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EFFECT OF FUSION BONDED ECO-EPOXY COATING AND RIB GEOMETRY ON REINFORCED CONCRETE STRUCTURES

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Abstract: The investigates the effect of fusion bonded epoxy coating and rib geometry on reinforced concrete structure .In this, some pullout specimen's cast with smooth bar's and bars having different rib geometry. It is observed that reduction in bond strength for all types of rib geometries used was less than that of the maximum reduction of 20% specified by IS 13620:1993 code (1). Corrosion of reinforcement in reinforced concrete is major problem in reinforced concrete structure because it affects the overall safety and serviceability of structures. Fusion bonded eco-epoxy coating is an effective method for corrosion-proofing and combating corrosion in reinforced concrete. The main object of this paper reported the evaluation of bond strength of eco-epoxy coated bar splices confined with lateral reinforcement (2). Test result indicate that transverse reinforcement improves the bond strength of coated bar and durability of structure. Also, the eco-epoxy coated bars have emerged as a viable and cost effective system for reinforced concrete structure (3). From research it is clear that the eco-epoxy coating is a physical barrier system which prevents the bar from corrosion. And it is eco friendly with nature.

Keywords: Wastewater Treatment, Environmental Problems, Cod, Dairy Industry.

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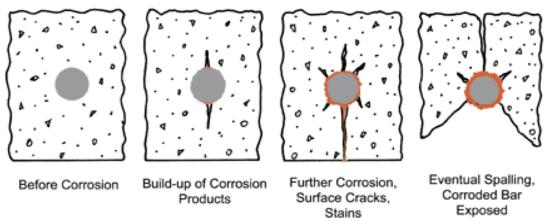
INTRODUCTION

Corrosion of reinforcement in reinforced concrete is a major problem in reinforced concrete structure .Corrosion is the process that gradually increases with time. Mainly, corrosion occurs in concrete structure due to harsh environmental condition due to exposure dicing salts or seawater and when chloride penetrates the concrete to the level of steel reinforcement.

When the corrosion of the reinforced steel is initiated, the products of corrosion expand and occupy a greater volume than the original volume of steel. I.e. corrosion occurs 20-30 times greater volume than the original volume of steel. Once, a corrosion of reinforced steel is initiated, then concrete has cracked and more chloride is enters to attack steel, and deterioration of concrete components or structure proceeds at faster pace. Corrosion affects the overall safety and serviceability of the structures (4).



The corrosion cycle of uncoated steel rebar begins with the rust expanding on the surface of the bar and causing cracking near the steel/concrete interface. As time marches on, the corrosion products build up and cause more extensive cracking until the concrete breaks away from the bar, eventually causing spalling.

For that one solution is apply to minimize such corrosion problems is to protective coating to the reinforcing steel. Now, a day the most popular is fusion bonded epoxy coating. The eco-epoxy coating reduces the bond stress between the reinforcement and concrete. This influences the force of transfer at interface and on cracking of reinforced concrete structure. Also, the eco-epoxy coated reinforcing bars have emerged and cost effective tool. According, to the original research, the eco-epoxy coating is a physical barrier system that prevents moisture and chloride from coming in contact with bar. As FBECB are used widely in structure such as water tanks, nuclear power plant structures and bridges predicting and controlling the crack width is important.

Crack width and crack spacing can be predicted theoretically if the bond stress variation is known .The bond stress at the interface is most commonly assumed to be uniform and the interface is modeled using appropriate bond stress vs. slip relationship. Bond in reinforced concrete is described by three components viz. chemical adhesion, friction and mechanical interaction between the bar and the ribs and the surrounding concrete (3). The resultant of these forces act inclined to the bar and resolved into two components viz. radial force and bond strength shown in fig.

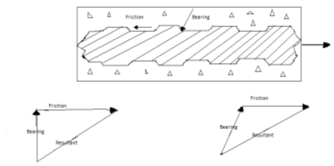


Fig. Transfer of force at interface

The coating on the bars also lowers the relative area and reduces the transfer of force from concrete to reinforcing bars decreases in mechanical interaction. The coating on bar is week layer between reinforcement and surrounding concrete. The shear deformation of coating enhances the slip between concrete and reinforcement (1).

METHODOLOGY

EXPERIMENTAL PROGRAMME (a)

1. Materials

A 43 grade Portland Pozzolonic Cement (PPC) is used for preparation of test specimens. Fe 415 grade high yield strength deformed (HYSD) bars of diameters 8mm, 20mm and 32 mm as main reinforcement, and 6 mm mild steel (MS) bars as spirals as confinement reinforcement, are used. Concrete is made from normal weight black granite aggregate.M30 concrete with the following proportions is used. Weight of cement is 300 kg/m3 and water cement ratio is 0.45. Fine aggregate in the total aggregate is 35%. The concrete mix proportions are (C: FA: CA: W) 1: 2.30: 4.27: 0.45.

2. Details of test specimen

The test specimen is basically a plain concrete cube dimensions 150mm x 150mmx150mm with a rebar embedded coaxially. One end of the rebar is projected about 15mm to measure the free end slip and the forced end is projected about 750mm in order to grip for applying the tensile force. Tests are conducted on pullout specimen with two parameters with one variable in each set of specimens. In a set, there are 11 cubes, out of which, four are with uncoated bars, and four are with coated bars. Three plain concrete cubes were tested for compressive strength. In the 80 pullout specimens, different bar diameters such as 8mm, 20mm and 32mm with different rib geometries such as diamond, inclined and plain were studied. Steel moulds are fabricated to prepare 8 specimens in a single casting. Holes are provided on the vertical faces of the mould to accommodate the re-bars centrally. Lubricating oil is applied on all the inner sides of the moulds for easy removal of specimens. After twenty four hours, the specimens were removed from the forms and cured for 28 days before testing of specimens (2).

3. Experimental set-up and testing

The testing of pullout specimens is carried out in a universal testing machine (UTM), which is shown in Figure 1. The UTM is connected with a data acquisition system, using which the slip and the corresponding loads are measured. The test specimen shall be mounted in the testing machine in such a manner that the bar is pulled out axially from the cube. A Teflon sheet used as a capping material is placed between the top surface of the machine and the bottom face of the concrete cube. This ensures smooth contact between the machine and concrete surface, which is used to avoid friction at the interface of the machine and specimen .The reinforcing bar, is pulled axially along the vertical direction. The load is applied to the reinforcing bar at a rate not greater than 2250 kg/min .The movement between the reinforcing bar and the concrete cube as indicated by the dial gauge is read at a sufficient number of intervals throughout the test. The loading is continuous and the movement of the bar is record at appropriate intervals until any one of the following conditions are reach (2).

1. The yield point of reinforcing bar is reach
2. The enclosing concrete is fail and the type of failure is noted, whether it is pull out failure or splitting failure or yield failure and
3. A minimum slip of 2.5mm occurs at the loaded end. The maximum load and the corresponding slip for each type of failure are record.

The comparison of bond strengths between the concrete and the reinforcing bar is made on the basis of the average bond stresses calculated from the loads at the measured slips.

The enclosing concrete is fail and type of failure is noted, weather it is pullout failure or splitting failure or yield failure. The test results are shown in table (2).

Table 1. Results of the Pull-out Test.

Diameter(mm)	Type of Rib	Bond Ratio
8	Diamond	0.811
20	Diamond	0.935
8	Inclined	0.994
20	Inclined	1.003
32	Inclined	0.906
8	Plain	0.977
20	Plain	0.921
32	Plain	0.902

RESULT AND DISCUSSION

Influence of Rib Geometry

Crack spacing depends on the bond strength. The bond strength is influenced by the bar diameter, rib geometry, coating to the bar etc. Transfer length, Lt is the length required to transfer the stress in the steel bar to the concrete. Along the transfer length, strain in steel reduces and strain in concrete increases and at the end of the transfer length, strain in concrete equals to the strain in steel. Spacing of primary cracks lies between Lt and 2Lt. Hence, the transfer length can be used to compare the effect of coating and rib geometry on the crack spacing and crack width (2).

Table 2.Transfer Length of rib geometry

Diameter (mm)	Type of Bar	Type of Rib	K_p (mm/N)	Transfer Length(mm)
8	Bare	Diamond	0.0183	122.75
8	Coated	Diamond	0.0224	140.01
8	Bare	Plain	0.0387	142.62
8	Coated	Plain	0.0400	143.96
8	Bare	Inclined	0.0182	146.00
8	Coated	Inclined	0.0218	170.01
20	Bare	Diamond	0.0183	279.34
20	Coated	Diamond	0.0224	180.02
20	Bare	Plain	0.0387	165.12
20	Coated	Plain	0.0400	157.13
20	Bare	Inclined	0.0182	120.47
20	Coated	Inclined	0.0218	144.32
32	Bare	Inclined	0.0182	229.68
32	Coated	Inclined	0.0218	248.35
32	Bare	Plain	0.0387	200.00
32	Coated	Plain	0.0400	187.00

The transfer lengths of various bars are listed in Table 2. The results indicate that irrespective of whether the bar is coated or not, the transfer length increases with increase in diameter of the bar. The transfer length of coated bars is more than the spacing of concrete reinforced with bare bars. Crack spacing in smaller diameter coated bars with diamond rib pattern is close to the transfer length of the plain bar, the influence of coating is found to be negligible. In bars with inclined rib pattern, crack spacing is 15 to 20 % more in smaller diameter bars and the influence of coating is less in larger diameter bars .The coating thickness provided to the bars ranges from 150 µm to 300 µm. As per the manufacturing standards, the thickness of coating applied to the bars is not proportional to the bar diameter. Therefore the coating to diameter ratio in smaller diameter bars is more when compared to large diameter bars.

Hence coating on smaller diameter bars will have more effect on the bond strength and crack width. The transfer length of bars with diamond rib pattern seems to be more than that with inclined rib pattern. This is due to the fact they restrain for the coating to flow out of the region covered by diamond rib pattern and due to this coating gets accumulated within the boundaries of the diamond pattern and the thickness of coating provided looks more (1).

The effect is more significant in smaller diameter bars usually used in reinforcing slabs and water tanks, where cracking is a very important criterion that is to be satisfied bars. In the case coating is found to be negligible. In bars with inclined rib pattern, crack spacing is 15 to 20 % more in smaller diameter bars and the influence of coating is less in larger diameter bars .The coating thickness provided to the bars ranges from 150 µm to 300 µm. As per the manufacturing standards, the thickness of coating applied to the bars is not proportional to the bar diameter (2). Therefore the coating to diameter ratio in smaller diameter bars is more when compared to large diameter bars .Moreover the rib heights are proportional to the bar diameters, smaller diameter bars have smaller ribs as compared to larger diameter bars. Hence coating on smaller diameter bars will have more effect on the bond strength and crack width. The transfer length of bars with diamond rib pattern seems to be more than that with inclined rib pattern. This is due to the fact they restrain for the coating to flow out of the region covered by diamond rib pattern and due to this coating gets accumulated within the boundaries of the diamond pattern and the thickness of coating provided looks more. This effect is more significant in smaller diameter bars usually used in reinforcing slabs and water tanks, where cracking is a very important criterion that is to be satisfied (3).

Modes of failure

The modes of bond failure is observes from in the pullout test. Three different types of failure such as the yielding of steel reinforcement, the pullout of reinforcing and splitting of concrete is observes in the specimens. Irrespective of the bar diameter, all the plain bars fails in pullout mode the 8mm bar with smooth inclined and diamond rib pattern fails by the yielding of the reinforcing bar. However, 20 mm and 32 mm diameter bars with both diamond rib and inclined pattern fails y pullout with splitting cracks of concrete. The average bond stress of bare and coated bars at the ultimate load in the splitting mode of failure is 12.65 and 12.31 MPa respectively. The bond ratio is 0.97(1).

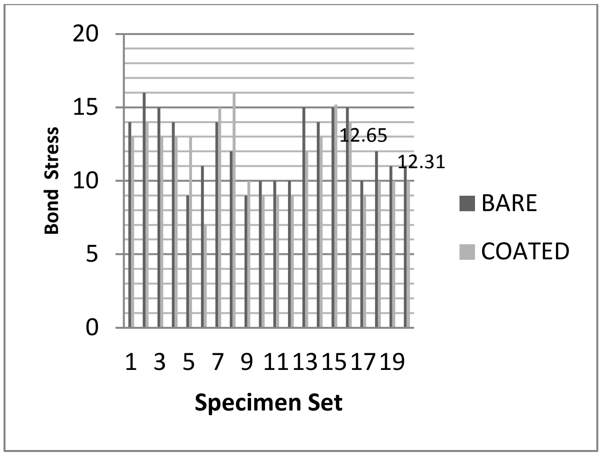


Fig. Average bond stress in bare and coated bars at ultimate load in splitting failure.

While, fusion bonded epoxy coating on reinforcing bars reduces the risk of steel corrosion, it also helps in reducing bond strength. Thickness of coating, rib geometry of bars and diameter of the bars are some factors which influences the bond strength. Most of the studies on this material are for independent influence of these factors. The combine effect influence of these factor is not investigates.

CONCLUSION

From the analysis of experimental work the following conclusion may be drawn.

1. The influence of fusion bonded eco-epoxy coating on the crack spacing in concrete with plain bars is negligible.

2. Irrespective of whether the bar is coated or not, the crack spacing with large diameter Bars seems to be more than that of smaller diameter bars.

3. Influence of fusion bonded eco-epoxy coating on small diameter bars with diamond rib pattern bars is more than that of large diameter bars.

4. Eco-epoxy coating bars have same strength as that of general simple epoxy coated bar.

5. Eco-epoxy coated bars have same strength in compression, tension, and flexure as that of general epoxy coated bars.

6. The bond strength of bare bar is more than coated bar.

7. All 8 mm, 20 mm, 32 mm bars with plain surface fails by pullout of bar from specimen.

8. At the ultimate stress, the reduction in bond strength is less than 10 % irrespective of the type of rib pattern and diameter of bar.

9. Irrespective of whether the bar is coated or not, the crack spacing with large diameter bars seems to be more than that of smaller diameter bars.

10. The Eco-epoxy coating material saves and protects the environment.

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