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An Experimental Study on Inhibitors in Quarry Dust Replaced Concrete

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Abstract—Concrete is a versatile material for the construction of various types of structures in civil engineering field. The quarry dust is the material which is obtained by breaking stones. This quarry dust can be utilized for making concrete since this can able to meet the demand of construction sector. The natural sand takes millions of years to form. Under these circumstances use of quarry dust becomes inevitable. This paper is summarizing the results of an experimental program to be undertaken to investigate the significances of quarry dust replaced concrete along with two types of inhibitors .Organic base (Amine) and inorganic base (Nitrite) have been known for protection of concrete structures but are not commercially indigenous to most developing economics due to manufacturing difficulties and are toxic to the environment. Hence the present paper is to study a novel, Eco-friendly and hydrophobic green plant extracts inhibitor. The fine aggregate in the concrete is to be replaced with quarry dust in the range of 25%, 50%, 75% and 100%. The Compressive strength, flexural strength, split tensile strength and bond strength are to be taken for all the ranges of replaced quarry dust and best is taken for further studies. 1% of diethanolamine and bambusa arundinacea inhibitors are to be added separately with quarry replaced concrete. Impressed voltage test is conducted for finding corrosion initiation of concrete. The results of the inhibitors studied showed that Bambusa arundinacea has superior compressive strength and the corrosion rate was the lowest compared to ethanolamine. Bambusa arundinacea may be considered a better substitute for amine- based corrosion inhibiting admixtures for durable concrete structures due to its hydrophobic effects and environmentally benign.

Keywords—Quarry dust, chloride attack, inhibitors, steel reinforcement, green plant extracts.

I. INTRODUCTION

The premature failure of reinforced structures is a serious problem for the developed and emerging economics. Corrosion of steel reinforcement is the major cause of these deterioration and early failure of reinforced concrete structures. The main cause of concrete contamination has been identified as chloride ions which depassivate otherwise passive alkaline concrete. Over the years, a number of protection measures have been suggested by many researchers to delay, slow or stop the corrosion process, thereby enhancing the service life of concrete structures. Some of the practical methods suggested for control corrosion in concrete were the uses of glass fires, silica fumes and corrosion inhibitor.

Here the quarry dust replaced concrete is used. The corrosion inhibitors are of two types namely anodic and cathodic. The cathodic inhibitors are used and it forms a film on the steel rod and it prevents oxidation. Inhibitors can be used in two forms as directly applying on steel rod & mixing with concrete.

Here inhibitors are mixed with quarry dust concrete are used. Inhibitor namely diethanolamine is used as chemical inhibitor. Most of these corrosion inhibitor's which are presently in use are not eco-friendly and biodegradable, hence the need to develop one which is sustainable. In this work, green plants extract bambusa arundinacea which has been proven to be biodegradable, cheap and environmentally benign was used to inhibit chloride induced corrosion in concrete.

II. COROSSION

Corrosion is a physiochemical interaction between a metal and its environment which results in changes in the properties of the metal and which may often lead to important of the function of the metal , the environment of which these form a part.

Corrosion is an international problem that causes extensive damages to various types of structures. RC is one of the most important structural materials. Many instances are raising doubts about its durability. Most of these failures attributed to the corrosion reinforcement.

2.1 Corrosion Mechanism

Corrosion of steel in concrete is initiated and maintained generally by two mechanisms

- Presence of depassivating ions (particularly chlorides) in large enough amounts to destroy passivating films locally.
- Reduction in alkalinity of concrete (PH around 9.5) due to the effect of atmospheric carbon-di-oxide.

Current flows in the steel from anode to cathode in the presence of oxygen and water. Results in the production of hydroxyl ions are at the cathode. As these migrate to the anode they react with ferrous iron and from hydrous iron oxide (Black Rust) [2][5]. The red rust is responsible for the cracking of concrete because its volume is four times larger than that of steel, while the black rust volume is only twice as large as steel. The reactions at the anode and cathode [3] are expressed as given below

$$Fe \longrightarrow Fe^{2+} + 2e^{-} \text{ (at anode)}$$

$$O_2 + 2H_2O + 4e^{-} \longrightarrow 4OH^{-} \text{ (at cathode)}$$

$$Fe^{2+} + 2OH \longrightarrow Fe\,(OH) \text{ (at anode)}$$

$$4Fe(OH)^{-}{}_2 + 2H_2O + O_2 \longrightarrow 4Fe\,(OH) \text{ (at anode) (Hydrated red rust)}$$

$$3Fe + 8OH^{-} \longrightarrow Fe_3O_4 + 8e^{-} + 4H_2O \text{ (Black rust)}$$

2.2 Corrosion Monitoring Techniques

Many types of experimental techniques have been developed to study the corrosion in reinforced concrete. A few of them are applicable at the laboratory level and some may be used in field as nondestructive or partially nondestructive to monitor corrosion damaged structure. A few techniques which are mostly adopted are detailed below.

2.2.1 Hammer – Impact Test

For measuring the surface hardness, which is affected by the deterioration of concrete due to cracking and corrosion of steel reinforcement, hammer impact test is adopted. The hammer rebound test is a measure of hardness of concrete.

2.2.2 Pulse – Velocity Test

The ultrasonic – pulse – velocity test has been developed to evaluate the relative quality and homogeneity of concrete. The Portable Ultrasonic Non-destructive Digital Indicating Tester (PUNDIT) is a device used to test the concrete strength. This test is also used primarily to identify the weaker locations affected by corrosion.

Table 2.1 Velocity and Concrete Quality

Velocity (Km/Sec)	Concrete Quality
> 4.0	Very good to Excellent
3.5 – 4.0	Good to Very good slight porosity may exist

3 – 3.5	Satisfactory but loss integrity is suspected
< 3.0	Poor and loss of integrity exists.

2.2.3 Potential Measurement

To identify the corrosion status of embedded steel in concrete structures, half-cell potential variation between the surface of the concrete and reinforcement is measures using a portable battery-powered instrument consisting of a reference electrode usually saturated calomel electrode (SCE) and copper-copper sulphate electrode (CSE) and a high impedance voltmeter. The electrical half-cell potential values are measured in millivolts. The measured potential difference between -200 millivolts and -350 millivolts indicates uncertain corrosion activity [9], as indicated by Suryavanshi and others (1990).

This method is a qualitative method of corrosion estimation. Interpretation of measured potential needs thorough knowledge of concrete resistivity, carbonation, polarization effects, etc., thorough experience is needed for the usage of this equipment.

2.3 Diethanolamine

Diethanolamine is a secondary amine with the molecular structure CH3CH2NHCH2CH3. It is a flammable, strongly alkaline liquid. It is miscible with water and ethanol. As a liquid it has a dark brown color due to impurities, however when distilled it is colorless. It is volatile and has a strong unpleasant odor.

Diethylamine is manufactured from ethanol and ammonia and is obtained together with ethylamine and triethylamine. It is uses as a corrosion inhibitor and also used in the production of rubber, resins, dyes and pharmaceuticals.

III. MATERIALS AND METHODS

Ordinary Portland cement (OPC) was used in this research. Chemical compositions accompanied by some important physical and mechanical properties of the cement are same as in the companion paper (The chloride was admixed into the concrete as magnesium chloride of analytical reagent grade. The concentrations of magnesium chloride used were 1.5% by mass of cement and the corresponding chloride concentrations was 0.94%. Coarse aggregates of size 20 and 10 mm of quartzite origin were used in the ratio of 1.78:1 to satisfy the overall grading requirement of coarse aggregate [4].

Quarry dust passing through Indian Standards for Testing of Materials (IS) sieve No.(4. 75 mm) conforming to zone II classification The sand has a fineness modulus of 2.5. Tap water was used for the preparation of specimens. All the concrete mixes were designed for similar workability with slump of 30 to 60 mm. The water content was kept constant to 191.6lit for the desired slump in all the mixes to have similar workability [7]. The water–cement ratio (w/c) used was 0.45. The fresh density of concrete was then obtained as per guidelines specified by Indian standard. Design mix is as presented in Table 3.1.

Table 3.1 Concrete mix proportions

Water (Litre)	Cement(kg/m3)	Fine aggregate (kg/m3)	Coarse aggregate (kg/ m3)
0.45	1	1.36	2.78
191.6	425.77	579.164	1183.768

3.1 Preparation of plant extracts

Fresh leaves of Bambusa Arundinacea (Indian Bamboo) was washed under running water, shade dried and ground into powder (Mohammad et al., 2011). The extraction was done using soxhlet extraction process. 3 g of pulverized samples were placed in a porous container and allowing condensed solvent (ethanol) to extract continuously. The condenser function was to cool the solvent vapour and cause it to condense (turn back to liquid). The extracts from soxhlet apparatus were rotary evaporated to expel the ethanol [6] [8].

3.2 Preparation of concrete specimens for compressive strength test

The 150 × 150 × 150 mm concrete cubes were prepared using 1: 1.36 : 2.78 designed with a water/cement ratio (w/c) of 0.45. Inhibitor admixtures, namely 2% of ethanolamine and green B. arundinacea were added on the basis of weight of cement. The concrete cubes were demoulded after 24 h of casting and subjected to water curing. The specimens were removed after 7, 14, 28, days of curing and subjected to compressive strength testing (as per Indian Standard using compression testing machine of 2000 kN capacity.

3.3 Preparation of concrete specimens for Split Tensile Strength

Tensile strength is indirect way of finding the tensile strength of concrete by subjecting the cylinder to a compressive force. Cylinder of size is 150mm diameter and 300mm long. After 24 hours the specimen were demoulded and subjected to water curing. After 7, 14 and 28days of curing, the curing three cylinders were taken and allowed to dry and tested in UTM by placing the specimen horizontal. The ultimate loads of the specimen were noted.

3.4 Preparation of concrete specimens for Flexural Strength

The beam of size 500x100x100mm is cast for determining the flexural strength of concrete. After 24hours the specimen were demoulded and subjected to water curing. After 7, 14 and 28days of curing, the curing three beams were taken and allowed to dry and tested in UTM. The two point load in applied to specimen and slow rate till the specimen fails.

Table 3.2 Compression of Strength Tests

System studied	Compressive strength 28 Days	Split tensile strength 28 Days	Flexural strength 28 Days
Control	28.88	2.40	7.89
25% quarry dust concrete (Q_{25})	30.25	2.51	8.01
Q_{25} with C_2H_7NO inhibitor	31.45	2.57	8.23
Q_{25} with B. arundinacea inhibitor	33.49	3.37	8.42

3.5 Impressed Voltage Technique

In this test helps to assess the material quality against rust expansion pressure by Chloride accumulation at the anode (rebar). In this technique the concrete specimen is immersed in 3.5% NaCl solution and embedded rebar is made anode (connected to the +ve terminal) with repeat to an external stainless steel electrode (Connected to the –ve terminal) [7] serving as cathode by applying a constant positive potential 6 Volts to the system from a DC source. The variation of current is recorded with time. A sharp rise in current indicates the onset of corrosion and cracking of the concrete is usually visible thereafter. The time taken for initiation of first crack can be considered as a measure of their relative resistance against chloride permeability and reinforcement corrosion.

Table 3.3 Corrosion Initiation Time

System studied	Corrosion Initiation time (Hours)
Control	156

25% quarry dust concrete (Q_{25})	158
Q_{25} with C_2H_7NO inhibitor	292
Q_{25} with B. arundinacea inhibitor	336

3.6 Weight loss method

The metal samples were separately weighed before embedding in concrete and labelled at the protruding end after embedding each of the samples [1]. After the corrosion experiments, the concretes were broken down completely and each of the samples re-weighed. Weight loss was obtained by computing the difference between the initial and final weights of the samples.

The results obtained were used to compute the corrosion rate and inhibitor efficiency. The corrosion rate (R) was calculated from the formula:

$$R = 87.6 * W / D * A * T$$

Where,

W is the weight loss in milligrams,
D is the density in g/cm2,
A is the area in cm2, and
T is the time of exposure in hours.

IV. CONCLUSIONS

The concrete specimens were cast with quarry dust as fine aggregate with addition of inhibitors namely Bambusa Arundinacea and Diethyl amine. Usage of quarry dust instead of natural sand has improved all the strength and durability properties. Though the concrete specimens cast with 25%Quarry dust along with 1% of bambusa and diethanolamine develops long term strength development. Bambusa arundinacea with 25% quarry dust concrete produce higher corrosion initiation time than Diethanolamine and control specimens. By adding corrosion inhibitor, water absorption properties are considerably reduced with increased bulk density than control specimens. The corrosion rate of Bambusa arundinacea is lesser than all other specimens under the chloride exposure conditions.

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