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ANALYSIS OF STRENGTH AND CORROSION RESISTANCE BEHAVIOR OF INHIBITORS IN CONCRETE CONTAINING QUARRY DUST AS FINE AGGREGATE

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ABSTRACT

The demand for natural sand in the construction industry has consecutively increased resulting in the reduction of sources and an increase in price. Thus, an increased need to identify a suitable substitute that is eco- friendly and inexpensive has emerged which boosted the usage of quarry dust as fine aggregate in concrete. Most of the studies on the usage of quarry dust as hundred percent substitutes were carried out to judge the properties of fresh concrete and strength properties. In this paper, an experimental study dealing with the strength and corrosion resistance behavior of various integral type corrosion inhibitors namely triethanolamine, diethanolamine, diethylamine, calcium nitrite and sodium nitrate at the dosage of 1%, 2%, 3% and 4% by weight of cement in concrete containing quarry dust as fine aggregate is carried out. Integral inhibitors are liquids or solids that are batched and mixed with the other concrete ingredients as a preventive measure for new construction or repair work. The influence of these inhibitors was evaluated using various electrochemical techniques such as Rapid Chloride Penetration Test (RCPT), Accelerated corrosion test, A.C. impedance measurement and Gravimetric weight loss measurement. The mechanical properties such as compressive strength, flexural strength, spilt tensile strength and bond strength in addition to water absorption were also studied and the optimum dosage of inhibitors was determined individually. Results herein revealed that replacement of sand by quarry dust increases the strength of the concrete; with addition of inhibitor it offers lower permeability and greater density which enable it to provide better resistance to corrosion and durability in adverse environment.

Keywords: concrete, quarry dust, super plasticizer, inhibitor, durability, corrosion resistance.

INTRODUCTION

The demand of natural sand is quite high in developing countries since the available sand is not able to meet the demand of construction sector. Natural sand takes millions of years to form and it is not replenishable. In such a situation the Quarry rock dust can be an economic alternative to the river sand. Ilangovan and Nagamani studied the usage of quarry dust as hundred percent substitute for natural sand in concrete and conducted experiments to judge the properties of fresh concrete and strength properties [1-3]. It is found that the compressive strength, flexural strength and durability properties of concrete made of quarry dust are nearly 10% more than conventional concrete. As reported by Shahul Hameed *et al.*, the quarry dust, which is produced as a residue after extraction and processing of rocks from crusher units, will also reduce environmental impact if consumed by the construction industry in large quantities [4]. Sahu *et al.*, reported that concrete containing quarry dust as fine aggregate is promising greater strength, lower permeability and greater density which enable it to provide better resistance to freeze/thaw cycles and durability in adverse environment [5]. Murugesan *et al.*, examined the effect of super plasticizer in quarry dust replaced concrete and reported that the compressive strength of quarry dust concrete can be improved with admixture E [6]. As suggested by Prachoom Khamput, super plasticizers can be used to improve the workability of quarry dust replaced concrete [7]. Nagaraj and David Manning have observed that concrete using quarry fines shows improvement in higher flexural strength, abrasion resistance and unit weight which are very important for reducing corrosion or leaching [8, 9]. Raman *et al.*, reported that self-compacting concrete can also be produced using quarry dust [10].

According to Shetty, durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack and abrasion while maintaining its desired engineering properties [11]. Corrosion of reinforcing steel is a major problem facing the concrete infrastructures [12]. Velu Saraswathy, Videm and Vedalakshmi have reported that many structures in adverse environments have experienced unacceptable loss in serviceability of safety earlier than anticipated due to the corrosion of reinforcing steel and thus need replacement, rehabilitation or strengthening [13-15]. R.D. Brown and Schutter G. LuoL suggested that corrosion can be prevented by chemical method using certain corrosion inhibiting chemical and coating to reinforcement [16, 17]. Ping Gu and Elliott have reported that corrosion inhibitors are becoming an accepted method of improving durability of reinforced concrete in chloride laden environment [18]. According to NACE (National Association of Corrosion Engineers) inhibitors are substances which, when added to an environment, decrease the rate of attack on a metal. David Bone, Hope and LuoL De. Schutter have concluded that corrosion inhibitors function by reinforcing a passive layer or by forming oxide layer and prevent outside agents and reduce the corrosion current [19-21]. Based on the mode of application, corrosion inhibitors can be classified into two types, integral inhibitors (cast - in) and migrating inhibitors. Integral inhibitors are liquids or solids that are batched and mixed with the other concrete ingredients as a preventive measure for new construction work or repair work. Migrating inhibitors are used in mature reinforced concrete structures that are showing signs of reinforcement corrosion. Violetta F. and Michael C. Brown and Ramachandran investigated the mechanism of inhibitors and reported that inhibitors can act as anodic inhibitors which block the corrosion reaction of the chloride-ions by chemically reinforcing and stabilizing the passive protective film on the steel (e.g. Nitrites); cathodic inhibitors react with the steel surface to interfere with the reduction of oxygen (e.g. Zinc oxide) or ambiodic inhibitors suppressing both anodic and cathodic sites by forming an adsorptive film on the metal surface (e.g. amines and fatty acids) [22-24]. Calcium nitrite has been used as a corrosion inhibitor against chloride attack and as a set accelerator in concrete for more than 20 years [25]. Prabhakar evaluated the performance of sodium nitrate inhibitor in concrete and suggested that addition of 4% sodium nitrate in concrete enhances the durability properties in addition to mechanical properties of concrete [26]. Numerous studies were carried out to investigate the use of corrosion inhibitors in enhancing the corrosion resistive properties of conventional concrete [27-30]. Studies on the corrosion resistance performance of concrete having quarry dust as fine aggregate with inhibiting admixtures are not available in the technical literature. This paper deals with the experimental study to investigate the effect of integral type inhibitors namely triethanolamine, diethanolamine, diethylamine, calcium nitrite and sodium nitrate at 1%, 2%, 3% and 4% by weight of cement in concrete containing quarry dust as fine aggregate in resisting corrosion.

MATERIALS AND METHODS

Materials used

The cement used was Ordinary Portland Cement (43 Grade) conforming to IS 8112-1989. Locally available well-graded quarry dust, conforming to Zone-II of IS 383-1970 having specific gravity 2.68 and fineness modulus 2.70 was used as fine aggregate. Natural granite aggregate having density of 2700kg/m^3, specific gravity 2.7 and fineness modulus 4.33 was used as coarse aggregate. High yield strength deformed 16mm diameter bars of Fe 415 grade conforming to IS 1786 was used for pullout and corrosion tests. To increase the workability of quarry dust concrete commercially available super plasticizer ROFF 320 has been used. The inhibitors used were triethanolamine $N(CH_2CH_2OH)_3$, diethanolamine $HN(CH_2CH_2OH)_2$, diethylamine $CH_3CH_2NHCH_2CH_3$, calcium nitrite $Ca(NO_2)_2$ and sodium nitrate $NaNO_3$ at the dosage of 1%, 2%, 3% and 4% by weight of cement. To attain strength of 20 N/mm^2 a mix proportion was designed based on IS 10262-1982 and SP23:1982(21). The mixture was 1:1.517:3.38 with water cement ratio 0.45.

Strength tests

Concrete cubes of size 150 x 150 x 150mm, beams of size 500 x 100 x 100 mm, cylinders of size 150mm diameter and 300 mm long were cast with 1%, 2%, 3%and 4% of triethanolamine, diethanolamine, diethylamine, calcium nitrite and sodium nitrate for compressive, flexural and split tensile strength tests. Triplicate specimens were cast for each percentage of every inhibitor for 3, 7 and 28 days strength. After 3, 7and 28 days curing, the specimens were tested as per IS: 516 - 1964. Cylinders of size 150mm diameter and 300 mm long with rods of 70cm length kept at the centre were used for determination of bond strength. Water absorption of hardened concrete specimens was calculated based on ASTM C642-81.

Durability tests

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.

Impressed Voltage test (ASTM-C876):

Impressed voltage test is based on electrochemical polarization principle. The experimental setup is shown in Figure-1. To assess the corrosion protection efficiency under accelerated test conditions, concrete cylinders of size 75 mm diameter and 150 mm length were cast with high yield strength deformed (HYSD) steel bar of 16mm diameter embedded centrally into it. The steel rods were cleaned with pickling acid and degreased and then embedded in such a way that a constant cover is maintained all round and also the protruding rod was insulated by PVC sleeve. After 28 days curing, all the triplicate specimens were taken out and dried for 24 hours then subjected to acceleration corrosion process in order to accelerate reinforcement corrosion. Each test specimen was immersed in the saline media (3% Sodium chloride solution). The rebar projecting at the top is connected to the positive terminals of the power pack (anode) and the stainless steel plate is connected to the negative terminal (cathode). The test specimens were subjected to a constant voltage of 6 volts from D.C power pack. This setup forms an electrochemical cell. The applied voltage is kept constant continuously and the current response is monitored with respect to time.

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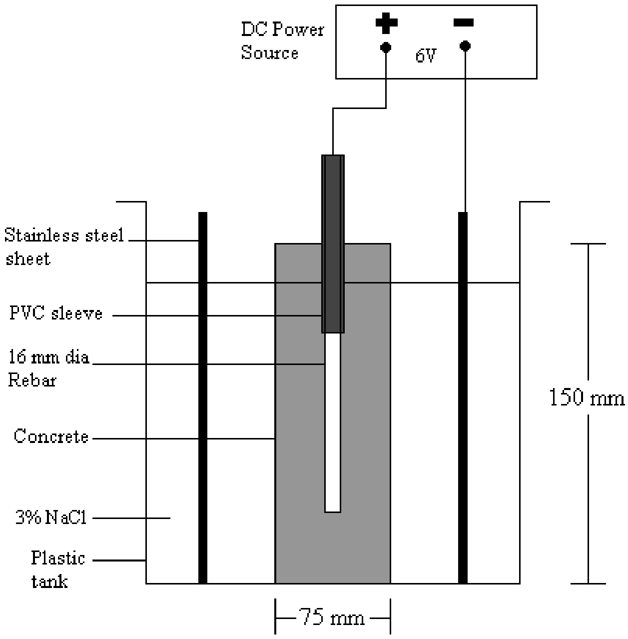

Figure-1. Test set up for impressed voltage technique.

AC impedance technique

AC impedance spectroscopy is being used as non-destructive technique for quantifying corrosion of steel rebar embedded in concrete. The experimental setup is shown in Figure-2.

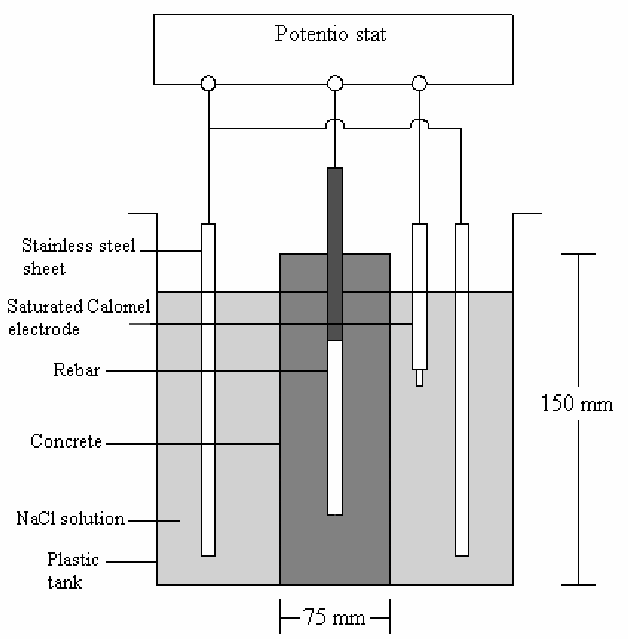

Figure-2. Test set up for AC impedance technique.

In this technique an A.C. signal is applied to the embedded rebar and the response is monitored in terms of phase shift of the current and voltage components and their amplitude. Cylindrical concrete specimens of size 75 mm diameter and 150 mm long were cast with centrally placed steel rod of diameter 12mm. The steel rod is placed in such a way that an equal cover of 31.5mm is maintained all-around. The potential of the rebar was measured periodically using a high input impedance multimeter. Impedance measurement was made using three electrode arrangements. Stainless steel electrode of size 10mmx80mm was used as an auxiliary electrode and saturated calomel electrode was used as a reference electrode. Rebar embedded in concrete acted as a working electrode. The experimental set up is shown in Figure-2. Chloride solution was used as a contacting solution to reduce the contact resistance between the electrode assembly and the concrete. A sinusoidal voltage signal of 20mV was applied over a frequency range of 100 KHz to 10 MHz using a computer controlled electrochemical analyzer. The impedance values were plotted on the Nyquist plot. From the Nyquist plot, using the software 'z view' the Resistance of concrete (R_c) and Polarization resistance (R_p) values were calculated. By assuming Stern-Geary constant (B) as 26mV (Andrade 1978), the corrosion current I_{corr} was calculated using the Stern-Geary relation (Stern 1975):

$$I_{corr} = B / R_p$$

Where

B = Stern-Geary constant, 26mV

R_p = Polarization resistance or Charge transfer resistance R_{ct}, ohms = cm^2

I_{corr} = Corrosion current, $\mu A/cm^2$

From the I_{corr}, the corrosion rate of rebar was calculated using the following formula:

Corrosion rate in mmpy = 0.0116 x I_{corr}

Where, I_{corr} is in $\mu A/cm^2$.

Gravimetric weight loss measurement

Steel embedded concrete cylinders were cast with various percentages of inhibitors and also without inhibitor. High yield strength deformed (HYSD) rods of size 16 mm diameter and 150 mm long were immersed in the pickling solution (Hydrochloric acid +water in equal parts) for 15 minutes to remove the initial rust. The initial weight (W_1) of the rod was measured and embedded in the center of cylindrical concrete specimens of size 75 mm diameter and 150 mm long. The specimens were subjected to 28 days curing in fresh water. After the curing period was completed the cylinders were immersed in 3% NaCl solution under alternate wetting (3days) and drying (3days) conditions over a period of 90 days. At the end of 90days the cylinders were broke open and the final weight of the specimens was taken. The difference between the initial and final weight gives the weight loss of the specimen. From the weight loss obtained corrosion rate can be calculated using the following formula:

Corrosion rate in mmpy = 87600 x W / DAT

Where

W = weight loss in grams (W_1-W_2)

D = Density of steel gm/ cm^3

A = Area of the embedded rebar in cm^2

T = Time in hours

RESULTS AND DISCUSSIONS

Compressive, split tensile, flexural and bond strength

The compressive strength results after 28 days curing are shown in Figure-1. From the figure it is evident that 1% addition of triethanolamine shows 9.8% increase in the compressive strength, while the addition of 2% of this inhibitor gives hike of 13% and this yields the maximum increase in the strength value. Further, addition of triethanolamine to 3% and 4% gives 7.2% and 0.7%, respectively which yields a comparatively lower value than using 2%. Similarly, the addition of diethanolamine, diethylamine and calcium nitrite gives the maximum increase in the strength value at 2% dosage and the increase in strength values are 12.45%, 6.55% and 18%, respectively. Considering the addition of sodium nitrate, the maximum strength value is obtained by adding 3% of the inhibitor to the concrete which yields about 7.6% improvement. The split tensile strength test results at the age of 28 days are shown in Figure-2. According to Figure-2, it is understood that addition of 2% triethanolamine, diethanolamine, diethylamine and calcium nitrite shows the maximum increase in the strength value by 14.55%, 11.43%, 9.74% and 17.54%, respectively, while the addition of 3% sodium nitrite to the concrete yields about 14.6% improvement.

Figure-3 shows the flexural strength test results after 28 days curing. Considering Figure-3, it is observed that the maximum increase in the strength is given by 2% addition of triethanolamine, diethanolamine, diethylamine and calcium nitrite. The strength values are increased by 12.68%, 10.38%, 9.43% and 16.61%, respectively. In case of the addition of sodium nitrite to the concrete by 3%, it yields maximum improvement in strength about 12.3% when compared with control specimen. The Bond strength test results at 28 days are shown in Figure-4. The specimens with 2% addition of triethanolamine, diethanolamine, diethylamine and calcium nitrite, show a maximum increase in the bond strength by 15.28%, 13.38%, 12.43% and 16.61%, respectively. However, by increasing the inhibitor to 3% and 4 % there was a marginal reduction in the strength values. The concrete with 3% addition of sodium nitrate gives the maximum improvement in the bond strength by 14.3%.

From the results of the strength tests, it is observed that when compared to control specimens, all the inhibitor added specimens display slightly a higher strength than the control specimen. The ethanolamine based organic inhibitors triethanolamine diethanolamine and diethylamine show improvement in strength properties for 1% and 2% dosage since the total porosity of the paste was lower in these percentages. For 3% and 4% addition of inhibitors, there was a slight reduction in strength due to retardation of C_3S hydration (24). In the case of nitrite based inorganic inhibitors, addition of 2% calcium nitrite and 3% sodium nitrate shows maximum strength and further increase in dosage resulting in decrease in strength due to decrease in the degree of hydration and therefore, a higher capillary porosity or a change in the cement micro structure. The samples with addition of 2% of calcium nitrite as inhibitor show higher strength and durability properties. The increment caused by the nitrite based inhibitor is higher than the other inhibitors because of its compatibility with concrete properties.

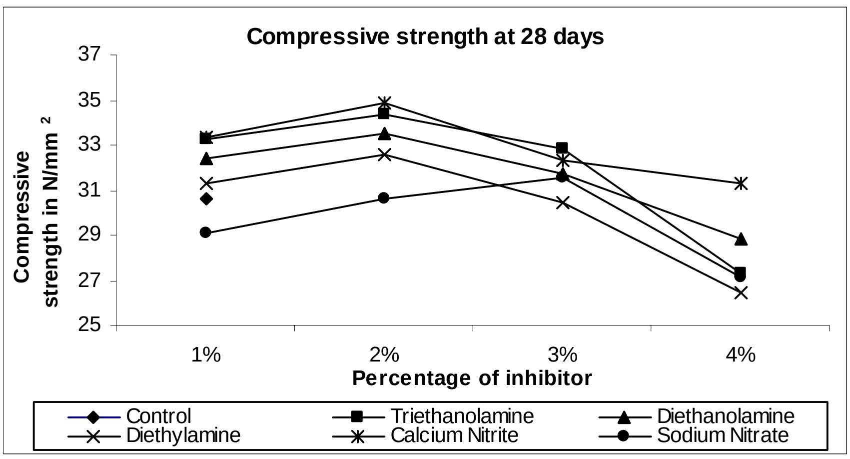

Figure-1. Compressive strength.

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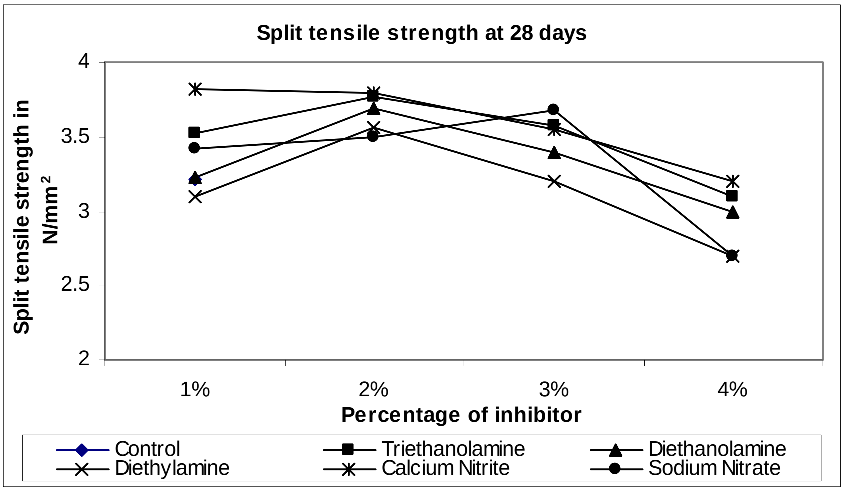

Figure-2. Split tensile strength.

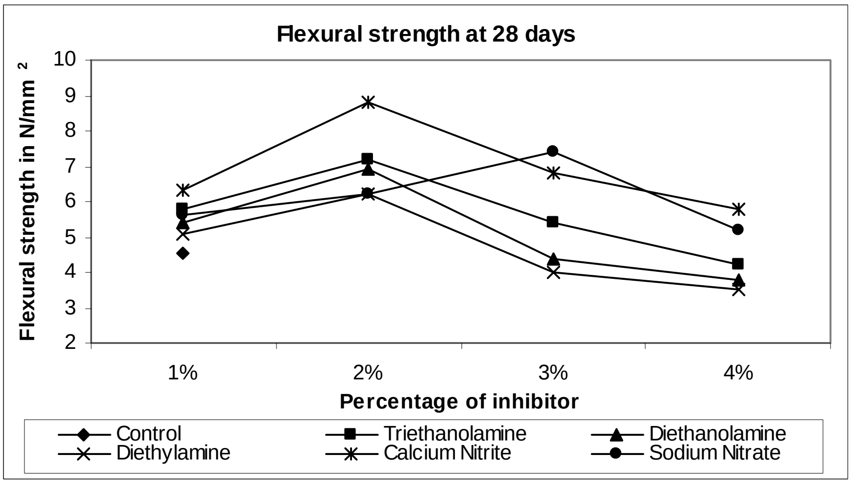

Figure-3. Flexural strength.

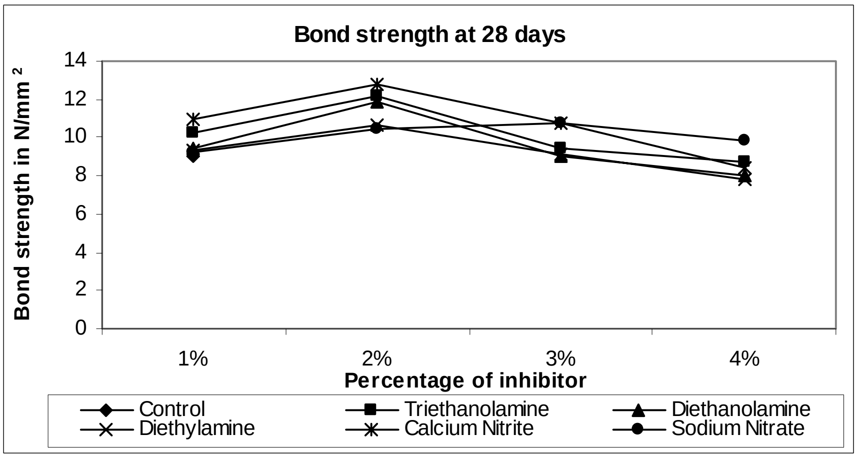

Figure-4. Bond strength.

Water absorption test

Figure-5 shows the water absorption verses percentage of inhibitors for all the mixes after 28 days curing. The control specimen shows the highest water absorption value than all mixes. For all the inhibitors except sodium nitrate the absorption decreases as the concentration of inhibitor increases up to 2% and for sodium nitrate it was 3%. A concentration of 4% sodium

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nitrate produces an increase in absorption than other percentages. Similarly, 3% and 4% addition of other inhibitors show relatively higher absorption than the optimal percentage. However, when compared to the control specimens, the addition of inhibitors definitely produces lower absorption values.

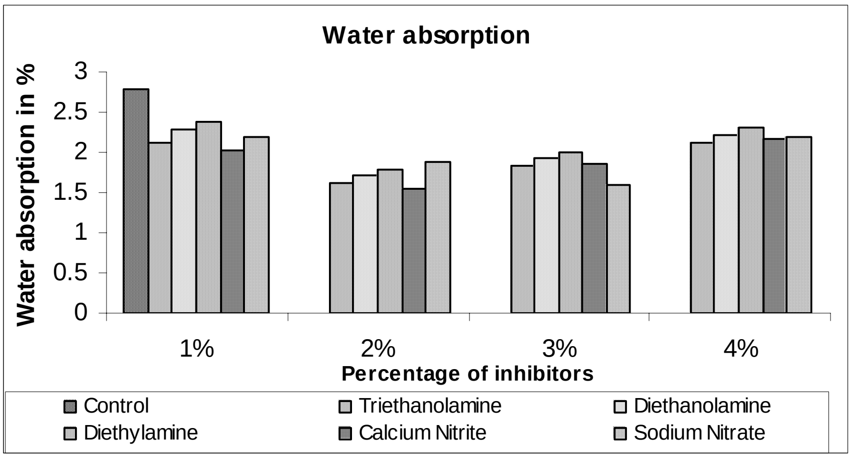

Figure-5. Water absorption.

Durability tests

Polarization or impressed current method

Corrosion inhibition of five commercially available integral corrosion inhibitors namely triethanolamine, diethanolamine, diethylamine, calcium nitrite and sodium nitrate at the dosage of 1%, 2%, 3% and 4% by weight of cement in concrete containing quarry dust as fine aggregate, was investigated using electrochemical monitoring techniques while the concrete was immersed in 3% NaCl at ambient temperature. The current taken to initiate corrosion in mA for various percentages of inhibitors was shown in Figures 6, 7, 8 and 9 and the time in hours to initiate corrosion was shown in Figure-10. From the figures, it is to be noted that the corrosion initiation time for control concrete is found to be 168 hours and also even the minimum value of the corrosion initiation time with respect to the addition of inhibitors is slightly higher than that of the control specimens. Among all the percentages added, 2% addition of triethanolamine, diethanolamine, diethylamine, and calcium nitrite proves to be more effective in resisting corrosion. However the corrosion resistance is slightly reduced for 3% and 4% addition of inhibitors. The reasons for decrease in resistance are formation of C-S-H with higher C/S ratio, rapid initial setting followed by large heat development and a more porous structure (24). Addition of 3% of the sodium nitrate has better corrosion protection than other percentages. The effect is similar to the other nitrite inhibitors which accelerate set but retard cement hardening.

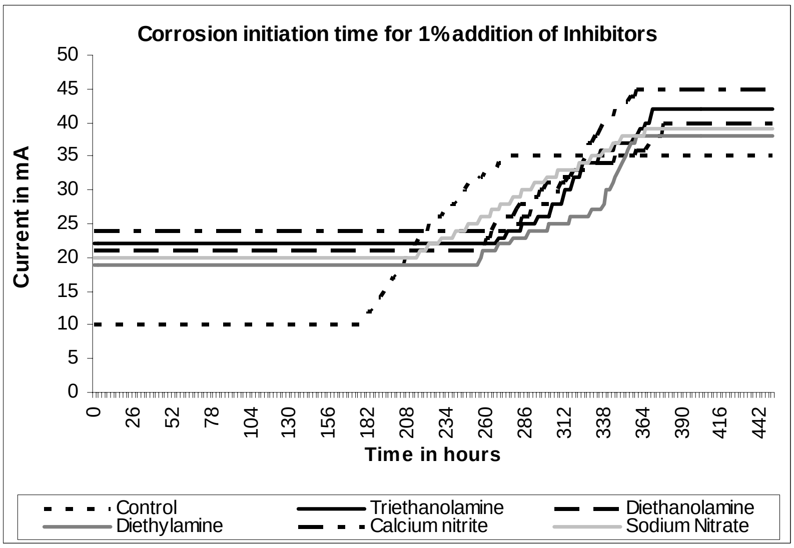

Figure-6. Corrosion initiation time for 1% addition of inhibitors.

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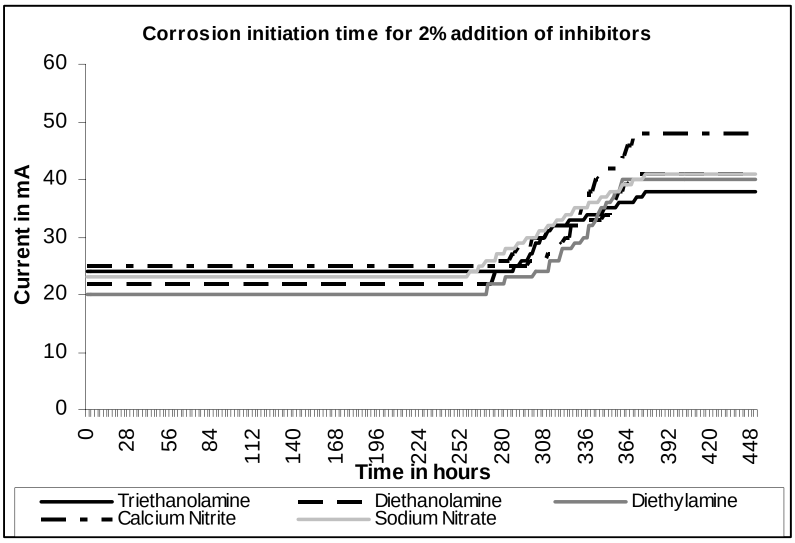

Figure-7. Corrosion initiation time for 2% addition of inhibitors.

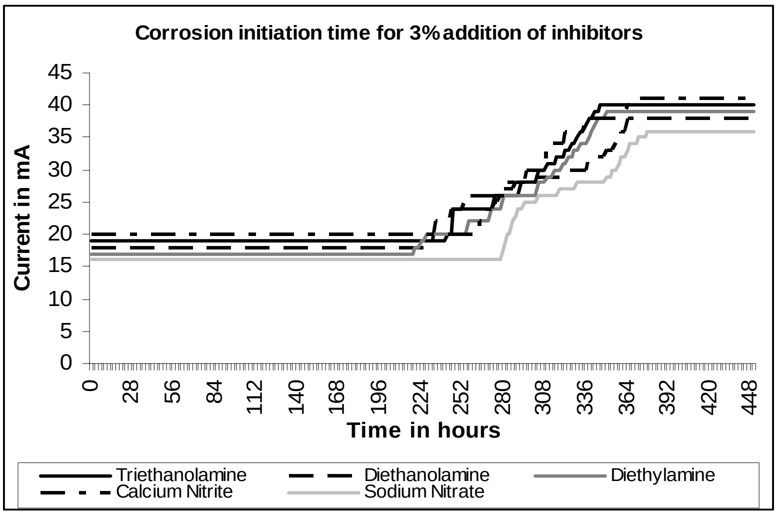

Figure-8. Corrosion initiation time for 3% addition of inhibitors.

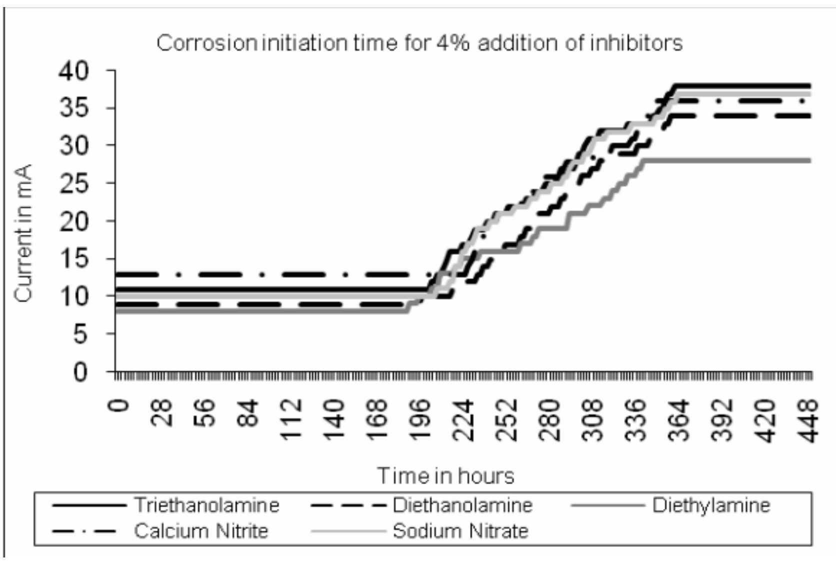

Figure-9. Corrosion initiation time for 4% addition of inhibitors.

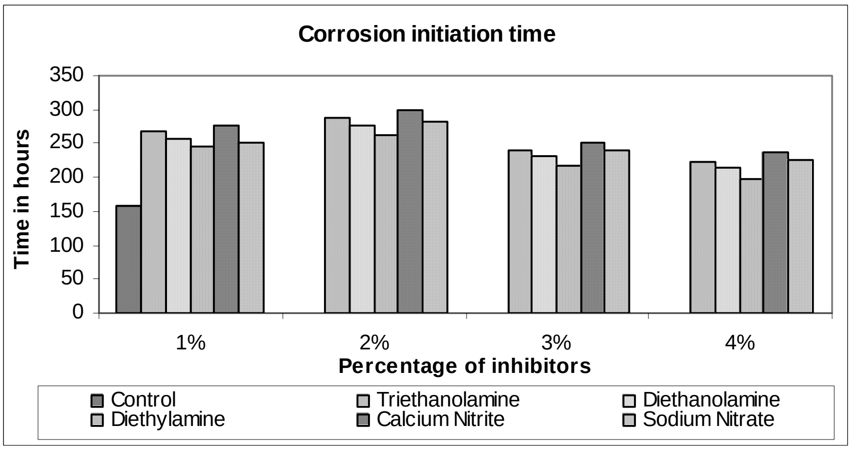

Figure-10. Corrosion initiation time.

From the results it is evident that the calcium nitrite shows 97.45% increase in corrosion resistance at its optimum percentage of 2% and similarly the triethanolamine, diethanolamine, diethylamine shows 82.27%, 72.15%, 69.6%, improvement in resisting corrosion respectively at their optimum percentage of 2%. In the same way the sodium nitrate shows 75.9% increase at its optimum percentage of 3%. The impressed voltage test results show that due to the addition of inhibitors permeability of the concrete was considerably reduced and the time taken for initiation of corrosion in concrete with respect to accelerated chloride penetration has been increased significantly.

Rapid chloride permeability test

Figure-11 shows the chloride diffusion results of the different percentages of inhibitors. The RCPT value for control concrete at 28 days is found to be 2426 Coulomb. From the figure it is evident that 1% addition of triethanolamine shows 51.8%improvement, while the addition of 2%and 3% gives 96.59% and 41.7%, respectively. Similarly the addition of diethanolamine shows 50.3%, 91.78% and 33.07% improvement at 1%,2% and 3%, respectively and the addition of diethylamine shows 43.04%, 85.9% and 25.43% , respectively for 1%, 2% and 3% of inhibitor. Further addition of 4% inhibitor yields a comparatively lower value than control specimen for all the organic inhibitors.
The performance of the quarry dust concrete with 1%, 2%, 3% and 4% addition of calcium nitrate are observed to be 61.9%, 97.87%, 51.05% and 19.27% greater than the control specimen.. Similarly, the performance of sodium nitrate is found to be 32.06%, 58.97%, 88.79% and 24.53% greater than control specimen. From the figure it is observed that addition of 2% calcium nitrite and addition of 3% sodium nitrate show lower coulomb values than the other mixes. The inhibitors reduce the ingress of chlorides by filling concrete pores and blocking the porosity of concrete by the formation of complex compounds and reduce the extent of corroded area.

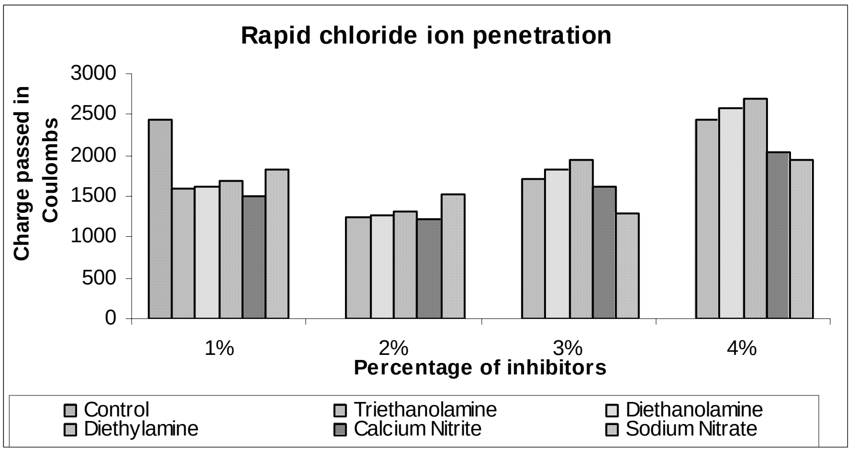

Figure-11. Rapid chloride permeability test.

AC impedance technique

Table-1 lists the impedance parameters such as charge transfer resistance Rct derived from Nyquist plots and Icorr values calculated using Stern-Geary relation. A good inhibitor system should show greater Rct values and lesser Icorr values when compared with the system without any inhibitor. Among all the percentages of inhibitors, the specimens with 2% addition of triethanolamine, diethanolamine, diethylamine and calcium nitrite and the specimens with 3% addition of sodium nitrate show higher Rct values and lesser Icorr values. Figure-12 shows the corrosion rates of all the specimens measured by AC Impedance technique. The corrosion rate of the control specimen is 0.193mmpy. From the figure it can be observed that, 2% addition of triethanolamine, diethanolamine, diethylamine and calcium nitrite and 3% addition of sodium nitrate were found to be more effective in controlling the corrosion rate of steel in 3% NaCl solution. However, the corrosion rates are increased for 4% addition of inhibitors which indicates that the tolerable limit of concentration is less than 4%.

Table-1. Parameters obtained from impedance measurements.

Systems	1% inhibitor		2% inhibitor		3% inhibitor		4% inhibitor	
	R_{ct} Ωcm^2	I_{corr} $\mu A/cm^2$	R_{ct} Ωcm^2	I_{corr} $\mu A/m^2$	R_{ct} Ωcm^2	I_{corr} $\mu A/m^2$	R_{ct} Ωcm^2	I_{corr} $\mu A/m^2$
Control	86.66	0.302	-	-	-	-	-	-
Triethanolamine	100	0.262	167.54	0.153	44.36	0.586	32.418	0.802
Diethanolamine	52	0.500	126.21	0.206	39.69	0.655	25.14	1.034
Diethylamine	42.48	0.612	107.88	0.241	39.69	0.655	16.77	1.552
Calcium nitrite	108.33	0.241	252.43	0.103	94.56	0.275	53.94	0.482
Sodium nitrate	36.69	0.655	73.65	0.352	137.5	0.189	30.48	0.853

Alonso and Andrade [31] have related the values of corrosion current, I_{corr}, to the corrosion state in concrete. An $I_{corr} \leq 0.1\text{-}0.2\ \mu A/cm^2$ indicates negligible corrosion, whereas greater values mean active corrosion. In terms of service life, an I_{corr} >1 μA/cm2 indicates high corrosion rate, while an I_{corr} > 10 μA/cm2 is severe corrosion rate. According to this statement, the corrosion rate of 2% addition of calcium nitrite and 3% addition of sodium nitrate were found to be within 0.1 to 0.2 which indicates negligible corrosion and proves to be more efficient. The results of AC Impedance show reasonable agreement with RCPT, Impressed voltage technique and weight loss measurement.

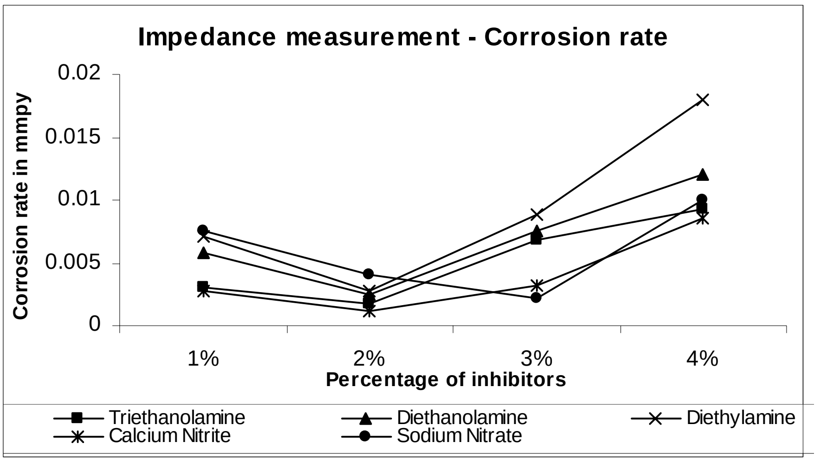

Figure-12. AC impedance - corrosion rate of specimens.

Gravimetric weight-loss method

Figure-13 demonstrates the corrosion rate from the weight - loss measurements. The average corrosion rate calculated in mmpy for various percentages of all the inhibitors are shown in Figure-13. From the figure, it is inferred that 2% addition of triethanolamine, diethanolamine, diethylamine, and calcium nitrite show the lowest corrosion rate values. Further, increase in percentage of inhibitors increases the corrosion rates. Sodium nitrate shows lowest corrosion rate at 3% dosage. On the other hand, 4% addition of sodium nitrate slightly increases the corrosion rate. The same trend was observed in other corrosion tests. Values obtained by weight loss measurement are higher than AC Impedance by 5%. The results obtained from this study are in good agreement with the results of other researchers [16, 17, 18, 27, 28].

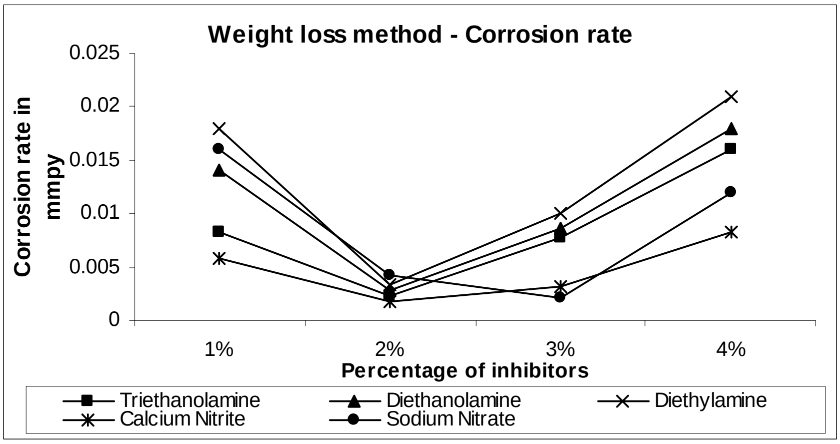

Figure-13. Corrosion rate - weight loss measurements.

The results obtained from all the corrosion tests revealed that addition of inhibitors offer protection for the steel rebar and promise as an inhibiting system in aggressive environments like seawater. The following is the trend observed on the basis of time taken for initiation of corrosion and reduction in corrosion rate:

Calcium Nitrite > Triethanolamine> Sodium Nitrate >Diethanolamine, >Diethylamine

CONCLUSIONS

From the experimental studies concerning the strength and durability behavior of inhibitors in concrete containing quarry dust as fine aggregate, the following conclusions have been obtained:

- The concrete containing quarry dust as fine aggregate can be effectively utilized in the construction industry with good quality materials, appropriate dosage of super plasticizer, appropriate mixing methods and proper curing thereby ensuring sustainable development against environmental pollution;
- Addition of super plasticizer not only reduces the water content without affecting the workability but also enhances the strength slightly due to effective dispersibilty of cement agglomerates in the concrete;
- The incorporation of inhibitors as admixture does not show any adverse effects on the strength properties and there was an increase in strength up to certain percentage. Among the various percentages of inhibitors added (1%, 2%, 3% and 4% by weight of cement), the specimens with 2% addition of triethanolamine, diethanolamine, diethylamine and calcium nitrite and the specimens with 3% addition of sodium nitrate show maximum improvement in the compressive, split tensile, flexural and bond strength when compared with the control specimen which is without addition of any inhibitor;
- Over dosing of corrosion inhibitors results in the acceleration of setting time which leads to a reduction in the ultimate strength of concrete;
- The addition of inhibitors as admixture to concrete displays very lower permeability and water absorption;
- The organic inhibitors i.e triethanolamine, diethanolamine and diethylamine designated as ‘film forming’ protect the steel by forming a hydrophobic film on the surface of the reinforcement. The inorganic inhibitors i.e calcium nitrite and sodium nitrate protect steel in concrete by keeping the chloride ions from reacting with the ferrous ions of ferric oxide defects and cause a large anodic shift of the corrosion potential, forcing the metallic surface into passivation range. The results obtained are in agreement with literatures; and
- To conclude, considering strength as well as durability criteria, the optimum percentage addition of various inhibitors by weight of cement in concrete containing quarry dust as fine aggregate, is 2% for calcium nitrite, triethanolamine, diethanolamine, diethylamine and 3% for sodium nitrate.

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