Tests And Criteria For Concrete Resistant To Chloride Ion Penetration

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ABSTRACT

The target experimentally investigate the effect of chloride resistance concrete with addition of Ground granulated blast furnace blast slag(GGBS) and Sodium Meta Silicate in varying proportions. In this paper examines effect of that material to the concrete on chloride resistance and voids filling as in concrete. The GGBS act as a filler in concrete. The experimental studies had conducted on mechanical properties tests and durability tests. The mechanical properties are compressive strength, split tensile strength and pullout test. The pullout test have been conducted to study the influence of reinforcing bar corrosion and cracking on bond behavior and bond strength of reinforced concrete members. Pullout tests are used to simulate severe local corrosion to simulate relatively uniform corrosion, along the reinforcing bar surface. The durability studies had to conducted on chloride penetration test and Rapid chloride permeability test (RCPT). Measured apparent chloride diffusion coefficients were correlated with results of rapid index test methods that provide an indication of the characteristics of concrete. A set of rapid chloride test methods and specification criteria that can reliably classify mixtures based on their resistance to chloride ion penetration are proposed.

Keywords—GGBS,RCPT,Sodium meta silicate,chloride penetration,Filler

I. INTRODUCTION

Chloride-induced corrosion of reinforcing steel in structures, such as bridges, has been a major concern for many years. Chlorides from deicing salts or seawater can penetrate the concrete and build up over time until the concentration reaches a level sufficient to depassivate the steel. Once this occurs, the steel will begin corroding and eventually the volume of the corrosion products will be sufficient to crack and spall the concrete cover. Corrosion-inhibiting admixtures, both inorganic and organic, have been developed with the goal of delaying the on set of corrosion or slowing the rate of corrosion once the steel has been depassivated. These admixtures work by interfering with the corrosion reaction or by slowing the rate of chloride, oxygen, and moisture penetration by decreasing the permeability of the concrete. Two inorganic corrosion inhibitors were evaluated in this study with the goals of:

1) comparing their performance based on the quantity of chlorides required to initiate corrosion and the rate of corrosion after initiation in cracked as well as uncracked concrete and

2) Examining and explaining the negative impact of the organic inhibitors on compressive strength. Sodium meta silicate and GGBS is an inorganic corrosion inhibitor that helps stabilize the passive layer on the steel surface. In addition to forming a passive layer, sodium meta silicate and GGBS also completes with chloride ions for ferrous ions, preventing the chlorides from initiating corrosion Studies examining the effectiveness of Sodium meta silicate have yielded positive results, with reinforcement in concrete with GGBS exhibiting a longer time to corrosion initiation and correspondingly higher chloride content in uncracked concrete. In addition to serving as a corrosion inhibitor, sodium meta silicate acts as a ponding strength for concrete. To counter act this, ggbs and sodium meta silicate based inhibitors are often combined with a set retarder. No significant reductions in compressive strength have been observed for concrete with sodium meta silicate and GGBS.

II. MATERIALS

A. Cement

The ordinary Portland cement confirming to IS 4031 was used for the preparation of specimens. OPC 53 grade was used.

B. Fine aggregate

Fine aggregate is used in the experimental investigation and confirming to zone-II of IS 383-1970.Sand is used in the work which has the particle was less than 4.75mm.

C. Coarse aggregate

The coarse aggregate particles passing through 20mm and retained on 12.5 mm I.S Sieve used as the natural aggregate which met the grading requirement of IS 383-1970.

D. Water

Water is the most important and least expensive ingredient of concrete. A part of mixing water is utilized in the hydration of cement to form binding matrix in which the inert aggregates are held in suspension until the matrix has harden. The remaining water serves as a lubricant between the fine and coarse aggregate and makes concrete workable.

E. Sodium Meta Silicate

Sodium silicate is the common name for compounds with the formula Na2Sio3. A well known member of this series is sodium metasilicateNa_2O_3si. Its forms known as a water glass or liquid glass these materials are available in aqueous solution and solid form. Its produced by sodium silicate with addition of soda ash and water through the heated in 9000c then taken in thin solid to be make powdered form. Its manufactured by smashed crystal method.

Fig 1- Sodium meta silicate

F. Ground Granulated Blast Slag(GGBS)

Ground granulated blast-furnace slag is the granular material formed when molten iron blast furnace slag is rapidly chilled (quenched) by immersion in water. It is a granular product with very limited crystal formation and is highly cementitious in nature. It is ground to cement fineness and hydrates like Portland cement. After the molten iron is tapped off, the remaining molten slag, which consists of mainly siliceous and aluminous residue is then water-quenched rapidly, resulting in the formation of glassy granulate. This glassy granulate is dried and ground to the required size , which is known as ground granulated blast furnace slag (GGBS).

III. Material Properties

A. Cement - Opc 53 grade

- Specific gravity -3.13
- Fineness modulus -3.6%
- Consistency -32%
- Initial setting time-30 mins
- Final setting time -10Hours

B. Fine aggregate

- Specific gravity -2.54
- Fineness modulus -3.33
- Water absorption 0.85%
- Bulk density-1782.46kg/m^3

C. Coarse aggregate

- Specific gravity -2.66
- Fineness modulus -84
- Water absorption 0.56%
- Bulk density-1693.46kg/m^3
- Impact test -15%

D. Sodium Meta Silicate

- Formula : Na_2O_3Si
- IUPAC ID : Sodium metasilicate
- Density : 2.4 g/cm^3
- Molar mass : 122.06 g/mol
- Melting point : 1,088 °C
- Soluble in : Water

Conforming to IS:9424-1979 of BIS

TABLE I - Chemical composition of sodium meta silicate

Technical specifications	Nano Hydrate	Penta Hydrate
Total alkalinity by% mass, min	21.00	29.00
Ratio of total alkalinity to total soluble silica	1:1 +0.05	1:1±0.05
Loss on evaporation% by mass, max	59.00	43.50
Matter insoluble in water % by mass, max	0.50	0.50
Free alkalinity %by mass, max	0.80	1.00

E. Ground Granulated Blast Furnace Slag

- Colour Off - white powder
- Bulk density (loose)- 1100 kg /m^3
- Bulk density (vibrated) -1300 kg/m^3
- Relative density -2950 kg/m^3

TABLE II: Chemical composition of GGBS

S.NO	Oxide composition	GGBS
1	SiO_2	37.73%
2	Fe_2O_3	1.11%
3	Al_2O_3	14.42%
4	CaO	37.34%
5	Mgo	8.71%
6	Mno	0.02%
7	Glass	92%
8	Loss of ignition	1.41%
9	Insoluble residue	1.59%

IV. MIX DESIGN

TABLE III: Mix design

Grade of concrete –M30

Water	Cement	Fine Aggregate	Coarse Aggregate
191.58	518	488.64	1142
0.37	1	0.92	2.2

For quantity of materials taken by per meter cube size mix proportions are given below table IV

TABLE IV: Mix Proportions

Mix ID	Cement (kg/m^3)	Fine agg. kg/m^3	Coarse agg. (kg/m^3)	Sodium meta silicate (kg/m^3)	GGBS (kg/m^3)
MC	593	546.3	1306.3	-	-
MGS1	593	518.9	1306.3	27.31	11.68
MGS2	593	505.32	1306.3	40.97	11.68
MGS3	593	491.67	1306.3	54.63	11.68

Mix Proportion ID

a. MC- cement+F.A+C.A

b. MGS1-cement+F.A+C.A+5%sodium metasilicate(replace F.A)+GGBS(20% filler)

c. MGS2-cement+F.A+C.A+7.5%sodium metasilicate(replace F.A)+GGBS(20% filler)

d. MGS3-cement+F.A+C.A+10%sodium metasilicate(replace F.A)+GGBS(20% filler)

V. EXPERIMENTAL WORK

A. Mechanical properties

Compressive strength

Compressive test was conducted in universal compressive testing machine of capacity 200 kN at a loading rate of 2.5 kN/sec. The compressive strength will achieved for thus combination results are below

TABLE V: Compressive strength

Mix Id	7 days (N/mm^2)	28days (N/mm^2)
MC	20	34.5
MGS1	22.6	36.4
MGS2	26.1	37.9
MGS3	24.8	36.2

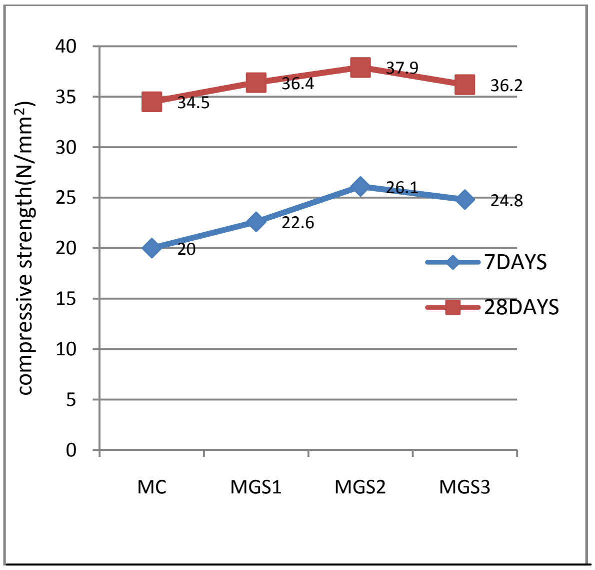

Fig 2 - Compressive strength

Split tensile strength

Split tensile strength test was conducted in universal compressive testing machine of capacity 200 kN at a loading rate of 2.5 kN/sec.

TABLE VI : Split tensile strength

Mix Id	7 days (N/mm^2)	28days (N/mm^2)
MC	1.73	2.758
MGS1	1.7	2.85
MGS2	1.65	2.9
MGS3	1.68	2.98

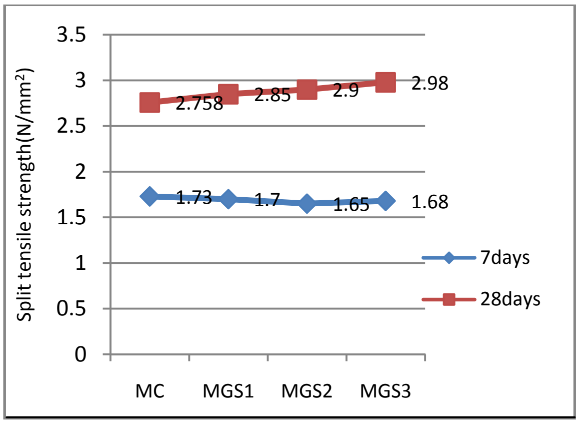

Fig 3 - Split tensile strength

Pull out strength Test

Concrete cylinder of size 150mm diameter and 300mm high were cast with centrally embedded rebar provided up to 16 mm from the face of the cylinder. The rebar extended over the top face of the cylinder. The rebar bonded length in concrete is restricted to 2 to2.4 times of diameter rebar. This test conducted by universal testing machine.

Fig 4- Pullout strength Test

TABLE VII. Pull out strength

Mix Id	Pullout strength (N/mm^2)
MC	43.28
MGS1	36.84
MGS2	34.99
MGS3	34.07

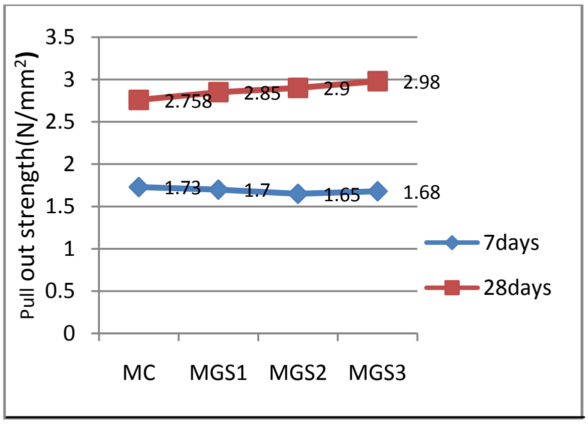

Fig 5 - Pull out strength

A. *Durability test*

Rapid chloride permeability test (ASTM-C1202)

The Rapid Chloride Penetration Test (RCPT) is used to determine the electrical conductance of concrete to provide a rapid indication of its resistance to the penetration of chloride ions. The RCPT is performed by monitoring the amount of electrical current that passes through concrete discs of 50mm thickness and 100mm diameter for a period of six hours. A voltage of 60 V DC is maintained across the ends of the specimen throughout the test. One lead is immersed in a sodium chloride (NaCl) solution (0.5N) and the other in a sodium hydroxide (NaOH) solution (0.3N). The total charge passed through the cell in coulomb has been found in order to determine the resistance of the specimen to chloride ion penetration.

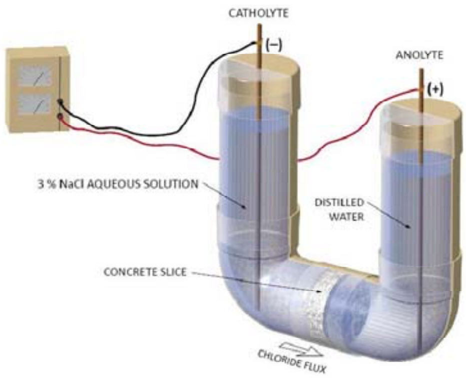

Fig 6 - Model set up for RCPT

$$Q = 900(I_0+2I_{30}+2I_{60}+2I_{90}+2I_{120}+\ldots+2I_{300}+2I_{330}+I_{360})$$

Where,

Q = current flowing through one cell (coulombs)

I_0 = Current reading in amperes immediately after voltage is applied, and

I_t = Current reading in amperes at t minutes after voltage is applied

The table VIII shows the rating of chloride permeability according to ASTM C 1202-97.

TABLE VIII : Rating of Chloride Permeability

Chloride Penetration	Rapid Chloride Permeability Charge Passed (Coulombs)
High	>4,000
Moderate	2,000 to 4,000
Low	1,000 to 2,000
Very Low	100 to 1,000
Negligible	<100

Fig 7 - Rapid chloride permeability Test

TABLE IX. Rapid chloride permeability Test

Mix Id	Charges passed(coulombs)	Chloride penetration
MC	8811	High
MGS1	7784	High
MGS2	6457	High
MGS3	3951	Moderate

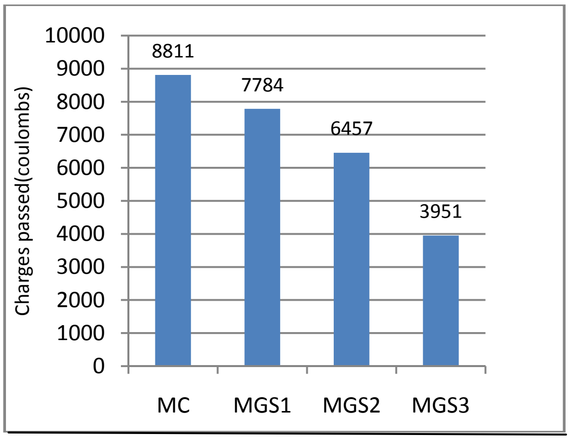

Fig 8 –Rapid Chloride Penetration Test Result

Chloride ion Penetration Test

This study was carried out to find out the influence of Sodium meta silicate and GGBS on chloride ion penetration. The concrete cylinders of 150 mm dia and 300 mm height are cast and,one day later, they are put in contact with a 0.3M CaCl2 solution. The specimens are covered with paraffin in their lower portion, while the upper portion was placed in a PVC pipe, tied to the specimens by a metallic clip. For each concrete mixture three specimens are made. Cylinders are broken after 56days, through splitting test. Chloride penetration depth was measured by using silver nitrate solution as a colorimetric indicator.

Fig 9. Chloride Penetration Test

TABLE X. Chloride Penetration Test Result

Mix ID	Chloride penetration depth(mm)	
	28 days	56 days
MC	3.2	6.2
MGS1	1.5	5.7
MGS2	1.2	8.21
MGS3	1.3	7.28

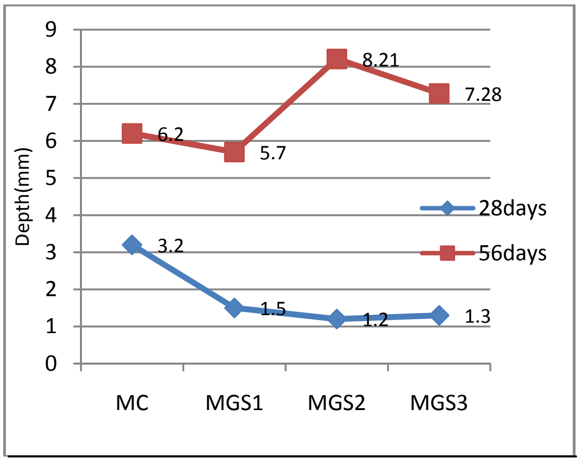

Fig 10- Chloride penetration Test Result

VI. Result and Discussion

Compressive strength

The compressive strength had achieved in MGS2 mix is high. That compressive strength result 26.1N/mm^2 for 7 days and 28 days strength is 36.2 N/mm^2.The low compressive strength is given MGS1 mix proportions.

Split tensile strength

The split tensile strength had achieved in MG2 mix is high. That Split tensile strength maximumresult 2.98N/mm^2 for 7 days and 28 days strength is 3 N/mm^{2}respectively.The low split tensile strength is given control mix proportions.

Pullout strength

The bonding strength had achieved in control mix is high. That bond strength result 43.28N/mm^2 for 7 days and 28 days strength is 36.2 N/mm^2.The low compressive strength is given MGS1 mix proportions.

Rapid chloride permeability Test

The RCPT result is MGS3 mix low level chloride diffusion rate. That to be given 3951coulombs which is moderate level chloride ion penetration. The comparison of conventional mix to their to reduce chloride penetration to increase quantity of sodium meta silicate mix proportion level.

Chloride penetration Test

The test results are conventional concrete and varies mixes to given that varies depth of chloride penetration. Its to be high penetration depth is 8.21mm for MGS2 mix in 56days and 3.2 mm in 28 days for conventional mix concrete compare that other mixes.

VII. Conclusion

All three inhibitors tested in this study were effective in increasing the time to corrosion initiation and reducing the chloride diffusion rate of reinforcing steel in uncracked concrete. The inhibitors, however, were significantly less effective in cracked concrete where the reinforcement in concrete containing or showed only slight reductions in corrosion rate compared to the bars in conventional concrete. In this studies sodium meta silicate and GGBS will react as the corrosion resistance material. That means it also as chloride diffusion rate will be controlled.

Its significantly that corrosion initation time controlled to their filler of GGBS used in this concrete as well as increase density of concrete. so its to be given good strength,and corrosion protection is given as the good ponding strength. It concluded in this studies to 7.5% of sodium silicate replace in fine aggregate have a good results compare to the control mix.

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