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Study On Corrosion Control Mechanism In Steel Reinforcement

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Abstract - *Corrosion is a process of formation of the compounds of pure metal by the chemical reaction between metallic surface and an environment. It is an oxidation process. It causes loss of metal Corrosion effect on reinforced concrete structures is one of the major issues in construction industry. Reinforced concrete structures shows a very good durability and capable of withstanding a different kind of environmental exposure. However, the main limitation of concrete, even of good quality, is that the penetration of chloride, carbon di oxide, moisture etc. can cause the corrosion of reinforcement bars. This increases the maintenance and repair cost of Reinforced concrete structures. Furthermore, it has turn out to be financial trouble to many agencies as lot of money is wasted due to this corrosion. It can be tested by various physical and chemical works using different methods to detect the cause of corrosion. The corrosion inhibitors like Sodium Meta silicate and glutamine is used. Rapid Chloride Penetration test, alkalinity method are to be compared with the controlled concrete for the corrosion behavior of chlorinated immersion and mixing medium in terms of electrochemical mass loss.*

Key Words: RCPT, Alkalinity, corrosion resistance

1. INTRODUCTION

Corrosion of steel is a critical phenomenon and it needs to be researched widely. It results in the deterioration of a material when they are exposed to different environmental conditions. Reinforcement of concrete with steel is used to strengthen the structural element in tension as concrete is weak in tension, but structures do fail as a result of corrosion attack on steel. Chloride plays an indirect role in steel corrosion. Chloride attack has been known to participate in the process and is primarily attributed for spalling and cracking in concrete. Corrosion can be reduced by chemical method using specific corrosion inhibiting materials such as silicate, glutamine. The steel corrosion in reinforced concrete reduces its durability and can even result in failure of the structure. Silica fumes adds to the overall improvements in concrete which helps in reducing corrosion of steel reinforcement.

As more and more experience is gained with the test as well as with other test methods new procedures may be developed that measure concrete permeability more accurately. This method covers the determination of an electoral conductance of the concrete to provide a rapid indication of its resistance to the penetration of chloride ions. The Permeability of concrete depends on the pore structure of the concrete, while electrical conductivity of concrete is determined by both pore structure and chemistry of pore solution. It can have great effects on electrical conductivity of concrete. Thus, the electrical conductivity of concretes cannot be used as an indication of their permeability. However, it can be used as quality control indicators when the concretes have the same components and mixing proportions.

The Rapid chloride penetration test (RCPT) method has proven to be a rapid and effective test method for different types of concrete or concrete containing conductive materials.

2. OBJECTIVE

The objective of the present research work is to find an influence of the partial replacement of cement by constant percentage (10%) of silica fume in addition with corrosion inhibitor added in varying proportions to evaluate the properties of M25 grade concrete. Alkalinity of concrete, Rapid Chloride Penetration test results are to be compared with the controlled concrete for the corrosion behavior of chlorinated immersion and mixing medium in terms of electrochemical mass loss.

3. MATERIAL AND METHODOLOGY

3.1 Cement

Ordinary Portland cement (OPC) available in the local market is used for the investigation. The Cement used has been found to be tested and confirming to 53 grade as per IS 12269-1993. The specific gravity was 3.15 and standard consistency 30 %.

Table 1.PROPERTIES OF CEMENT

S.No.	Description	Value
1.	Grade	53
2.	Fineness	2.41%
3.	Specific gravity	3.15
4.	Consistency	30%
5.	Initial setting time	35min
6.	Final setting time	620mins

3.2 Fine Aggregate

Manufactured sand (M- sand) was used as the fine aggregate. M-sand is a substitute of river sand for construction purposes. This is mainly crushed fine aggregate produced from a source material with appropriate strength, shape and durability. The size of manufactured sand is less than 4.75mm which is sieved using the 4.75mm sieve. The specific gravity was 2.68.

3.3 Coarse Aggregate

The crushed granite stone aggregate of 20mm size is obtained from local crushing plants are used as coarse aggregate in the present investigation. The specific gravity, water absorption, fineness modulus of 20mm coarse aggregate are 2.56, 0.24% and 1.13 respectively. The properties were determined as per IS 2386-1999.

3.4 Silica fume

Silica fume is an ultrafine powder collected as a by-product from silicon production and consist of spherical particles less than 1μm in diameter, the average being about 0.15μm. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon production. The cement is replaced by 10% of silica fume. The specific gravity of silica fume is 2.2 respectively.

3.5 Corrosion inhibitor

Sodium Meta silicate is used in powder form as a corrosion inhibitor having a molecular formula of Na2SiO3.

Glutamine ($C_5H_{10}N_2O3$) is an amino acid. It is widely used as a corrosion inhibitor because it has an ability to control the corrosion of steel.

4. Mix proportions

The concrete mix design is a process of selecting suitable ingredients and determine their relative proportions with an object of producing the concrete of certain minimum strength and durability as economical as possible. The mix design was proposed by using IS 10262:2009. Concrete cubes of size 150mm x 150mm x 150mm were cast in cube moulds using the design mix of 1:1.75:2.69 with w/c ratio of 0.5. The cylindrical specimen of 150mm height and 75mm radius and the prism of 75mm×75mm were casted for the testing of corrosion resistance. Four mixes were used i.e.M0, M1, M2 and M3. M0 is a control mix used with 0% of silica fume. M1 contains 10% silica fume by weight of cement content and inhibitor as sodium silicate (30gm/lit of water). M2 contains 10% silica fume by weight of cement content and inhibitor as glutamine. The combination of sodium Meta silicate and glutamine is used as an inhibitor for the mix 3.

5. Test on specimens

Testing of specimens plays an important role in controlling the quality and quantity of concrete. All the specimens cast were subjected to testing to study the effect of partial replacement of silica fume with respect to cement (constant 10%silica fume) on strength and corrosion resistance. Thus the experiential investigations carried out was divided into two categories. They are

Test1: Study on strength properties

- Compressive Strength
- Flexure Strength
- Split Tensile Strength

Test2: Study on corrosion resistance

- RCPT
- Alkalinity of concrete

TEST 1. STUDY ON STRENGTH PROPERTIE

5.1 COMPRESSIVE STRENGTH TEST

The test was carried out on 150mm×150mm×150mm cubes as specified by IS 516-1959 (1989). This concrete is properly poured and tampered in the mould so as not to have any voids. After 24hours these concrete specimens are removed from the mould and put inside the water for curing. The top surface of these concrete specimen should be made even, flat and smooth. After 7 and 28 days of curing these specimens are taken from the

water and tested by compression testing machine. Load should be applied gradually at the rate of 140 kg/cm²/min till the specimen fails. Load at the failure should be noted. Three specimens where tested at each stage and average of the three specimens gives the crushing strength of concrete.

5.2 SPLIT TENSILE STRENGTH TEST

Split tension strength is an indirect way of finding the tensile strength of concrete by subjecting the cylinder to compressive force. Cylinders of size 75mm diameter and 150mm long were cast with Sodium Meta silicate, Glutamine and without adding Sodium Meta silicate, Glutamine.

After 24 hours the concrete specimen were taken from the mould and subjected to water curing. After 7 and 28 days of curing the cylinder were taken allowed to dry and tested in compression testing machine by placing the specimen horizontal. The ultimate load of the specimen is at which the cylinder has been failed.

5.3 FLEXURAL STRENGTH TEST

Concrete is weak in tension and strong in compression. Directly measuring the tensile strength of concrete is very difficult. Concrete beams of size 700×150×150 mm are found to be dependable to measure flexural strength property of concrete. The systems of loading used in finding out flexural strength are central and third point loading. Flexural strength is expressed as modulus of rupture and it is given by (M/Z).

TEST 2. STUDY ON CORROSION RESISTANCE

5.4 RAPID CHLORIDE PENETRATION TEST

Corrosion in reinforced structures is mainly caused by the ingress of chloride ions into concrete annulling the original passivity present. The RCPT is performed by monitoring the amount of electrical current that passes through a sample 50 mm thick by 100 mm in diameter in 6 hours using the apparatus and the cell arrangement. Readings are taken every 30 minutes. This sample is typically cut as a slice of cylinder. Throughout the test a voltage of 60V DC is maintained across the ends of the sample. One lead is immersed in a 3% sodium chloride (NaCl) solution and the other in a 0.3M sodium hydroxide (Na OH) solution. After 6 hours the sample is removed from the cell and the amount of coulombs passed through the specimens are calculated.

Table.2. Determination of Chloride Permeability

CHARGE PASSED IN COLOUMBS	CHLORIDE ION PENETRABILITY
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very low
<100	Negligible

5.5 ALKALINITY OF CONCRETE

Take 100ml beaker and filled with 50cc standard filtered solution. The alkalinity of the sample was measured in terms of PH using standard PH meter. The results shown that no significant variation of PH even after 28 days curing, indicated that the alkalinity of concrete was not affected by adding the admixture.

6. RESULTS AND DISCUSSION

The results obtained from the experimental system were represented both in tabular form and graphical means.

COMPRESSIVE STRENGTH TEST

It is one of the most important strength properties of concrete. Concrete cubes of size 150 x150x150mm where casted with sodium silicate, glutamine and without adding sodium silicate and glutamine (control). At the end of 24 hours the specimen were demolded and subjected to water curing. After 7 and 28 days of curing two cubes were taken and allowed to dry and tested in compression machine. The ultimate load at which the cubes failed were noted. The test result shows that the increase in % of SF, with sodium silicate and glutamine, the strength

values are getting increased. The result of the compressive strength of conventional and various mix proportioned concrete at 7 days and 28 days for M25 grade concrete are tabulated below.

Table.3. Compressive Strength at 7th day and 28th day

Mix ID	Mix proportions	Load (KN)		Compressive strength(N/mm²)	
		7days	28days	7days	28 days
M0	Conventional	433.8	602.55	19.28	26.78
M1	Sodium silicate	460.35	626.17	20.46	27.83
M2	Glutamine	493.2	667.8	21.92	29.68
M3	Sodium silicate and Glutamine	515.025	648.9	22.89	28.84

SPLIT TENSILE STRENGTH TEST

The split tensile strength test was performed on cylindrical specimen of 150 mm diameter and 300 mm length. The splitting tensile strength of concrete specimens where measured at 7 days and 28 days. Increase in split-tensile strength of concrete was absorbed from the replacement of silica fume (10%) and corrosion inhibitors (sodium silicate, glutamine). The result of the split tensile strength and corrosion inhibitors with silica fume concrete for M25 grade are tabulated.

Table.4. Split-Tensile Strength at 7th day and 28th day

Mix ID	Mix proportions	Load (KN)		Split-Tensile strength(N/mm²)	
		7days	28days	7days	28 days
M0	Conventional	255.8	303.2	3.62	4.29
M1	Sodium silicate	267.2	325.6	3.78	4.56
M2	Glutamine	272.8	332.8	3.86	4.68
M3	Sodium silicate and Glutamine	265.07	319.4	3.75	4.49

FLEXRAL STRENGTH TEST

The flexural strength test was carried out on prisms of cross-section 150 mm × 150 mm × 700 mm. The flexural strength of concrete, strength increased from the replacement of silica fume 10% with cement at 7 days and 28 days. The results of flexural strength of conventional and corrosion inhibitors with silica fume at 7 days and 28 days for M25 grade concrete are tabulated.

Table.5. Flexural Strength at 7th day and 28th day

Mix ID	Mix proportions	Load (KN)		Flexural strength(N/mm²)	
		7days	28days	7days	28 days
M0	Conventional	647.1	765.3	3.12	3.69
M1	Sodium silicate	659.5	775.7	3.18	3.74
M2	Glutamine	678.2	790.2	3.27	3.81
M3	Sodium silicate and Glutamine	674.0	777.7	3.25	3.75

RAPID CHLORIDE PERMEABILITY TEST

The specimens were fits within the chamber along the brass as well as rubber oaring. The record time is set as 30 minutes and also the log time as 6 hours and 30 minutes and the current of60 V is passed continuously. The data were recorded in the record logger and the reading of corresponding cells at the even interval record time from the initial readings. At the end of the experiment system stops after taking the final reading.

Table.6. Test results of RCPT		
Mix ID	**Mix proportions**	**Chloride Penetration Value**
M0	Conventional	899
M1	Sodium silicate	635
M2	Glutamine	382
M3	Sodium silicate and Glutamine	769

ALKALINITY TEST

Table.7. Results of alkalinity test		
Percentage of admixture	**Initial PH**	**Final PH (28 days)**
0	11.7	11.7
10	10.2	10.2

7. CONCLUSION

1. Silica fume is having greater fineness and surface area than cement, so that the consistency increases greatly, as consistency is depends upon fineness.

2. For permeability of chloride it is found that Silica Fume yielded good results in decreasing the permeability of chloride compared to other admixtures, however the resistance against chloride can be increased by replacing the cement with both mineral and chemical admixtures.

3. Either the compressive strength or the PH was adversely affected by this admixture in fact there was increase in compressive strength.

4. Addition of the corrosion inhibitors to silica fume in concrete, offers very good resistance against chemical attack and increases corrosion resistance by forming thin oxide layer to prevent outside agents and protecting the anodic sites.

5. Rapid Chloride permeability of concrete mix shows less permeability of chlorides into concrete resulting into reduction of cracks causing inter connecting voids to be minimum.

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