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. 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     | 77 min | Shall not be less than 30 minutes           |
| 4      | Final Setting       | 588 min| Shall not be greater than 600 minutes       |
| 5      | Specific Surface    | 344.30 cm²/g | Not Specified                             |

B. Ground granulated blast furnace slag (ggb)

Ground Granulated Blast Furnace Slag (GGBS) is obtained from factory outlet and the physical properties are as follows which is directly received from the manufacturer.
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 45µm 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 |
|--------|---------------------|--------|
| 1      | Specific Gravity    | 2.50   |
| 2      | Fineness Modulus    | 2.12   |

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

| Aggregate 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.
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

| 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                          |

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                          |

Figure Number 6.2: Marine environment Environment RCPT Results

Table No. 6.3: Comparison between Normal and Marine environment RCPT

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

| 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                            |

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                             |

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

Table No 6.3: Comparison between Normal and Marine environment RCPT

| GGBS Replacement(%) | Marine Environment Chloride Penetration in coulomb | Normal Environment Chloride penetration (Coulomb) | Increase in penetration (Coulomb) | Percentage Increase |
|---------------------|-----------------------------------------------|-----------------------------------------------|----------------------------------|--------------------|
| 0%                  | 1450                                          | 1256                                          | 194                              | 13.37931034        |
| 10%                 | 1150                                          | 1003                                          | 147                              | 12.7826087         |
| 20%                 | 810                                           | 745                                           | 65                               | 8.024691558        |
| 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.

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

| GGBS Replacement(%) | Marine Environment Chloride Penetration in mm | Normal Environment Chloride penetration in mm | Increase in penetration | Percentage Increase |
|---------------------|-----------------------------------------------|-----------------------------------------------|-------------------------|--------------------|
| 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                                          | 3.2                                          | 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.

REFERENCE
1. Saravanavan Ramalingam and Manu Santhanam, “Environmental exposure classifications for concrete construction – A relook”, The Indian Concrete Journal MAY 2012
2. Kohki Eguchi, Koji Takewaka, Toshinobu Yamaguchi and Naomichi Ueda, “A Study on Durability of Blast Furnace Slag Cement Concrete Mixed With Metaalkolin-Based Artificial Pozzolan in Actual Marine Environment” Third international conference on construction materials
3. B.S. Dhanya, Manu Santhanam, Vijay Kulkarni, Prakash Nanthagopalan, Shashank Bishno, S.P. Singh, G. Indu Siva Ranjani, P. Dinakar, and S. Bhaskar, “Round robin testing of durability parameters – Towards identification of suitable durability tests for concrete”, The Indian concrete journal July 2017
4. S. Sahoo, P.K. Parhi and B.C. Panda, “Strength and durability characteristics of cement mortar” The Indian concrete journal July 2017
5. Arun K. Chakraborty and Sandip Mondal, “Bacterial concrete: A way to enhance the durability of concrete structures” The Indian concrete journal July 2017
6. Saarthak Surana, Radhakrishna G. Pillai and Manu Santhanam, “Performance evaluation of field curing methods using durability index tests” The Indian concrete journal July 2017
7. Aditya S. Rajput and Umesh K. Sharma, “Durability and serviceability performance of GFRP rebars as concrete reinforcement” The Indian concrete journal July 2017
8. Naveena M.P., G. Narayana and Ravichandran R., “Study on strength and durability properties of fly ash aggregates concrete” The Indian concrete journal July 2017
9. Vinayak Awasewar, Prof. M. V. Nagendra, “ANALYSIS OF STRENGTH CHARACTERISTICS OF GGBS CONCRETE”, International Journal of Advanced Engineering Technology E-ISSN 0976-3945
10. Anand V R, Prof. Dr. A. V. Pradeep Kumar, Aneesh V Bhat, “An experimental investigation on theperformance of high volume ground granulated blast furnace slag concrete” International Journal of Civil Engineering and Technology (IJICT) Volume 8, Issue 2, February 2017, pp. 328–337
11. SHAHAB SAMAD, ATTAULLAH SHAH and MUKESH C LIMBACHIYA, “Strength development characteristics of concrete produced with blended cement using ground granulated blast furnace slag (GGBS) under various curing conditions”, Sa’dhana Vol. 42, No. 7, July-2017, pp. 1203–1213
12. RAJESH KUMAR, AMIYA K. SAMANTA2 AND D. K. SINGHA ROY, “Characterization and development of eco-friendly concrete using industrial waste – A Review”, Journal of Urban and Environmental Engineering, v.8, n.1 p. 98-108, 2014
13. KELIANG LI, “Ocean Engineering Concrete using High-volume GGBS”, Applied Mechanics and Materials Vol. 228 (2012) pp 71-74
14. J. WAWRZENCZYK, T. JUSZCZAK, and A. MOLENDOWSKA “Determining equivalent performance for frost durability of concrete containing different amounts of ground granulated blast furnace slag”, Bulletin of the polish academy of sciences technical sciences, vol. 64, no. 4, 2016
15. RAFAT SIDDIQUE “Utilization (recycling) of iron and steel industry by-product (GGBS) in concrete: strength and durability properties”, J Mater Cycles Waste Manag (2014) 16:460–467
16. CHITHRA D , NAZEER M “Strength and Chloride Permeability Studies on Ground Granulated Blast Furnace Slag Admixed Medium Strength Concrete”, ©2012 IEEE
17. GÉRALDINE VILLAIN, RAEIZÉ DU PLOOY, AMINE IHAMOUTEN, SERGIO PALMA-LOPES, BENOÎT THAUVIN, XAVIER DÉROBERT “Use of electromagnetic non-destructive techniques for monitoring the chloride ingress into concrete”,©2013 IEEE
18. SANTOSH KUMAR KARRI, G.V.RAMA RAO, P.MARKANDEYA RAJU “Strength and Durability Studies on GGBS Concrete”, SSRG International Journal of Civil Engineering (SSRG-ICE) – volume 2 Issue 10 October 2015
19. S. PAVIA AND E. CONDREN “Study of the Durability of OPC versus GGBS Concrete on Exposure to Silage Effluent” Journal of materials in civil engineering © asce / april 2008
20. M. VIAYA SEKAR REDDY AND M.C. NATARAJA, “Performance of standard and high strength concrete mixes consisting of different combination of supplementary cementing materials based on RCPT”, The Indian Concrete Journal, December 2017, Vol. 91, Issue 12, pp. 19-26.

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 fibre reinforced concrete. He has carried out four funded research projects. His research areas are special concretes, reliability analysis and structural optimization.

Retrieval Number: A4699111919/2019©BEIESP
DOI: 10.35940/ijitee.A4699.111919
1664
Published By: Blue Eyes Intelligence Engineering & Sciences Publication

IJITEE