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INFLUENCE OF PROTECTIVE COATING ON BOND STRENGTH DEVELOPMENT OF STEEL WITH CONCRETE

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ABSTRACT

This investigation presents the influence of protective coating on bond strength development of steel with concrete. Pull-out test was conducted in the 1000 kN capacity Universal Testing Machine as per procedure outlined in Indian Standards. The tested rebar includes rusted (uncoated) rebar as available in the site, acid pickled rebar (Rust free rebar) and cement polymer anticorrosive coated rebar obtained from a single source. Concrete of M25 grade were used and totally 18 specimens were tested. The loads at the free end slip of 0.025mm, 0.25mm, loaded end slip of 0.25mm and ultimate pull out load were observed. The load-versus slip behaviour was studied at the free end and loaded end using precision dial gauges. The bond stress corresponding to the lowest load value of 0.025mm FE slip and 0.25mm LE slip was considered as the usable bond strength. The test results revealed that a well defined correlation exists between Load at 0.025mm Free end slip and 0.25mm Loaded end slip. It was found that presence of rust and cement polymer anticorrosive coating in the steel concrete interface appreciably increases the bond strength of the order of 16%, 35% respectively for 16mm diameter bars as compared to rust free rebar. For 20mm dia. bars, marginal reduction in bond strength for rusted rebars and significant increase in bond strength for coated bars as compared to uncoated bars were observed. It is concluded that presence of rust influences in reduction / increase in bond strength depending on the nature of rust at the interface in the initial ages. Application of cement polymer coating improves the bond strength of the order of 30 – 35% due to excellent compatibility at the steel concrete interface, satisfies the codal requirements of Indian Standards.

INTRODUCTION

The bond between rebar and concrete is essential for reliable performance of reinforced concrete structures(8). The rebar concrete bond is due to various parameters such as chemical adhesion, bearing action of concrete against deformations of rebar and frictional

resistance offered by concrete against movement. The introduction of coating at the steel concrete interface will definitely modify the bond behaviour of steel with concrete. The application of protective coating to rebar becomes an efficient and popular method of protecting steel rebar from corrosion inside the concrete (7). The most widely used commercial coating methods are Fusion Bonded Epoxy Coating, Galvanization, Cement Polymer Composite coating and Inhibited Cement Slurry Coating. Nowadays a simple, Cement Polymer Anticorrosive Coating was developed and used in various parts of South India. It has been reported that epoxy coated bars offers less slip resistance and bond strength as compared to uncoated bars. The bond splitting cracks are also initiated at lower loads for epoxy coated bars(1). There is no adverse effect on bond strength for galvanized steel even without chromate treatment where as epoxy coating reduces the bond strength of the order of 20% as compared to uncoated bars (6). The improved bond strength upon increase in coating thickness was also reported by the researchers (8). It is necessary to investigate the influence of cement polymer anticorrosive coating at the steel concrete interface on the bond strength development.

EXPERIMENTAL INVESTIGATION

The mix design for M25 concrete was carried out as per American Concrete Institute (ACI) method. The concrete material comprises of 20 mm downgraded jelly, natural sand available from local source, 53 grade Ordinary Portland Cement obtained from single source and potable water. The Mix ratio obtained is 1 : 1.6 : 3.2, w/c ratio 0.45. The steel rebar comprises of heavily rusted 16 mm and 20 mm TMT rebar obtained from a single length. The coating material is a commercially available Cement Polymer Anticorrosive solution - CORROCON – CPAC.

The type of rebar used in the study includes rusted rebar (uncoated bar) as available in the site, the rebar pickled in 20% HCL acid for rust removal (rust free rebar) and the rebar coated with Cement polymer anticorrosive coating. To maintain uniform material and chemical properties, all the three type of rebars were prepared from the single rebar length. The coated bars were prepared by thoroughly cleaning the loose rust over rebar by steel wire brush followed by application of one coat of Polymer cementious anticorrosive slurry (Mix proportion : 500 ml. Anticorrosive polymer solution with 1 kg. cement).

Pull out test was carried out as per IS 2770 – 1967 – Part I (Methods of Testing Bond in Reinforced Concrete) considering the modifications outlined in IS 1786 – 1985(3). The test results were compared with IS 13620 – 1993(5). Three each in rusted rebars, rust free rebars

and coated rebars were tested. The diameter of the rebar varied is 16mm and 20mm. Totally 18 pull-out tests were conducted. Universal Testing Machine of 1000 kN capacity (Model : UTES 100) with computer interface was used to carryout the test. Concrete cubes of size 150mm were cast with centrally embedded rebar provided upto 20mm from the bottom face of the cube.The rebar extended over the top face of the cube upto sufficient length to facilitate gripping on the bottom platen of the machine. To resist bursting stress during testing, the concrete cube were provided with 6mm diameter helical reinforcement with 130mm diameter and 25mm pitch.

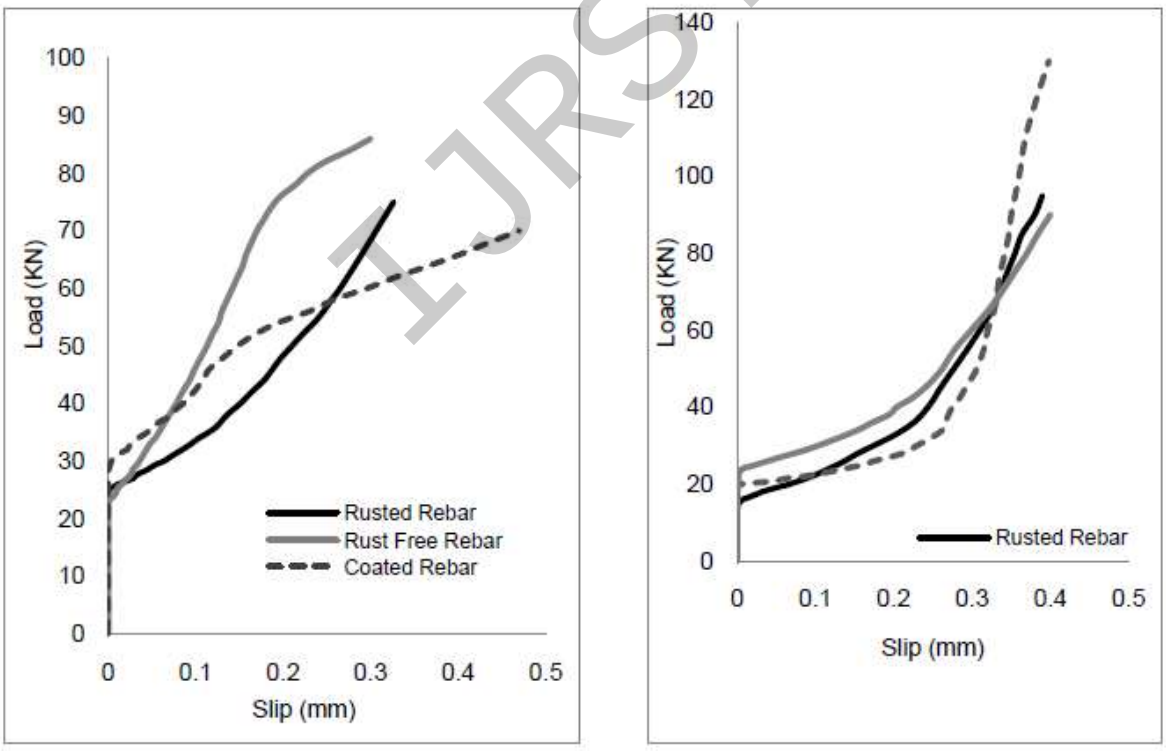
Figure 1 shows the arrangement of rebar inside the mould. The test was carried out as per IS 2770 -1967(4). Figure 2 shows the Pull-out test in progress. The load – slip behaviour was observed using sophisticated dial gauges at free end and loaded end. The load at the Free end slip of 0.025mm, 0.25mm and loaded end slip of 0.25mm were found out. The ultimate pull-out load was also observed.

RESULTS AND DISCUSSION

According to Indian standards the rebars used in the Reinforced cement concrete should be free from rust. The Bond strength results of rust free rebars are compared with rusted rebar, coated rebar and analysed. The lowest bond strength value at the measured free end slip of 0.025mm and loaded end slip of 0.25mm was considered as the usable bond strength. Figure 3(a) and (b) shows the Load versus slip behaviour of rust free, rusted and coated rebars at the free end. It can be seen that at the 0.025mm slip level, the load values observed for coated bar is appreciably higher than the rusted and rust free rebar. It is due to the fact that at the initial stage of pull-out, the resistance offered is due to chemical adhesion between cement concrete and steel. Since the coating material contains cement, the simulataneous hydration of cement in the coating material and concrete improves the adhesion appreciably as compared to rust free and rusted rebar. It can also be seen that the bond strength at 0.025mm slip for rusted and rust free rebar is not following a standard pattern irrespective of the diameter of rebar. It is due to the fact that presence of rust at the interface may influence in increment or reduction in in bond strength at the initial stages depending upon the nature and intensity of rust.

Fig.1 Arrangement of Rebar inside

Fig. 2 Pull-Out Test in Progress

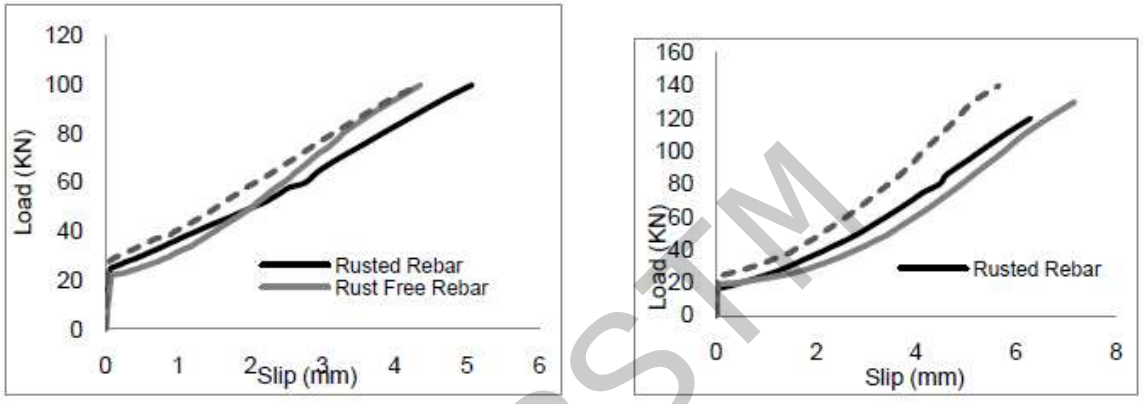


(a) For 16mm diameter bars

(b) For 20mm diameter bars

Fig. 3 Load versus Slip Behaviour of Rebars at the Free End

Figure 4(a) and (b) shows the Load versus slip behaviour of rust free, rusted and coated rebars at the loaded end. It can be seen that the behaviour at the 0.25mm slip level is almost similar to that of free end behaviour for both 16mm and 20mm rebar. The important observation from the obtained behaviour is that the load values at 0.25mm LE slip is almost similar to the 0.025mm FE slip values. The Indian standards gives more important to the 0.025mm FE slip and 0.25mm LE slip. Therefore the lowest bond strength obtained from both the above condition is the usable bond strength. The ultimate pull out strength is the other important parameter emphasised by the IS 2770 – 1967. Hence bond strength was also anayled based on this values.



(a) For 16mm Diamter Bars (b) For 20mm Diameter Bars

Fig. 4 Load versus Slip Behaviour of Rebars at the Loaded End

Table 1 shows the observation on Pull-out test for Rust free, Rusted and Coated rebars. It can be observed that load values at 0.025 FE slip, 0.25mm LE slip were appreciably higher for coated rebars as compared to Rust free and Rusted rebars irrespective of diameter of rebar. Whereas ultimate strength obtained for coated bars is marginally less as compared to rusted and rust free rebars. This may be due to the fact that the later stage bond resistance contributed from bearing action of rib and frictional resistance is marginally affected for coated rebars due to the existence of barrier layer for 200 micon thickness at the interface. Table 2 shows the usable bond srength values for Rust free, Rusted and Coated rebars for both 16mm and 20mm diameter rebars. It can be observed that there is an appreciable bond strength improvement for Rusted and Coated rebars of the order of 16% and 35% respectively as compared to Rust free rebars in case of 16mm diameter bars. For 20mm diameter bars, appreciable reduction in bond strength of the order of 12% for Rusted rebars as compared to Rust free rebar, whereas coated rebar improves the bond strength upto 29%. The

improved performance of coated rebar is due to excellent compatibility at the steel-concrete interface. It can be concluded that application of Cement polymer anticorrosive coating improves the bond strength development of rebar with concrete appreciably.

Table 1.Observation on Pull-out test for Rust free, Rusted and Coated rebars

Sl. No.	Type of Rebar	Load at (kN)			Ultimate Load (kN)
		0.025mm FE slip	0.25mm FE slip	0.25mm LE slip	
1.	16mm – Rust free rebar	27.50	67.00	23.00	120.80
2.	16mm – Rusted rebar	26.75	57.50	27.25	115.20
3.	16mm – Coated rebar*	32.50	57.50	31.00	105.20
4.	20mm – Rust free rebar	20.25	32.50	19.75	157.98
5.	20mm – Rusted rebar	17.25	42.00	18.00	169.15
6.	20mm – Coated rebar*	25.50	48.00	26.00	159.15

* - Cement Polymer Anticorrosive Coated bars.

Table 2. Bond Strength of Rust free, Rusted and Coated Rebars

Sl. No.	Type of Rebar	Load at (kN)		Usable Bond Strength (N/mm^2)	Variation (%)
		0.025mm FE slip	0.25mm LE slip		
1.	16mm – Rust free rebar	27.50	23.00	5.72	-
2.	16mm – Rusted rebar	26.75	27.25	6.65	**+16.25**
3.	16mm – Coated rebar	32.50	31.00	7.71	**+34.80**
4.	20mm – Rust free rebar	20.25	19.75	3.14	-
5.	20mm – Rusted rebar	17.25	18.00	2.75	**- 12.42**
6.	20mm – Coated rebar	25.50	26.00	4.06	**+ 29.30**

Table 3 shows the ultimate bond strength values for Rust free, Rusted and Coated rebars. It can be observed that the ultimate bond strength values for Rust free rebar is 4.5%, 13% more than the Rusted and Coated rebars respectively for 16mm diameter rebar. Incase of 20mm rebar there is a reduction in ultimated bond strength value for Rust free rebar of the order 7% as compared to Rusted rebar where as coated rebar exhibits similar behaviour. It

can be concluded that presence of Cement polymer anticorrosive coating at the steel-concrete interface did not influence any modifications in the Ultimate bond strength values. Accoriding to IS 13620 – 1993, the reduction in bond strength due to the presence of coating is permitted as 20%. Whereas Cement polymer anticorrosive coating improves the bond strength appreciably of the order of 30% as compared to Rust free rebar.

Table 3. Ultimate Bond Strength of Rust free, Rusted and Coated rebars

Sl. No.	Type of Rebar	Ultimate Load (kN)	Ultimate Bond Strength (N/mm^2)	Variation (%)
1.	16mm – Rust free rebar	120.80	30.04	-
2.	16mm – Rusted rebar	115.20	28.65	**-4.63**
3.	16mm – Coated rebar	105.20	26.16	**-12.92**
4.	20mm – Rust free rebar	157.98	25.14	-
5.	20mm – Rusted rebar	169.15	26.92	**+7.08**
6.	20mm – Coated rebar	159.15	25.33	**+0.76**

CONCLUSIONS

Based on the tests conducted on 16mm, 20mm TMT rebar with Rusted, Acid pickled (Rust free) and Coated rebars, the following conclusions were drawn:

1. There is an appreciable influence on development of bond strength of steel with concrete due to the presence of rust and coating at the interface.
2. Coated rebars improve the usable bond strength to 30-35% as compared to Rust free rebars due to excellent compatibility at the steel-concrete interface.
3. Presence of rust at the interface influences in reduction/increase in usuable bond strength depending on the nature and severiety of corrosion.
4. There is no major variation in ultimate bond strength for tested rebars, irrespective of the type when tested at the age of 28 days.
5. Cement polymer anticorrosive coated bars satisfy the codal requirements of IS 13620 – 1993 with respect to bond strength.

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