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Behaviour of Ground Granulated Blast Furnace Slag Concrete in Marine Environment under Chloride Attack

Aneesh V Bhat, Sunil Kumar Tengli

Abstract- ***In conventional concrete, one of the ingredients Cement is partially replaced by Ground Granulated Blast Furnace Slag and its nature is studied in this project.. In the present paper, a comparison of Chloride ion penetration is been done on Concrete specimens with partial GGBS replacement. Two tests have been performed on the concrete specimens in both normal environment and artificial marine environment. One is the conventional RCPT and the other one is the chloride ion penetration test using silver nitrate. Comparison of both the tests under normal and marine environment is the main aim of this paper. After compiling the data both RCPT and the Chloride ion penetration test goes hand in hand and this proves the compatibility of the new chloride ion penetration test using silver nitrate. This work has the comparison of the concrete specimens in normal and marine environments as well with different levels of GGBS replacement.***

I. INTRODUCTION

In today's industry, the use of concrete is increasing day by day.. Hence it is necessary to find a replacement to cement in concrete as a substitute to it. In order to find the alternative material, different alternatives should be checked for their properties in concrete production and the behaviour of concrete when these materials are used in it. One of the alternatives which can be used is Ground Granulated Blast Furnace Slag (GGBS). GGBS is a by-product in the steel manufacturing industry and it can be used as an alternative material to OPC due to its inherent binding properties. When cement is replaced by another product, its behaviour with respect to strength and durability is to be checked thoroughly. In the durability aspects, Chloride ion attack is predominant in marine environment and all the tests and facts related to chloride ion attack is been discussed here in this paper. Chloride ion penetration is to be studied with the help of different tests and should be analysed to reduce the effect of chloride ion attack by replacing cement by GGBS in this particular case. All the properties checked in marine environment is to be compared with the results in the normal environment.

II. METHODOLOGY

In the present paper, a comparison of Chloride ion penetration tests is been done on Concrete specimens with partial GGBS replacement.

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***** Correspondence Author
Aneesh V Bhat*, is a Research Scholar from REVA University, Bengaluru from School of Civil Engineering.
Dr. Sunil Kumar Tengli, Professor, & PG Coordinator (Structural Engineering), holds Ph. D. degree from Visvesvaraya Technological University, Belagavi.

Two tests have been performed on the concrete specimens in both normal environment and artificial marine environment. One is the conventional RCPT and the other one is the chloride ion penetration test using silver nitrate.
Two tests in two environments with GGBS replacement up to 70% since chloride ion penetration is one of the key parameter in marine environment.

III. OBJECTIVES

- To compare the GGBS replaced concrete with normal concrete in marine environment by keeping chloride ion penetration as a key factor
- To compare the two tests related to chloride ion penetration in two environments with GGBS replacement up to 70%
- To decide the feasibility of GGBS replacement in normal concrete in marine environment so as to counterattack the chloride ion penetration
- To check the above parameters for M40 and M20 grade concrete specimens in two environmental exposure conditions

IV. INGREDIENTS AND THEIR PROPERTIES

A. Cement

For the present study OPC 53 grade JK cement is been used and all the initial tests related to cement is been done and it is been tabulated as below.

Table 4.1 Physical properties of Cement

Sl No.	Properties	Values	Requirements as per IS 4031:1988(Part 1 to 5)
1	Specific Gravity	3.14	Not Specified
2	Normal Consistency	32%	Not Specified
3	Initial Setting Time	77 min	Shall not be less than 30 minutes
4	Final Setting Time	588 min	Shall not be greater than 600 minutes
5	Specific Surface	344.30 cm^2/g	Not Specified

B. Ground granulated blast furnace slag (ggbs)

Ground Granulated Blast Furnace Slag (GGBS) is obtained from factory outlet and the physical properties are as follows which is directly received from the manyfacturer

Table 4.2 Physical Properties of GGBS

Sl No.	Properties	Values
1	Specific Gravity	2.90
2	Bulk Density	1245
3	Colour	Whitish
4	Fineness by 45µ sieve	6.90%

C. Fine aggregates and coarse aggregates

Fine aggregates are the material passing through IS sieve that is less than 4.75 mm gauge, beyond which they are called as coarse aggregates. Here we have used river sand as fine aggregates and coarse aggregates of 20 mm down-size and 12 mm down-size for the study.

Table 4.3 Physical properties of Fine Aggregates

Sl No.	Properties	Values	Requirements as per IS 383: 1970 ; RA 2007
1	Specific Gravity	2.50	Not Specifies
2	Fineness Modulus	2.12	Should be less than 10% by its weight

Table 4.4 Physical Properties of 20 mm down-size Aggregates

Aggregate Impact Value	16.74%	Max. 45%
Specific Gravity	2.7	2.6-2.8
Elongation Index	18.70%	Shall not be more than 30%
Flakiness Index	22.00%	Shall not be more than 30%

Table 4.5 Physical Properties of 12.5 mm Down-size Aggregates

Aggregates Impact Value	18.44%	Max. 45%
Specific Gravity	2.67	2.6-2.8
Elongation Index	10.74%	Shall not be greater than 30%
Flakiness Index	18.10 %	Shall not be greater than 30%

D. Water

Almost any natural water that is drinkable and has no odour can be used to prepare concrete. Water containing less than 2000 ppm of total dissolved solids can be satisfactorily used to make concrete. pH level up to 9 is allowed. For this study, the potable water according to IS 456:2000 has been used.

V. TESTING OF SPECIMENS

A. Rapid chloride ion penetration test (rcpt)

Rapid Chloride Ion Penetration Test is based on ASTM C1202. This test indicates the chloride ion penetration in terms of Coulombs. For this particular test the cylinders of 20cm height and 10cm diameter are casted and kept in water curing. These cylinders are then cut in to 50 mm thick slices for the purpose of experiment. The experiment setup has two cell chambers, one with 3% Nacl solution and another one with 0.3N NaOH solution. The 50mm thick specimen is covered with insulating tape and is kept in between the two cells and electricity is passed through it. When the electricity is passed, the chloride ion passes from one cell to another through the concrete specimen and the amount of chloride ion passed between the specimens is noted down in coulombs. This test is conducted for 6 hours or 360 minutes.

Figure Number 5.1: Total RCPT arrangement.

Figure Number 5.2: Total RCPT arrangement.

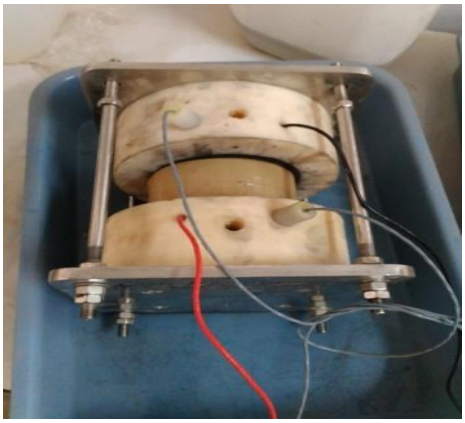

Figure Number 5.3: Cell arrangement in RCPT and total RCPT arrangement.

B. Chloride penetration TEST using silver nitrate

To conduct chloride immersion test, the concrete cubes which are 28days water cured are immersed in 5% sodium chloride solution and they are tested for compression for 28, 56,90 days of Nacl curing. The compression test results are tabulated and also the surface damage if any is studied. After the compression test, the specimen is broken in to two pieces and Silver Nitrate solution is sprinkled in to the inside section of the concrete specimen and the whitish precipitate occurs wherever the chloride penetration persists. The depth of the chloride penetration can be found out by the colour change and can be tabulated.

Figure Number 5.4: Chloride ion penetration test showing the penetration pattern

VI. TEST RESULTS AND DISCUSSION

A. M40 grade concrete results

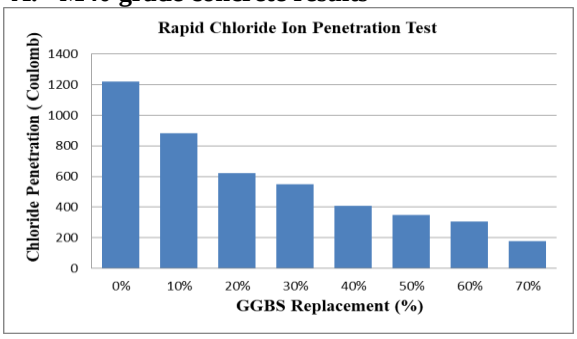

Figure Number 6.1: Normal Environment RCPT Results

Table No. 6.2: Marine environment Environment RCPT Results

GGBS Replacement(%)	Chloride Penetration (Coulomb)
0%	1220.3
10%	880.5
20%	620.3
30%	550.6
40%	410.1
50%	350.6
60%	305.8
70%	177.7

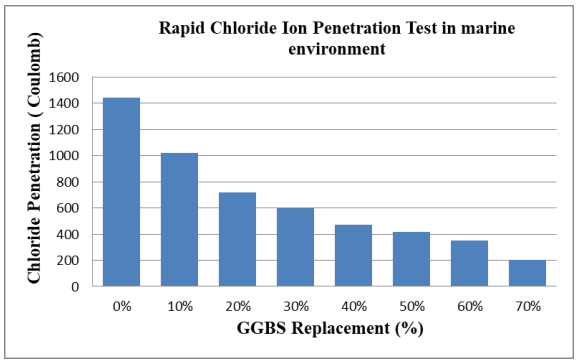

Figure Number 6.2: Marine environment Environment RCPT Results

Table No. 6.2: Marine environment Environment RCPT Results

GGBS Replacement(%)	Chloride Penetration (Coulomb)
0%	1440.3
10%	1020.4
20%	720.2
30%	600.1
40%	474.3
50%	416.1
60%	350.3
70%	200.3

Table No 6.3: Comparison between Normal and Marine environment RCPT

	Marine Environment	Normal Environment	Increase in penetration	Percentage Increase in Penetration
GGBS Replacement(%)	Chloride Penetration (Coulomb)	Chloride Penetration (Coulomb)	(Coulombs)	(Percentage)
0%	1440.3	1220.3	220	15.27459557
10%	1020.4	880.5	139.9	13.71030968
20%	720.2	620.3	99.9	13.8711469
30%	600.1	550.6	49.5	8.248625229
40%	474.3	410.1	64.2	13.53573688
50%	416.1	350.6	65.5	15.74140832
60%	350.3	305.8	44.5	12.70339709
70%	200.3	177.7	22.6	11.28307539

With reference to the above table, the comparison between normal and marine environment is been done with reference to RCPT and by going through the comparison we can observe that the GGBS replacement in between the range of 30 to 40 percentage has least difference or in this range the concrete in marine environment almost behaves as concrete in normal environment.

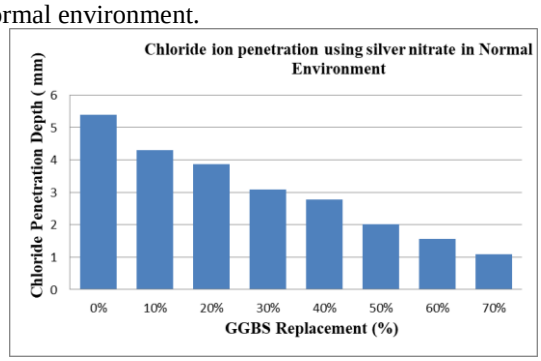

Figure Number 6.3: Normal environment Chloride ion Penetration Results

Table No. 6.4: Normal environment Chloride ion Penetration Results

GGBS Replacement(%)	Chloride Penetration depth (mm)
0%	5.4
10%	4.3
20%	3.87
30%	3.09
40%	2.77
50%	2.01
60%	1.56
70%	1.09

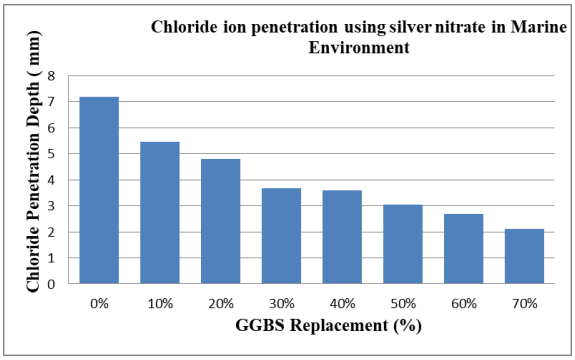

Figure Number 6.4: Marine environment Chloride ion Penetration Results

Table No. 6.5: Marine environment Chloride ion Penetration Results

GGBS Replacement(%)	Chloride Penetration depth (mm)
0%	7.2
10%	5.45
20%	4.8
30%	3.68
40%	3.6
50%	3.04
60%	2.7
70%	2.1

Table No 6.6: Comparison between Normal and Marine environment Penetration Test

	Marine Environment	Normal Environment	Increase in penetration	Percentage Increase in Penetration
GGBS Replacement(%)	**Chloride Penetration (mm)**	**Chloride Penetration (mm)**	**(mm)**	**(Percentage)**
0%	7.2	5.4	**1.8**	**25**
10%	5.45	4.3	**1.15**	**21.10091743**
20%	4.8	3.87	**0.93**	**19.375**
30%	3.68	3.09	**0.59**	**16.0326087**
40%	3.6	2.77	**0.83**	**23.05555556**
50%	3.04	2.01	**1.03**	**33.88157895**
60%	2.7	1.56	**1.14**	**42.22222222**
70%	2.1	1.09	**1.01**	**48.0952381**

With reference to the above table, the comparison between normal and marine environment is been done with reference to chloride ion penetration test using silver nitrate and by going through the comparison we can observe that the GGBS replacement in between the range of 30 to 40 percentage has least difference or in this range the concrete in marine environment almost behaves as concrete in normal environment

B. M20 grade concrete results

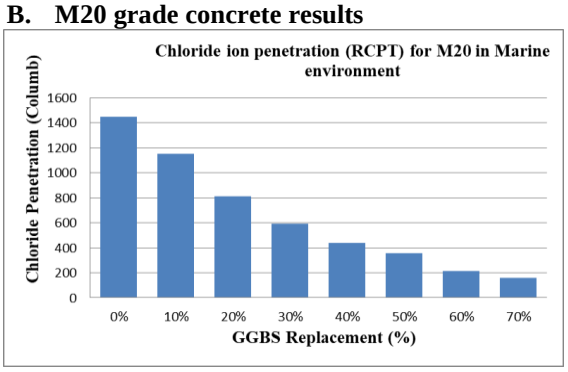

Figure Number 6.1: Normal Environment RCPT Results

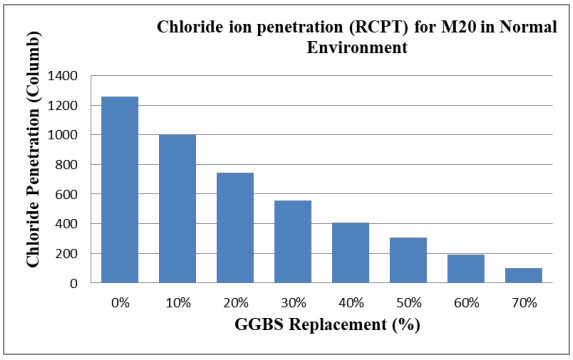

Figure Number 6.2: Marine environment Environment RCPT Results

Table No 6.3: Comparison between Normal and Marine environment RCPT

	Marine Environment	Normal Environment	Increase in penetration	Percentage Increase
GGBS Replacement(%)	Chloride Penetration in coulomb	Chloride penetration (Coulomb)	(Coulomb)	
0%	1450	1256	194	13.37931034
10%	1150	1003	147	12.7826087
20%	810	745	65	8.024691358
30%	590	556	34	5.762711864
40%	440	409	31	7.045454545
50%	357	308	49	13.7254902
60%	213	190	23	10.79812207
70%	158	102	56	35.44303797

With reference to the above table, the comparison between normal and marine environment is been done with reference to RCPT and by going through the comparison we can observe that the GGBS replacement in between the range of 30 to 40 percentage has least difference or in this range the concrete in marine environment almost behaves as concrete in normal environment.

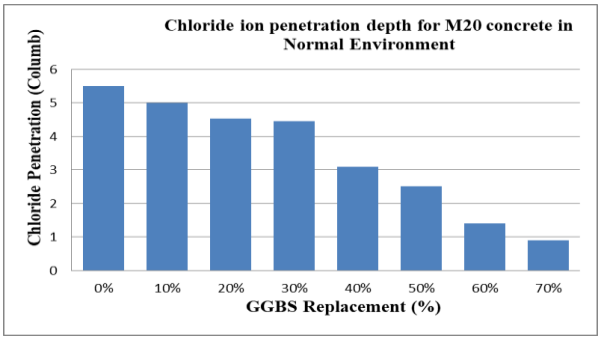

Figure Number 6.3: Normal environment Chloride ion Penetration Results

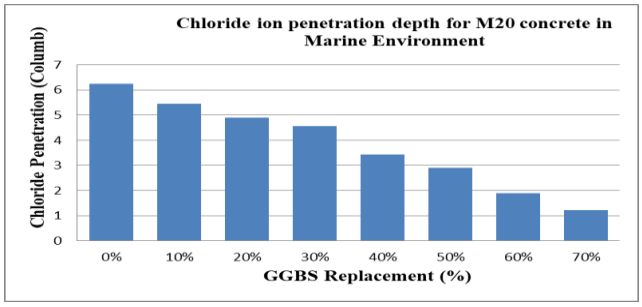

Figure Number 6.4: Marine environment Chloride ion Penetration Results

Table No 6.6: Comparison between Normal and Marine environment Penetration Test

	Marine Environment	Normal Environment	Increase in penetration	Percentage Increase
GGBS Replacement(%)	Chloride Penetration in mm	Chloride penetration in mm	mm	
0%	6.23	5.5	0.73	11.71749599
10%	5.45	4.99	0.46	8.440366972
20%	4.89	4.53	0.36	7.36196319
30%	4.56	4.46	0.1	2.192982456
40%	3.44	3.1	0.34	9.88372093
50%	2.9	2.5	0.4	13.79310345
60%	1.9	1.4	0.5	26.31578947
70%	1.23	0.9	0.33	26.82926829

With reference to the above table, the comparison between normal and marine environment is been done with reference to chloride ion penetration test using silver nitrate and by going through the comparison we can observe that the GGBS replacement in between the range of 30 to 40 percentage has least difference or in this range the concrete in marine environment almost behaves as concrete in normal environment.

VII. CONCLUSION

- Based on both the tests so as to avoid the chloride ion penetration both in normal as well as marine environment,

30 to 50% of cement can be replaced by GGBS

- In marine environment the extent of chloride ion penetration is more as explained by both the tests
- As per both the tests, chloride ion penetration was maximum for 0% replacement and minimum for 30 to 50% replacement
- Concrete in Marine environment behaves almost as normal concrete when the GGBS replacement is in the range of 30 to 50%
- As RCPT is the standard chloride ion penetration test, the new test using silver nitrate could be compared with RCPT since the new test gave the same output as that of RCPT.

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AUTHORS PROFILE

Aneesh V Bhat is a Research Scholar from REVA University, Bengaluru from School of Civil Engineering. He is working on Marine concrete Behaviour with GGBS replacement for Cement as a partial replacement. He has published a number of International Journal papers and National Journal papers and has presented papers in a number of Conferences.

Dr. Sunil Kumar Tengli, Professor, & PG Coordinator (Structural Engineering), holds Ph. D. degree from Visvesvaraya Technological University, Belagavi. He has 31 years of teaching experience for Undergraduate students of Civil Engineering and Post Graduate students of Structural Engineering. He has guided 39 dissertations for Structural Engineering students. He has published 14 technical papers in National/International Journal/ Conferences. He is a member in technical organizations such as Institution of Engineers (India), Indian Concrete Institute, Indian society of Technical Education, International Centre for fiber reinforced concrete. He has carried out four funded research projects. His research areas are special concretes, reliability analysis and structural optimization.