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Performance Evaluations of Calcium Nitrite on Steel Rebar Corrosion in Quarry Dust Concrete

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Abstract: *The utilization of quarry dust as fine aggregate in concrete is advantageous because of the benefits such as reduction in demand for river sand, environment load and cost of concrete. In this study, experimental investigation has been done to explore the significance of quarry dust as fine aggregate in concrete. Corrosion is the major durability problem causing deterioration of concrete structures. Hence, the objective of this work is to study the strength and corrosion resisting properties of concrete containing quarry dust as fine aggregate along with calcium nitrite as corrosion inhibiting admixture at the dosage of 1%, 2%, 3% and 4% by weight of cement. Strength tests, water absorption test and the durability tests were carried out and the results were compared with the natural sand concrete. The corrosion resistance performance was determined by impressed voltage method, rapid chloride permeability test and gravimetric weight loss method. The results proved that quarry dust as substitute for river sand in concrete increases the strength of the concrete, with addition of inhibitor it proffer very good resistance against corrosion.*

Key Words: *Concrete, quarry dust, super plasticizer, inhibitor, chloride ingress, corrosion resistance, durability*

I. INTRODUCTION

Utilization of quarry dust as fine aggregate in concrete is giving good strength and density and hence lower permeability which enable it to provide better resistance to freeze/thaw cycles and chemical attack in adverse environment [1,2]. A complete replacement of sand by quarry dust in concrete is possible with proper gradation of quarry dust before utilization [3,4]. The compressive strength of quarry dust concrete can be improved with admixture E [5] and super plasticizers can be used to improve the workability of quarry dust replaced concrete [6]. Concrete produced using quarry fines shows improvement in higher flexural strength, abrasion resistance, and unit weight which are very important for reducing corrosion or leaching [7,8]. Self-compacting concrete can also be produced using quarry dust [9]. 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 [9,10]. Corrosion of reinforcing steel is a major problem facing the concrete infrastructures [11,12]. Many structures in adverse environments have experienced unacceptable loss in serviceability of safety earlier than anticipated due to the corrosion of reinforcing steel [13] and thus need replacement, rehabilitation or strengthening. Corrosion can be prevented by chemical method by using certain corrosion inhibiting chemical and coating to reinforcement. 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 [14]. Corrosion inhibitors function by reinforcing a passive layer or by forming oxide layer and prevent outside agents and reduce the corrosion current [16-18]. Corrosion inhibitors are becoming an accepted method of improving durability of reinforced concrete in chloride laden environments [19,20].This paper deals with the experimental study to investigate the effect of calcium nitrite as inhibitor in concrete containing quarry dust as fine aggregate in resisting corrosion.

II. MATERIALS

Ordinary Portland Cement [43 grade] has been used throughout the investigation. River sand, confirmed to grading zone – II as per table 4 of IS 383-1970 has been used as fine aggregate for control specimen with specific gravity 2.57, fineness modulus 2.67 and bulk density 1460kg/m^3.Quarry dust conforming to grading Zone - II was used as fine aggregate instead of river sand with specific gravity 2.68, fineness modulus 2.7 and bulk density 1790kg/m^3. Aggregate obtained from nearby granite quarry has been used for this study. The maximum size of aggregate is 20 mm with specific gravity 2.7, and fineness modulus 4.33. Potable tap water available in the laboratory was used for mixing and curing of concrete. High yield strength deformed bars of diameter 16mm was used for pullout and corrosion tests. To increase the workability of quarry dust concrete commercially available super plasticizer ROFF 320 has been used. To attain strength of 20N/mm^2 a mixture proportion was designed based on IS: 10262 – 1982 and SP 23: 1982[21]. The mixture was 1: 1.517: 3.38 with water cement ratio 0.45.

III. METHODOLOGY

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 and without calcium nitrite for compressive, flexural and split tensile strength. After 24 hours the specimens were demoulded and subjected to water curing. After 3, 7and 28 days the specimens were tested as per IS: 516 – 1964. Water absorption of hardened concrete specimens was calculated based on ASTM C642-81.To assess the corrosion protection efficiency under impressed voltage method and weight loss method, concrete cylinders of size 75mm diameter and 150mm length, with centrally placed steel rod of 16mm diameter were cast. The steel rod is placed in such a way that a constant cover is maintained all round. Concrete discs of 100mm diameter and 50mm depth were cast for rapid chloride permeability test.

3.1 Specimen identification

The various specimen cast are shown in table 1.

Table1–Specimen identification

Mix	Definition
C	Conventional concrete with river sand as fine aggregate
Q	Quarry dust concrete having quarry dust as fine aggregate
Q1	Quarry dust concrete with addition of 1% calcium nitrite
Q 2	Quarry dust concrete with addition of 2 % calcium nitrite
Q 3	Quarry dust concrete with addition of 3 % calcium nitrite
Q 4	Quarry dust concrete with addition of 4 % calcium nitrite

IV. RESULTS AND DISCUSSION

4.1 Discussion on conventional concrete and quarry dust replaced concrete:

The compressive, split tensile, and flexural strength results after 28 days curing are given in Table 2 and figures 1to 3.. When comparing the results of conventional concrete [C] and quarry dust concrete [Q], it is obvious that quarry dust replaced concrete specimens have shown improvement in the above strength properties. There was 8.75% increase in compressive strength, 2.5% increase in split tensile strength and 1.68% increase in flexural strength. From the impressed voltage test results it is evident that, the corrosion resistance performance of quarry dust concrete was 10.62% greater than the conventional concrete. Weight loss measurement result shows that the corrosion rate of quarry dust concrete specimen decreased by 9.12% when compared with conventional concrete. The rapid chloride permeability test results clearly indicate that, the corrosion resistance performance of quarry dust concrete is 8.84% greater than conventional concrete.

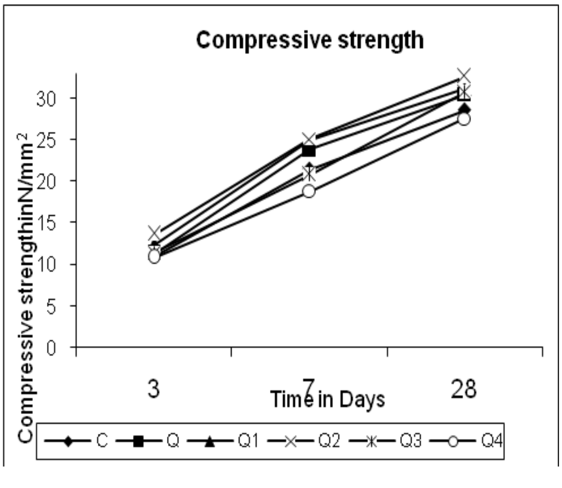

Fig . 1Compressive strength

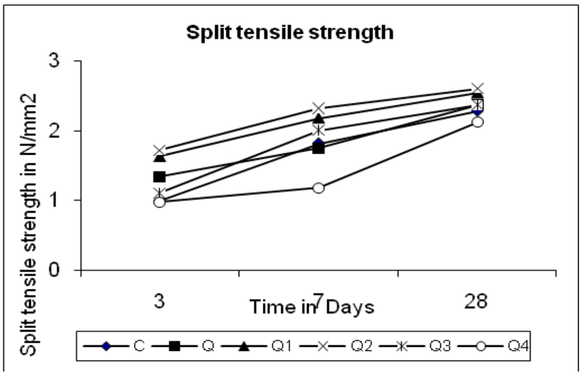

Fig. 2 Split Tensile Strength

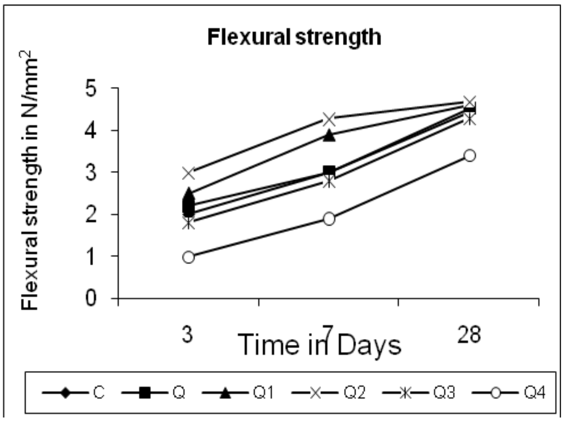

Fig. 3 Flexural strength

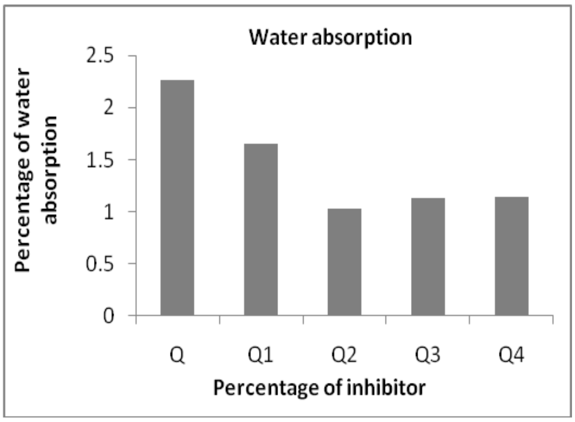

Fig.4 Water absorption Test

4.2 Discussion on quarry dust concrete with and without inhibitor

The strength test results for concrete containing quarry dust as fine aggregate along with calcium nitrite at 1%, 2%, 3% and 4% are shown in figures 1,2 and 3. The compressive strength results after 28 days curing are shown in figure 1. From the figure it is evident that 1% addition of calcium nitrite shows 3.29% increase in the compressive strength, while the addition of 2% of this inhibitor gives hike of 7.28% and this yields the maximum increase in the strength value. Further, addition of calcium nitrite to 3% gives 1.64% increase in compressive strength. From fig 2it is observed that quarry dust concrete specimens along with 2% inhibitor showed the maximum increase in split tensile strength by 5.26 %. However the strength is reducing gradually for 3% and 4% addition of inhibitor. All quarry dust replaced specimens with addition of inhibitor have shown slight increase in flexural strength when compared to control specimen Q[fig 3]. Especially the addition of 2% of the inhibitor shows the maximum improvement of 3.53%, %. Among all the percentages 2% Addition of Calcium nitrite shows maximum improvement in all the strength values. For 3% and 4% addition of inhibitor there was a slight reduction in strength due to retardation of C_3S hydration. Over dosing of corrosion inhibitors resulted in acceleration in setting time which lead to a reduction in ultimate strength of concrete. In accordance with figure 4, the water absorption of quarry dust replaced concrete after saturation is found to be less when compared with ordinary concrete specimens. Among all the percentages of inhibitors added 2% of calcium nitrite was found to be the optimum.

V. IMPRESSED VOLTAGE TEST

The specimens were tested by impressed voltage technique and the time taken for initiation of corrosion in the specimen is shown in figure 5. Test results have shown that the ordinary concrete specimen C started to corrode after 146 hrs. Specimen with 100% replacement of river sand with quarry dust Q, started at 160 hrs. Quarry dust replaced concrete specimen with addition of 1% inhibitor MIX Q1 started after 280hrs. The specimen with 2% inhibitor MIX Q2, started after 288 hrs and MIX Q3 with 3% of inhibitor, started to corrode after 270 hours and for 4% it was 238 hrs. The above results clearly indicated that corrosion resistance increased with increase of percentage of corrosion inhibitor.

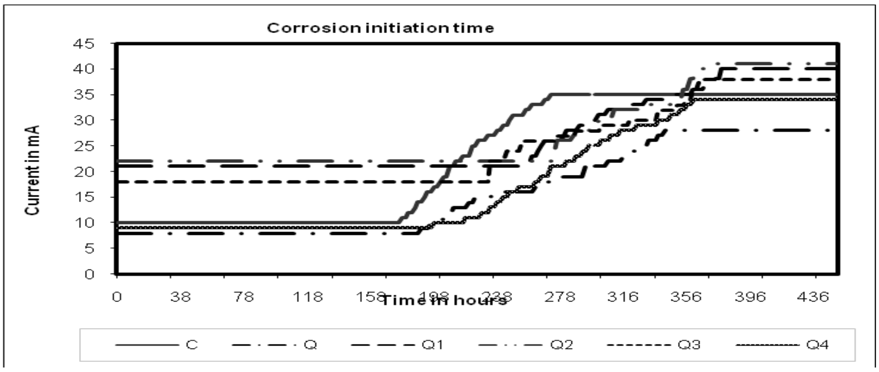

Fig.5 Corrosion initiation time

Rapid Chloride Permeability and Weight loss measurements

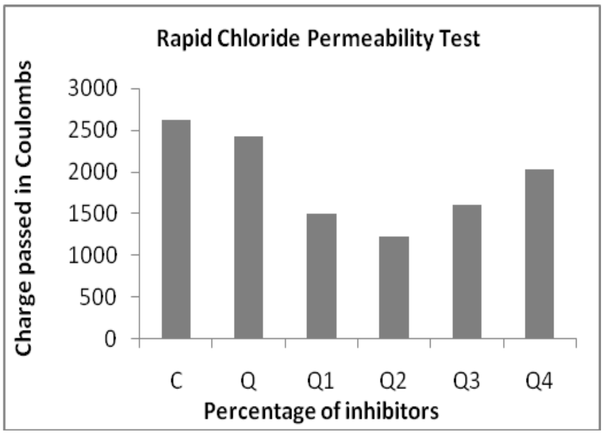

Fig 6 Rapid Chloride Permeability Test

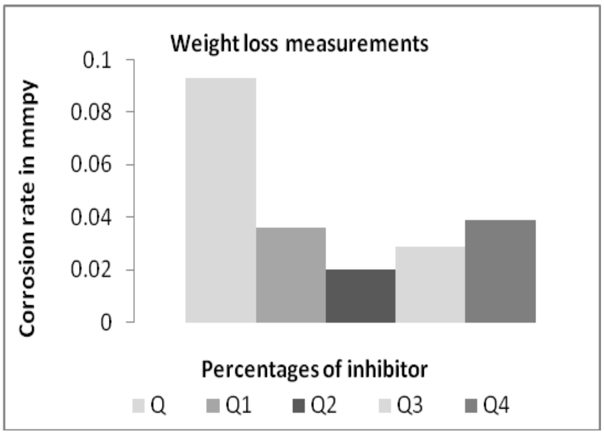

Fig 7 Corrosion rate with addition of inhibitor

Figure 6 shows the chloride diffusion results of the different percentages of inhibitors. The RCPT value for conventional concrete at 28 days is 2678 Coulombs whereas for quarry dust concrete it is found to be 2426 Coulombs. The performance of the quarry dust concrete with 1%, 2%, 3% and 4% addition of calcium nitrite are observed to be 61.9%, 97.87%, 51.05% and 19.27% greater than the control specimen. From the figure it is observed that addition of 2% calcium nitrite shows lower coulomb values than the other mixes. Corrosion rate from the weight – loss measurements [figure 7] clearly indicates that the rate of corrosion decreases with the increase of percentage of inhibitor up to 2% and further addition shows a slight increase when compared to MIX

VI. CONCLUSION

From the experimental studies the following conclusions were drawn

- Concrete containing quarry dust as fine aggregate along with appropriate dosage of super plasticizer gives slightly higher strength when compared with conventional concrete
- Among all the percentages of calcium nitrite added, 2% addition of calcium nitrite shows maximum improvement in the compressive strength, split tensile strength, and flexural strength when compared to the control specimen.
- Incorporation of inhibitor decreases permeability & water absorption of quarry dust concrete.
- The results of corrosion tests indicate that, corrosion initiation time of steel rod embedded quarry dust concrete is delayed due to the addition of inhibitor and also there was a reduction in corrosion rate. Among all the percentages of inhibitors 2% was found to be the optimum percentage for getting maximum corrosion resistance
- Considering strength as well as durability criteria quarry dust concrete along with 2% of calcium nitrite can be effectively used in reinforced concrete structures for delaying corrosion and to increase other strength and durability characteristics.

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