Strength Characteristics and Corrosion of Glass Fibre Reinforced Concrete Column Exposed in Sea Water Environmental Condition

C.Lakshmi Priya, N.Savitha, K.Jagadeesan

Abstract: ***This paper highlights the investigation on the strength and corrosion study of glass fibre reinforced concrete (GFRP) column in sea water environmental condition. Specimen of size 600 mm length x 150 mm wide x 300 mm deep columns were cast. Totally 8 columns were cast. Out of which, 4 columns were cured using potable water and 4 columns were cured using in artificial sea water. Among 8 reinforced concrete columns, two concrete columns were used, as the reference column containing steel rods both in longitudinal and horizontal ties and were cured both in potable and artificial sea water. For the corrosion study, 2 concrete columns reinforced by GFRP bars in the longitudinal direction and steel rods as horizontal ties and were cured using artificial sea water. Rebound hammer and Ultrasonic Pulse Velocity tests were performed on columns to evaluate the strength characteristics at the end of 7, 14, 28, 56 and 90 days of curing. The results will also be validated using destructive methods. Corrosion study was also performed by single Cu-CuSo$_4$ Half-Cell equipment. Based on the observation, it was found that the compressive strength in artificial sea water curing exhibited better performance than in potable water curing.***

Keywords : Corrosion, , Glass Fibre Reinforced concrete column , Rebound hammer, Ultrasonic Pulse Velocity.

I. INTRODUCTION

Corrosion is a major problem in day to day life, and its study shows the strength of the structure to expose under sea environmental condition. The corrosion study were done with the help of Half cell potentiometer (Single Half - cell). Copper - Copper Sulphate electrode was used to determine the corrosion level in RCC columns. About 10 % replacement of Metakaolin to cement were used for cast the specimens. Metakaolin contains high silica and alumina content, hence metakaolin blended cement increases the strength and durability of concrete, decreases water absorption, porosity and setting time of concrete.

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Sand coated GFRP (Glass Fibre Reinforced Polymer) rebars are provided as longitudinal reinforcement and steel as horizontal ties.

The GFRP rebars are nonmagnetic, high stiffness and ease of fabrication. Non – destructive testing such as Rebound Hammer and Ultrasonic Pulse Velocity tests were conducted on columns to determine the strength characteristics. The quality of the concrete was also determined. The tests were performed both in potable and in artificial sea water curing at the end of 7, 14, 28, 56 and 90 days.

Carlos Eduardo Tino Balestra [1] had described that the structures present in tidal and splash zones have the low values of electrical resistivity due to the reinforcement corrosion. Qualitative analysis was done regarding the service life of concrete structures. Phenolphthalein solutions are used for obtaining the carbonation depths. E. Sola [2] evaluates the 3D Chemo – Hygro – Thermo - Mechanical (CHTM) models in both natural and accelerated corrosion due to various cover and diameter patterns and concluded that the models are mainly responsible for transport of rust through pores and cracks of concrete. M. Otieno [3] observed that as the quality of concrete increases, the corrosion gets decreased. To measure the corrosion rate, coulostatic technique was used and the results were observed in the half cell potentiometer. Yafei Ma [4] investigates about the bond behaviour between the steel bars and concrete and concluded that when load gets increased, movement of the crest of bond stress has been occurred. Dif Fodil [5] evaluates that in aggressive environment, the concrete contains the pozzolana and perlite and finally found that the corrosion is not affected by sulphate ions. Du Peng [6] investigates the corrosion behaviour mainly for the structural safety purpose. Variation based on acoustic parameters such as initial corrosion and development period when its rate is greater than 6 %. Acoustic parameters namely, amplitude, wave velocity and dominant frequency were discussed. He concluded that the electrochemical method was suitable to accelerate the corrosion of the reinforced concrete. Jiezhen Hu [7] exposes various damages occurs in the surface of the structure due to corrosion of bars in the marine environments. The chloride ion content and pH measurements were done. The moisture content of the concrete controls the corrosion process. According to the Ficks diffusion law, the submerged zone depth increases in the chloride profile of the concrete. The magnitude of the carbonation rate of concrete in sea water is found to be greater than in fresh water gets concluded.

II. EXPERIMENTAL PROGRAM

A. Materials

The materials used in this research include the Ordinary Portland cement (53 grade), coarse aggregate (20 mm grade), fine aggregate (M Sand), potable water (drinking water), artificial sea water (salt water), GFRP and metakaolin. The metakaolin gets replaced 10 % to cement, in order to enhance the mechanical properties, workability, durability and setting time of concrete. Metakaolin is produced from kaolin by thermal treatment and its reactivity and quality depends upon the characteristics of the raw material used for the production. The crushed angular coarse aggregate retained on 4.75 mm sieve used for this study.

Table- I: Properties of GFRP rebars

Diameter (mm)	8
Density (g/cm^3)	2.2
Ultimate tensile strength (MPa)	980
Ultimate shear strength (MPa)	150
E – Modulus (GPa)	40

Table- II: Properties of artificial sea water

Properties	Values
pH	8.2
Chloride	15246 ppm
Sulphate	214 ppm
Total Hardness	752 ppm
Total Dissolved Solids	18513 ppm
Calcium	123 ppm
Magnesium	81 ppm
Alkalinity	614 ppm

Table- III: Properties of Metakaolin

Characteristics	Observation
Appearance	White Powder
Colour	Off White
Odour	Odourless
Explosive Properties	Insoluble in Water
Solubility Description	Non - Explosive
Specific Gravity	2.6

B. Test Specimens and Methods

Rebound hammer, Ultrasonic pulse velocity and Single half cell potentiometer were carried out to evaluate the strength characteristics of column specimens. The tests were carried out at 7, 14, 28, 56 and 90 days of curing both in potable and salt water. The concrete column specimens of size 600 x 150 x 300 mm were cast and tested. Totally, 8 columns were cast.

III. RESULTS AND DISCUSSION

A. Rebound Hammer

Rebound hammer or Schmidt hammer test is one of the non – destructive testing methods in which it gives a rapid compressive strength of the concrete columns. The plunger of Schmidt hammer is pressed against the concrete surface and the values are measured as rebound index.

The top surface of the concrete column specimens were chosen for obtaining the results. As the ages of curing get increased, the C-S-H gel plays a major role in the strength of concrete column specimens.

The compressive strength of the column is evaluated and the results are shown in the Table IV.

Table- IV: Compressive strength of Rebound hammer

Days	Compressive Strength N/mm^2	
	Potable Water	*Salt Water*
7	11	13
14	21	23
28	25	38
56	36	41
90	51	59

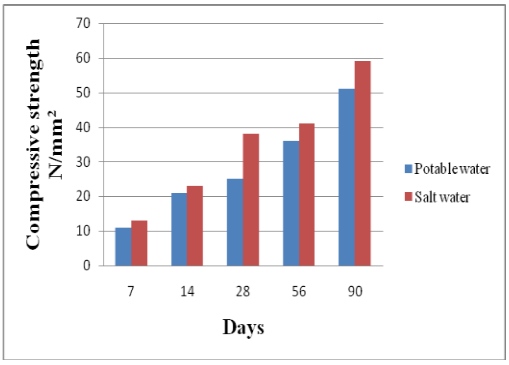

Fig. 1.Test results of Rebound Hammer

B. Ultrasonic Pulse Velocity

UPV is one of the in-situ nondestructive testing method in which the quality of the concrete column specimen is determined by the value of pulse velocity.

The transducer and receiver are placed perfectly and the time taken for travelling the thickness of RCC column in microseconds and hence the pulse velocity can be calculated and tabulated in the Table V.

Table- V: Concrete Quality

Days	Pulse Velocity km/s		Concrete Quality
	Potable Water	*Salt Water*	
7	2.2	2.3	Poor
14	3.1	3.4	Satisfactory
28	3.7	3.9	Good
56	5.1	5.3	Excellent
90	6.2	6.6	Excellent

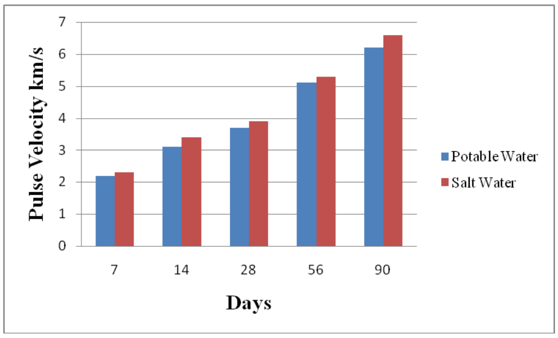

Fig. 2.Test results of UPV

C. ASTM Limits

The ASTM (American Society for Testing and Materials) limits are shown in the table VI.

Table- VI: ASTM Limits

ASTM Limits	Measured Potential (-mV/CSE)	Corrosion Condition
I	> 200	Low (10 % risk)
II	350 to 200	Intermediate risk
III	< 350	High (< 90 % risk)
IV	< 500	Severe

D. Half Cell measurements on RCC column with steel rebars

The Half cell potentiometer is applied for the corrosion monitoring technique which is standardized by ASTM to determine the corrosion probability within the rebar of reinforced concrete structures. The surface of RCC column specimens become wet condition before taking Half Cell measurements. The Half cell measurements were taken using saturated Cu - $CuSo_4$ electrode. The half cell measurements were tabulated in the table VII.

Fig. 3.Table- VII: Half Cell measurements on RCC column (steel rebars) soaked in potable water and artificial sea water

Days	Single Half Cell- Measured Potential (-mV /CSE)	
	Potable Water	*Artificial sea Water*
7	164	209
14	244	275
28	321	348
56	338	364
90	470	560

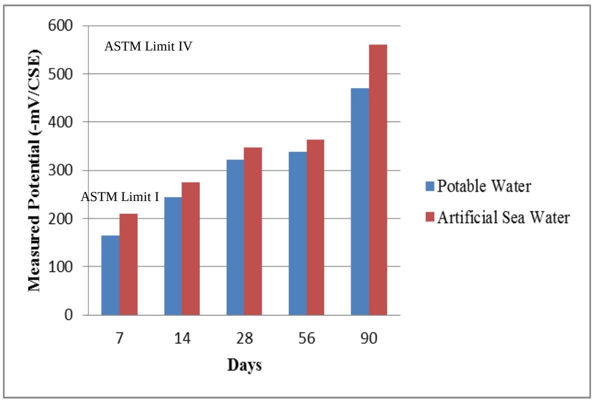

Fig. 4.Half Cell measurements on RCC column with steel rebars

E. Half Cell Measurements on RCC column with GFRP and Steel rebars

The concrete column which has GFRP rebar provided longitudinally and steel rebars as horizontal ties. The Half cell measurements taken on this RCC column were tabulated in the table VIII.

Table- VIII: Half Cell measurements on RCC column (GFRP and steel rebars) soaked in potable and artificial sea water

Days	Single Half Cell- Measured Potential (-mV /CSE)	
	Potable Water	*Artificial Sea Water*
7	79	84
14	128	141
28	214	236
56	276	295
90	308	352

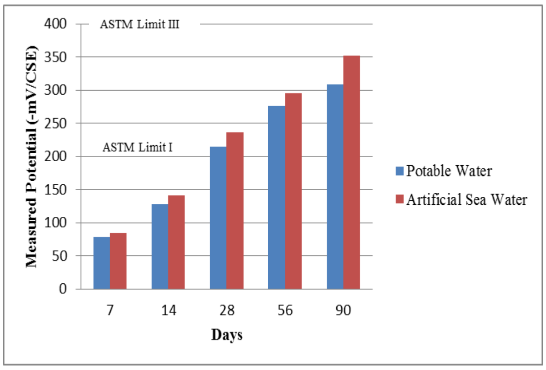

Fig. 5.Half Cell measurements on RCC column with GFRP and steel rebars

IV. CONCLUSION

From the above results, it was found that the compressive strength of the Reinforced concrete column specimens after 90 days of curing in potable water is 51 N/mm^2 and artificial sea water as 59 N/mm^2. The artificial sea water curing increases the strength of RCC column as 13.6 % than that of the RCC column cured in potable water curing. The behaviour of the concrete is found to be excellent both in potable and artificial sea water curing. The Half cell readings in artificial sea water are found to be greater than the potable water curing.

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