EFFECT OF USING QUARRYDUST, REPLACED CONCRETE USING ORGANIC INHIBITOR TO RESISTIVE CORROSION PROPERTY

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ABSTRAC:- Concrete is the most widely used building material in the world due to its versatility, low cost and durability. The most commonly used fine aggregate is natural river sand. The demand for natural sand in the construction industry has consequently increased due to the extensive use of concrete resulting in the reduction of sand sources and increase in price. The government has already banned sand mining due to environmental problems in identified areas of major rivers. Thus an investigation is needed to identify a suitable substitute that is eco-friendly and inexpensive and in this connection the use of quarry dust as fine aggregate has occupied a promising factor in the preparation of concrete.

Quarry dust has been defined as residue, tailing material after the extraction and processing of rocks to form fine particles less than 4.75mm. Quarry dust being, by and large a waste products, will also reduce environmental impacts, if consumed by construction industry in large quantities. Hence, the use of quarry dust as fine aggregate in concrete will reduce not only the demand for natural sand but also reduces the environmental problems. Moreover replacement of sand by quarry dust will off set the production cost of concrete and hence the successful utilization of quarry dust as fine aggregate will turn this waste material into valuable resource.
Among all construction materials, the reinforced concrete is more important, since it can be cast to any size and shape with proper design care. All the reinforced concrete structures are designed for limit state of collapse and checked for limit state of serviceability. The process of corrosion in reinforced concrete structures is governed by factors such as entrance of chloride ions and H+ions(acid). The technical economical and social importance of the construction industry makes the deterioration of the reinforced concrete structures the greatest challenge facing civil engineering in the developing countries. Therefore, the rebar corrosion acknowledged to be the most influential cause of premature failure of both reinforced concrete and pre-stressed concrete. A number of remedies such as use of mineral admixtures, addition of inhibitors and rebar coating have been suggested to prevent corrosion of steel in concrete structures. Corrosion inhibitors are widely used to delay or retard corrosion of reinforced steel in concrete. In this study multi-functional benefits are organic inhibitors are discussed with regard to the strength, corrosion production of embedded steel and resistance to chemical attack. In order to enhance the strength and durability characteristics of quarry dust concrete. Concrete construction along the coastal areas is frequently reported to be unsatisfactory as the concrete in these areas are found to be deteriorating rapidly due to the effect chloride. The use of corrosion inhibitors is found to be one of the effective methods to control corrosion. Therefore, an attempt has been made to study the performance of the organic inhibitors with the dosage of 1%,

2%, 3% and 4% by weight of cement in quarry dust concrete to control rebar corrosion. The organic inhibitors used were ethyldimethylamine, ethyleneglycolamine, diethyleneglycolamine, monoethanolamine and methyldiethenolamine.

Concrete cubes of size 150 x 150 x 150mm, beams of size 500 x 100 x100mm, cylinders of size150mm diameter and 300mm long were cast for compressive, flexural and split tensile strength tests. After 28 days curing the specimens have been tested as per IS: 516 – 1964. Concrete cylinders of size 75mm diameter and 150mm length have been cast with a High Yield Strength Deformed (HYSD) steel bar of 16mm diameter embedded centrally in to it to assess the corrosion protection by weight loss method. Concrete discs of size 100 mm diameters and 50mm thickness had been developed to measure the rate of transport of chloride ions in to the concrete by Rapid Chloride Permeability (RCPT) test. Cylindrical concrete specimens of size 3.2 cm diameter and 20 cm long were cast with centrally placed steel rod of diameter 8mm had been developed to measure the corrosion resistance of the steel rebar by AC impedance method and Polarisation study method. From the embedded portion, 2cm length has been cut and examined using scanning electron microscope for interpreting microstructures of materials on the surface of the specimen. The elements present in the steel rebar was evaluated by Energy Dispersive X-ray (EDAX) technique and FTIR spectra analysis.

KEY WORDS: concrete, quarry dust, super plasticizer, corrosion resistance, inhibitors

I. INTRODUCTION

Concrete is the most common material used in the construction industry. Concrete is used to construct buildings, highways, bridges, runway, railways etc., Rebars made of steel are introduced in the concrete structures. But due to carbonation, the pH of the pore solutions decreases the pH value even below 9. Hence carbonation leads to corrosion which is a natural, spontaneous process in where metals are converted into thermodynamically stable metal oxide. The process of corrosion can be controlled by addition of chemical compounds in small quantities. These substances are called corrosion inhibitors. Several researchers have discussed the use of corrosion inhibitors in concrete and simulated concrete pore solutions. Calcium nitrite has been used to prevent corrosion of steel in concrete. Polarization resistance method has been employed to the corrosion inhibition efficiency. It was observed that the passivation of rebar was observed in presence of calcium nitrite. Alkylaminoalcohol has been used to prevent the corrosion of steel in concrete. Compressive strength, flexural strength and tensile strength properties of concrete play an important role in deciding strength and durability of concrete structures .Devi and kannan have used Trienanolamine, Diethanolamine, Diethylamine, Calcium nitrite and Sodium nitrite as corrosion inhibitors. They have carried out compressive, flexural and split tensile strength tests also. Devi et al., have used Triethanolamine and Diethanolamine at the dosage of 1%, 2%, 3% and 4% by weight of cement. They have carried out strength tests, durability test, polarization technique and weight loss method (for corrosion inhibition study) [19].Concrete is the widely used building materials. River sand is the most popular choice for the fine aggregate in concrete. But over use of river sand has invited warnings from environmentalists. Hence quarry dust has been proposed as an alternative to river sand. Quarry dust gives strength to concrete. In the present study fine aggregate has been replaced by quarry dust. The present work is undertaken to investigate the strength tests, rapid chloride permeability test and corrosion resistance properties of the quarry dust replaced concrete without and with inhibitors such as Ethyldimethylamine, Ethyleneglycolamine and Diglycolamine at the dosage of 1%, 2%, 3% and 4% weight of cement.

Causes of Corrosion

Following are the causes of corrosion in concrete structures

1. Use of poor quality materials
2. Use of poor quality of concrete mix
3. Inadequate cover thickness to reinforcement in the concrete
4. Use of more chloride-contaminated water at the time of casting
5. Porosity of concrete at the time of casting
6. Type of environment such as marine and industrial environment.

Mechanism of Corrosion

Corrosion can be defined as the destruction or deterioration of a material because of reaction with its environment (Fontana 1987). Corrosion of steel in concrete is an electrochemical process. When there is a difference in electrode potential along the steel reinforcement in concrete, an electrochemical cell is setup. In the steel, one part becomes anode and other part becomes cathode. They are connected by an electrolyte in the form of pore water (water accumulating in concrete pores) in the hardened cement paste. The positively charged ferrous ions Fe++ at the anode pass into solution while they are absorbed by the constituents of the electrolyte and combine with water and oxygen to form hydroxyl ions (OH)-. They travel through the electrolyte and combine with the ferrous ions to form ferric hydroxide which is converted by further oxidation to rust.

2. MATERIALS

2.1 CEMENT:- Ordinary Portland Cement (43 Grade) with specific gravity of 3.15 was used for this experimental investigation

2.2 FINE AGGREGATE (NATURAL RIVER SAND):-Locally available river sand having density of 1700kg/m3 and fineness modules (FM) of 2.369 was used. The specific gravity was found to be 2.67.The fine aggregate was found to be conforming to zone II as per IS 383:1970.

2.3 COARSE AGGREGATE:- Natural granite aggregate having density of 2600kg/m3 and fineness modules (FM) 4.33 was used. The specific gravity was found to be 2.7 and maximum size of aggregate was 20mm.

2.4 WATER:- Potable tap water available in the laboratory was used for mixing and curing of the concrete.

2.5 ADMIXTURES:- To impart workability to the mix, Super plasticizer (SNF) was used to the dosage of 2% by weight of cement

2.6 CORROSION INHIBITOR:- Corrosion inhibitors and chemicals which were added in small concentration to the environment decreases the corrosion rate or completely arrests the corrosion process. In the present study to impart protection of concrete against chlorides are Ethyldimethylamine (CH3-CH2-N-(CH3)2), Ethyleneglycolamine (HO- CH2-CH2-NH2) and Diglycolamine (H2N-CH2-CH2- O-CH2-CH2-OH) were used as corrosion inhibitors. They were used to the dosage of 1%, 2%, 3% and 4% by weight of cement.

2.7 QUARRY DUST:- Quarry dust is fine rock particles when boulders are broken into small pieces quarry dust is formed. It is gray in colour it is like fine aggregate locally available well-graded quarry dust conforming to zone II of IS 383- 1970 having specific gravity 2.68 and fineness modules 2.70 was used. The bulk density was found to be 2600kg/m3.

3. EXPERIMENTAL PROGRAM AND TEST SPECIMENS

The following experiments were conducted to thoroughly investigate the strength and corrosion resistance properties of the quarry dust replaced concrete with and without inhibitors. For each inhibitor, the dosage added were 1%, 2%, 3% and 4% by weight of cement. The test were conducted on a minimum of 3 specimens were casted after 3 days,7 days and 28 days curing and a the average values are reported. The experimental investigation consisted of making M20 concrete with various proportions of quarry dust as a replacement to fine aggregate and determining the strength properties of concrete.M20 mix was design as per IS10262: 2009 and its mix ratio was found to be 1:1.515:3.16 with water cement ratio 0.45.

3.1 STRENGTH TEST

Concrete cube specimens of size 150 x 150 x 150mm, beam specimens of size500 x 100 x 100 mm, cylinder specimens of size 150mm diameter and 300 mm long were cast with and without inhibitors for compressive, flexural and split tensile strength respectively. The specimens were demoulded after 24 hours of casting and the specimens were cured 3 days, 7 days and 28 days. The testing was carried out in the structural Engineering laboratory using a Computerized Universal Testing machine and a Digital compression testing machine.

3.2 DURABILITY TESTS

3.2.1 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.

3.2.2 Weight loss measurement

The composition steel rod of size 16mm diameter and 150mm long is immersed in the pickling solution (hydrochloric acid + water in equal parts) for 15 minutes to remove the initial rust. The initial Weight (W1) of the rod was measured at the end of accelerated corrosion process the cylinder specimens were broken open and weight loss rods were retrieved. After cleaning with water, the rod was air dried and its final weight (W2) was measured. From the initial and final weight, the corrosion rate was calculated.

The corrosion rate is calculated using the following formula:

Corrosion rate in mmpy = $87.6\,(W_1 - W_2)/DAT$

Where,W1 = Initial weight in milligrams,

W2 = Final weight in milligrams

D = Density of steel gm/ cm^3,

A = Area of the specimen in cm^2,

T=Test period in hours

Table 1- Specimen identification

Mix	Definition
CM	Ordinary concrete prepared with River sand (Control Mix)
QD	Concrete prepared with Quarry Dust
IE(%)	Inhibition efficiency percentage
1%	Addition of 1% inhibitors
2%	Addition of 2% inhibitors
3%	Addition of 3% inhibitors
4%	Addition of 4% inhibitors
A1	Ethyldimethylamine
A2	Ethyleneglycolamine
A3	Diglycolamine

4. RESULTS AND DISCUSSION:

4.1 STRENGTH TESTS:

Compressive strength test, flexural strength test and split tensile strength test were performed. The results are summarised in tables 2, 3, 4, 5, &6 and figures 1, 2, 3, 4& 5.

4.2 COMPRESSIVE STRENGTH TEST:

The results of the compressive strength test are summarized in table 2 and figure 1.It is observed from table 2 that for inhibitor A1 (Ethyldimethylamine), as the concentration of inhibitor increases from 1% to 2%, the compressive strength increases. Upon further increases in concentration of the inhibitor, the compressive strength slightly decreases. Similar is the case with inhibitor A2 and A3.The results are graphically represented in figure 1

Table 2 Compressive Strength after 28 days

Inhibitors	Average Compressive Strength after 28 days (N/mm^2)			
	1 %	2%	3%	4%
A1	24.0	25.8	23.64	22.6
A2	24.8	26.1	24.3	22.62
A3	25.2	26.4	24.6	22.76
CM- Average value of 22				

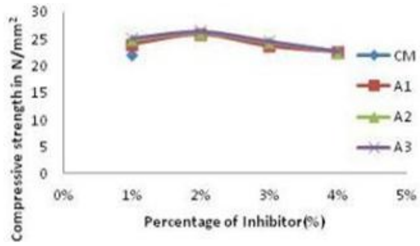

Fig.1Compressive Strength

Fig.2 Compressive strength test on cube

- It is also observed from table 2 that at a given concentration of the inhibitor, the ability of an inhibitor to offer compressive strength decreases in the order: A3>A2>A1.
- For example when the concentration of the inhibitor is 1% the average compressive strength is as follows: A3 (25.20N/mm2)>A2 (24.80N/mm2)>A1(24.0N/mm2).
- The study reveals that the maximum compressive strength after 28 days is offered by 2%, A3 system and it is found to be 26.4%.

4.3 SPLIT TENSILE STRENGTH:

The results of the split tensile strength test are summarized in table 3 and figure 3.

It is observed from table 3 that for inhibitor A1 (Ethyldimethylamine), as the concentration of inhibitor increases from 1% to 2%, the split tensile strength increases.

Upon further increase in concentration of the inhibitor, the split tensile strength slightly decreases. Similar observations are made in the case of inhibitors A2 and A3 also. The results are graphically shown in figure 3.

Table 3 Split tensile strength on after 28 days

Inhibitors	Average split tensile strength after 28 days (N/mm^2)			
	1 %	2%	3%	4%
A1	3.0	3.42	3.05	2.98
A2	3.1	3.53	3.18	3.06
A3	3.2	3.65	3.26	3.12
CM- Average value of 2.95				

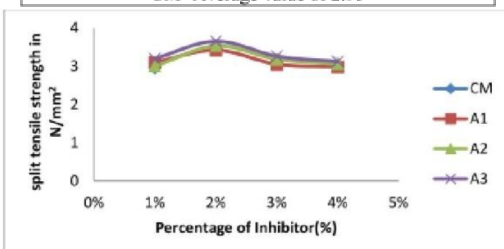

Fig.3 Split tensile strength

Fig.4 Split Tensile strength test on cylinder

It is also observed from table 3 that at a given concentration of the inhibitor, the ability of an inhibitor to offer split tensile strength decreases in the order:A3>A2>A1.For example, when the concentration of the inhibitor is 1%, the average split tensile strength are in the order:

A3 (3.20N/mm2)>A2 (3.1 N/mm2)>A1 (3.0 N/mm2).Thus

It is concluded that inhibitor A3 offers better split tensile strength than other two inhibitors.

4.4 FLEXURAL STRENGTH:

The results of the flexural strength test are summarised in the table 4 and figure 5.It is observed from table 4, that for inhibitor A1 (Ethyldimethylamine), as the concentration of inhibitor increases from 1% to 2%, the flexural strength increases. However, on further increase in concentration of the inhibitor, the flexural strength slightly decreases. Similar is the case with inhibitors A2 and A3 also. The results are graphically presented in figure 5.

Table 4 Flexural strength on after 28 days

Inhibitors	Average flexural strength after 28 days (N/mm^2)			
	1 %	2%	3%	4%
A1	4.82	4.96	4.86	4.80
A2	4.88	5.01	4.92	4.88
A3	4.91	5.13	4.98	4.89
CM- Average value of 4.54				

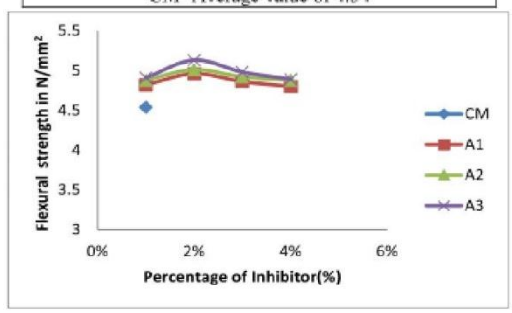

Fig.5 Flexural Strength

Fig.6 Flexural strength testing on beam

It is also observed from table 4 that at a given concentration of the inhibitor, the ability of an inhibitor to offer flexural strength decreases in the order: A3>A2>A1.For example, when the concentration of the inhibitor is 1%, the average flexural strengths are as follows: A3 (4.91N/mm2)>A2 (4.88N/mm2)>A1 (4.82 N/mm2).

DURABILITY TEST:

RAPID CHLORIDE PERMEABILITY TEST:

Low permeability is the key to good durability. Permeability, cracking and corrosion are found to be interrelated. The effects of these factors affect the durability of concrete. The results of the rapid chloride permeability test are given in table 5. The charge passed in coulombs as a function of percentage of inhibitor shown in figure 4. It is observed from table 5, that the permeability is low, when the concentration of the inhibitor is 2%. Among the three inhibitors under investigation, A3 inhibitor has the lowest charge passed in coulomb.

Table 5 Rapid chloride permeability test

Inhibitors	Charge passed (coulombs)			
	1 %	2%	3%	4%
A1	1653	1234	1702	1896
A2	1578	1228	1654	1864
A3	1534	1216	1642	1840
CM-Average value of 2426				

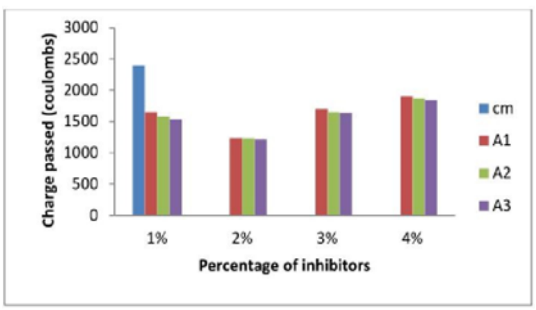

Fig.7 Rapid chloride permeability test

Fig.8 Vacuum pump with desiccator (RCPT)

Table 6 Weight Loss Measurement

Inhibitors	Corrosion rate in mmpy			
	1 % (IE%)	2% (IE%)	3% (IE %)	4% (IE%)
A1	0.197 (55)	0.182 (58)	0.189 (57)	0.263 (40)
A2	0.194 (56)	0.178 (59)	0.187 (57)	0.253 (42)
A3	0.192 (56)	0.176 (60)	0.184 (58)	0.246n (44)
CM- Average value of 0.436				

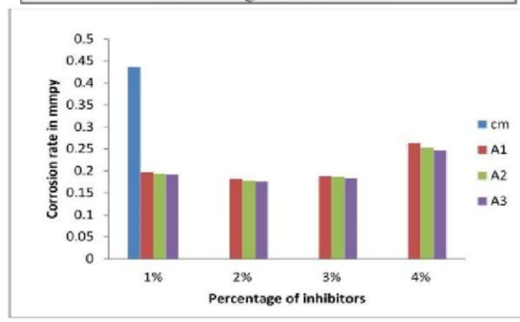

Fig.9Weight Loss Measurement

WEIGHT LOSS MEASUREMENT:

The results of the weight loss measurement are given in table 8. It is observed from table 8 that for a given concentration (%) of inhibitors, the corrosion rate decreases in the order: A1>A2>A3.For example, the corrosion rates when the inhibitors concentration is 1%, are as follows:

- A1 (0.197 mmpy)>A2 (0.194 mmpy)>A3 (0.192mmpy). That is for a given concentration inhibitors, A3 is found to be best inhibitor.
- For given inhibitor, minimum corrosion rate is observed at 2% concentration of the inhibitor. At higher concentration, namely, 3% and 4%, the corrosion rate increases. So, the amount of inhibitor added should be very accurate; otherwise, there will be enhancement of corrosion rate.
- Among the various inhibitors studied at various concentration, the inhibitor A3 shows maximum corrosion inhibition efficiency of 60% when its concentration is 2%.

CONCLUSIONS

From the above test results concerning the strength and durability behaviour of inhibitors in concrete containing quarry dust, the following conclusions have been obtained.

- Concrete is commonly used in the construction industry. River sand is very often used as fine aggregate in concrete.
- But over use of sand has made the constructors to think of an alternative for sand. Quarry dust has been considered as an substitute for river sand.
- The compressive strength , flexure strength and split tensile strength of concrete cube, concrete beam and cylinder have been measured often curing the specimens three days, seven days , twenty eight days in the absence and presence inhibitors namely , Ethyldimethylamine (A1), Ethyleneglycolamine(A2) and Diglycolamine(A3) at the dosage of 1%,2%,3%and 4% weight of cement.
- It is observed that compressive strength increase in presence of inhibitors , the ability of the inhibitors to often compressive strength decreases in the order A3>A2>A1. Maximum compressive strength (26.4)Nmm2 is offered by 2% of A3 after 28 days
- The ability of the inhibitors to offer split tensile strength decreases in the order : A3>A2>A1. Maximum split tensile strength(3.65) N/mm2 is offered by 2% of A3.
- The ability of the inhibitor to offer flexural strength decreases in the order A3>A2>A1. Maximum flexural strength (5.13 N/mm2) is offered by 1% inhibitor A3.
- Rapid chloride permeability test reveals that the inhibitor A3 has higher durability at 2% concentration.
- Weight loss measurement shows that lowest corrosion rate (0.176mmpy) is offered by 2% of inhibitor A3.
- 2% of inhibitor glycol amine often maximum compressive strength, flexural strength, split tensile strength, higher durability and higher corrosion protection of steel rebar.

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