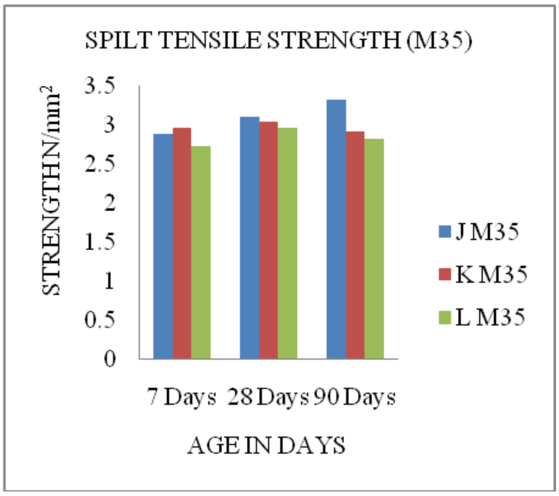

Fig.4. Tensile strength of M35 Grade concrete and Age in number of days

FLEXURAL STRENGTH

The flexural strength of M30 and M35 concretes under potable water mixing and sea water curing at 7 days are more compared to the reference concrete and concrete with mixing and curing by sea water. There is no much reduction or gain in flexural strength for 28days and 90days both for M30 and M35 concretes. The results are plotted in "Fig 5 & 6".

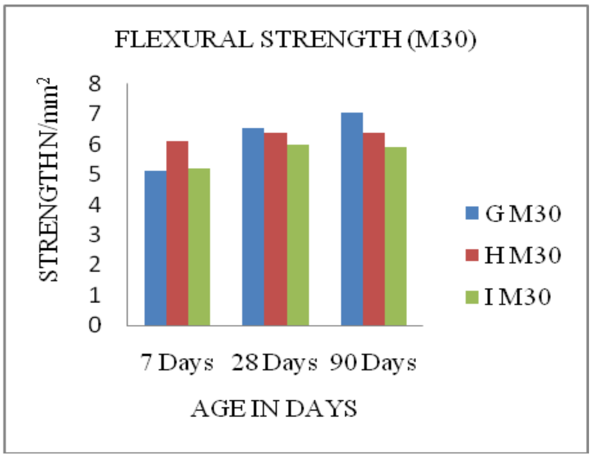

Fig.5. Flexural strength of M30 Grade concrete and Age in number of days

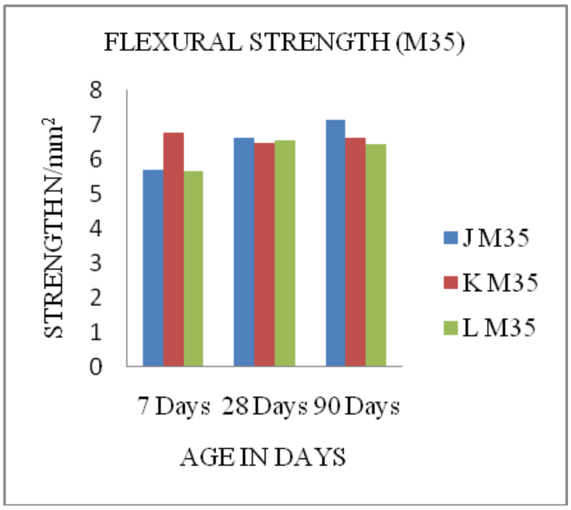

Fig.6. Flexural strength of M35 Grade concrete and Age in number of days

V. CONCLUSIONS

There is no quantitative reduction in compressive strength compared to target strength when the concrete is exposed to both "potable water mixing and sea water curing" and "mixing and curing by sea water".

There is an increase in 7 days Split tensile strength of concrete for "Potable water mixing and sea water curing" in M30 and M35 Grades compared to the Reference concrete i.e., "Potable water mixing and potable water curing". However decrease in the same strength was noticed for both the concrete Grades with "Sea water mixing and sea water curing".

Percentage reduction in Split tensile strength is comparatively higher for the concrete of Grade M30 than M35 in both the exposure conditions i.e., "Potable water mixing and sea water curing" and "Sea water mixing and sea water curing". It may perhaps be the higher cement content in M35 concrete.

Flexural strength also shows increase of strength initially for 7 days under "Potable water mixing and sea water curing" compared to the Reference concrete in both the Grades.

Investigations can be carried out for pozzolana and ground granulated blast furnace slag cements.

Further studies may be carried out using anti–chloride admixtures, if available, so as to avoid the sea water effects on concrete.

Investigations can be extended to higher strength concretes i.e., M40 and above grades.

Long terms studies are also suggested to investigate the durability aspects when sea water is used both for mixing and curing.

REFERENCES

Journal Papers:

[1] Akinsola Olufemi Emmanuel., et al, "Investigation of salinity effect on compressive strength of reinforced concrete", *Journal of Sustainable Development*; *Vol. 5, No. 6;* 2012. Published by Canadian Center of Science and Education.

[2] Falah M. Wegian; "Effects of sea water for mixing and curing on structural concrete Studies", *The IES Journal Part A: Civil & Structural Engineering, Vol .3, No.4,* November 2010, 235 – 243.

[3] O. O. Akinkurolere; et al, "The influence of salt water on the Compressive strength of concrete", *Journal of Engineering and Applied Science 2(2)* 112 – 115, 2007.

[4] Md. Moinual Islam., et al, "Suitability of sea water on curing and compressive strength of structural concrete", *Journal of Civil Engineering (IEB), 40 (I)* (2012) 37 – 45.

[5] M. I. Retno Susilorini., et al, "The performance of early – age concrete with sea water curing", *Journal of Coastal Department, Vol. 8, No. 2,* February 2005, 85 – 95.

[6] E. M. Mbadike., et al, "Effect of salt water in the production of concrete", *Nigerian Journal of Technology, Vol. 30, No. 2,* June 2011.