ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Analysis of durability of coastal concrete structures

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ABSTRACT

As the usage of ordinary Portland cement is not meeting the durability requirements of the residential buildings situated along the coastal side and not providing the required durability of the structure, it is necessary to impart high durability in coastal concrete structures. The project deals with the study of deterioration of concrete exposed to saline atmosphere. It involves the detailed investigation of structures situated in coastal zone and assessing the chemical properties of sea water. The project involves the usage of alternatives chosen such as GGBS cement, corrosion inhibiting liquid admixture and granite powder. A study is also made on durability conditions of concrete structures on coastal region. It is intended to make inferences from performing experiments such as, Rapid chloride migration test, Compressive strength test and Weight loss test. It is concluded that GGBS [Ground Granulated Blast furnace Slag] and Granite combination has shown adequate abrasion resistance, permeability resistance and chemical resistance to corrosion by sea water.

KEY WORDS: Durability, coastal structures, corrosion, abrasion resistance, Rapid chloride migration, weight loss.

1. INTRODUCTION

The main objective of the project is to determine the best alternatives to the conventional concrete that can resist the detrimental effects on structures located in marine environment. Concrete structures in the coastal areas can be distinguished with respect to corrosion risk as the submerged zone (under seawater), the splash and tide zone (intermittently wet and dry) and the atmospheric zone (well above the high tide level).

Durability study: It is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration. Carbonation of concrete is a process by which carbon dioxide from the air penetrates into concrete and reacts with calcium hydroxide to form calcium carbonates. The Three alternatives namely granite, GGBS and admixture are also used.

Granite: The values of both plastic and drying shrinkage of concrete in the granite powder concrete specimens were nominal than those of ordinary concrete specimens.

GGBS: Ground Granulated Blast furnace Slag (GGBS) which is a by-product from the blast-furnaces used to make iron. Generally, higher the proportions of GGBS, the greater will be the resistance to chloride penetration.

Liquid admixture: It acts as corrosion protection for reinforcing steel embedded in concrete, increasing the life expectancy of exposed building elements.

Material test: The materials like sea water, fine and course aggregates, Portland cement, cement with partial replacement of GGBS, Granite and admixture. The sea water used for this project were taken from Eliots' beech, Chennai. Concrete mix design of M20 grade is adopted with varying water-cement ratio. The cement: fine aggregate: coarse aggregate ratio for Portland cement concrete is 1:1.53:3.33 and for GGBS cement concrete is 1:1.54:3.40.

Table.1.Test on sea water

Name of the test	Test values
pH	8.30
Turbidity	22.2 NTU
Conductivity	2.5 ms
Chloride content	12265.7 ppm
Sulphate content	21530.5 ppm
Dissolved oxygen	41 ppm

Table.2.Test on cement

Name of the test	Test Values	
	Portland cement	**GGBS cement**
Specific gravity	3.05	3.27
Consistency test	33%	29%
Compressive strength	33 grade	33 grade

Table.3.Concrete characteristics

Type of concrete	w/c ratio	Slump test (mm)	Compaction factor
Portland concrete(PC)	0.49	51	0.90
PC + Liquid admixture	0.46	58	0.98
PC + Granite	0.52	42	0.88
GGBS concrete	0.47	53	0.90
GGBS + Liquid admixture	0.45	60	0.91
GGBS + Granite	0.51	47	0.81

2. EXPERIMENTAL WORK

Compressive strength: Compression test is the most common test conducted on hardened concrete. Concrete is filled in cube moulds of standard size (15x15x15cm) in two layers of approximately 75mm and ramming each layer with 35 blows evenly distributed over the surface of layer. The loading rate was 5.2kN/m^2. 7 days and 14 days curing specimens were tested in normal water whereas 28 days cured specimen was tested on both sea and normal water.

Table.4.Compression Test on 7 and 14 days

Concrete type	7 days		14 days	
	Load KN	Compressive strength (N/mm^2)	Load KN	Compressive strength (N/mm^2)
PC concrete	410.40	18.21	589.87	26.22
GGBS concrete	456.33	20.28	635.67	28.25

Table.5.Compression test for 28 days curing

Concrete type	Sea water		Normal water	
	Load KN	Compressive strength N/mm^2	Load KN	Compressive strength N/mm^2
PC Concrete	801.8	35.64	831.2	36.94
	780.3	34.68	866.7	38.52
	812.6	36.12	818.7	36.39
PC + Granite Concrete	809.2	35.96	856.1	38.05
	832.6	37.00	820.4	36.46
	798.3	35.48	791.3	35.17
PPC Admixture Concrete	750.8	33.60	778.4	34.60
	798.6	35.49	791.9	35.20
	804.9	35.77	821.4	36.51
GGBS Concrete	882.6	39.27	901.9	40.08
	856.4	38.06	878.3	39.03
	898.2	39.92	856.5	38.07
GGBS Granite Concrete	928.5	41.27	978.0	43.47
	944.9	41.99	969.2	43.08
	901.8	40.08	911.6	40.51
GGBS Admixture Concrete	834.1	37.07	822.9	36.57
	822.5	36.56	836.3	37.17
	864.6	38.43	818.4	36.37

Rapid chloride migration test: The experimental set up consists of two electrodes in which one copper electrode connected to (+) terminal of the battery which acts as anode and another copper electrode connected to (-) terminal of the battery which acts as cathode. The anode is dipped in NaOH solution whereas the cathode is dipped in NaCl solution.

Figure.1.Lab image of RCM test

Table.6.Rapid chloride migration test for PC concrete

Time interval (Minutes)	PC Concrete		GGBS concrete	
	Current passed (A)	Voltage (V)	Current passed (A)	Voltage (V)
0	0.25	60	0.15	60
30	0.25	60	0.175	60
60	0.25	60	0.175	60
90	0.25	60	0.175	60
120	0.30	60	0.20	60
150	0.30	60	0.20	60
180	0.35	60	0.20	60
210	0.35	60	0.20	60
240	0.35	60	0.225	60
270	0.35	60	0.225	60
300	0.375	60	0.225	60
330	0.375	60	0.25	60
360	0.40	60	0.25	60

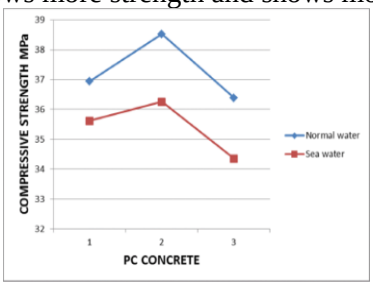
Weight loss test: The concrete with different alternatives are submerged in sea water and normal water for a period of 28 days curing. The difference between weight of concrete before immersion and after immersion gives the loss in weight.

Table.7.Weight loss test in sea water after 28 days curing

Concrete type	Sea water			Normal water		
	Initial kg	Final Kg	Difference kg	Initial kg	Final Kg	Difference kg
PC Concrete	8.21	8.19	-0.02	8.14	8.14	0
	8.28	8.27	-0.01	8.17	8.18	0.01
	8.23	8.23	0	8.22	8.24	0.02
PC Granite Concrete	8.29	8.28	-0.01	8.24	8.24	0
	8.17	8.17	0	8.18	8.18	0
	8.22	8.20	-0.02	8.28	8.28	0
PC Admixture Concrete	8.32	8.32	0	8.25	8.25	0
	8.21	8.21	0	8.29	8.29	0
	8.38	8.38	0	8.22	8.22	0
GGBS Concrete	8.27	8.27	0	8.26	8.27	0.01
	8.20	8.20	0	8.16	8.17	0.01
	8.25	8.25	0	8.29	8.29	0
GGBS Granite Concrete	8.37	8.38	-0.01	8.35	8.35	0
	8.43	8.43	0	8.47	8.48	0.01
	8.41	8.41	0	8.48	8.48	0
GGBS Admixture Concrete	8.36	8.36	0	8.31	8.31	0
	8.25	8.24	-0.01	8.35	8.35	0
	8.41	8.41	0	8.29	8.29	0

3. RESULT ANALYSIS

Compressive strength: From the graph are plotted between normal and sea water and it shows that GGBS concrete shows more strength and shows more durability than the conventional concrete.



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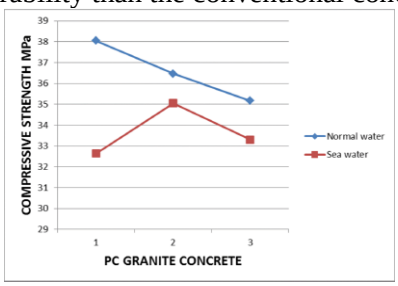

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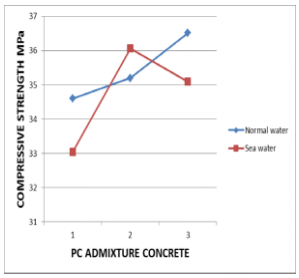

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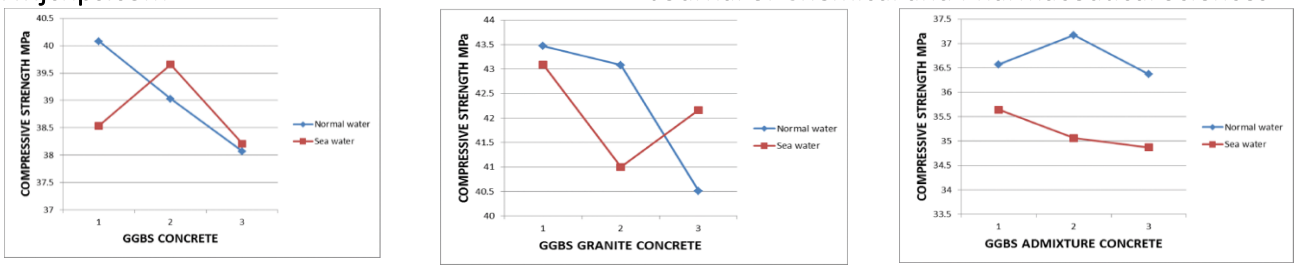
Figure.2.PC compressive strength



a b c

Figure.3.GGBS concrete compressive strength

RCM analysis: It is proven that from the bar graph plotted the more GGBS replacement with cement, the more resistance occurs.

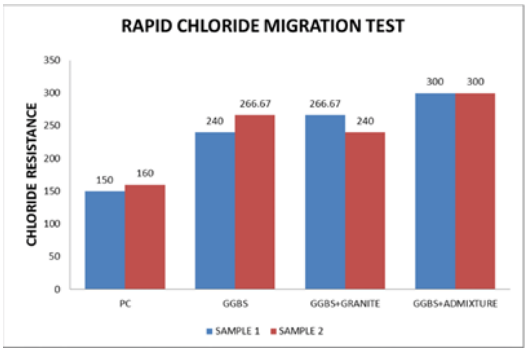


Figure.4. RCM Analysis

Weight loss test analysis: It is found that concrete with 40% replacement of cement with GGBS and 30% replacement of fine aggregate with granite and GGBS liquid admixture has shown nil loss in weight thus this peculiar property could bear the chemical attack by sulphate, acids, etc.

4. CONCLUSION

From the above investigations it is inferred that the formulated concrete are having good durability properties. Among the six formulated concretes, GGBS Granite concrete is showing better performance than the other system alternatives. Therefore GGBS Granite concrete can be applied to all the three zones. The GGBS concrete can be applied to the atmospheric zone (well above the high tide level) and GGBS admixture concrete can be applies to the submerged zone (under sea water)

5. ACKNOWLEDGEMENT

We would like to thank Department of Civil Engineering, Panimalar Engineering College, Chennai and my family and friends for completing this paper without any hindrance.

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