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POWDER EPOXY COATING OF STEEL REBARS - STATE OF ART REPORT

G. T. PARTHIBAN, N. S. RENGASWAMY and K. BALAKRISHNAN

Central Electrochemical Research Institute, Karaikudi - 6

The various standards and specifications evolved for powder epoxy coating material, performance data, likely suppliers, etc., are discussed in detail. The coat benefit ratio based on durability factor and unit cost of material is also worked out. Considering the Indian scene, the various limitations coming in the way of large scale adoption are pointed out.

Key words : Powder epoxy, Reinforcing steel, Electrostatic coating system

COATING PROCESS

Powder epoxy coatings for steel rebars were developed in the early 70's in USA and since then have been widely used in forty states in that country [1]. The process of applying epoxy coatings onto the surface of reinforcement steel bars involves several steps [2]. Initially, the surface of the steel to be coated has to be cleaned. Reinforcing bars are cleaned by passing them through an abrasive blast cleaning machine. Inside the cleaning chamber of the machine, the bars are blasted with a combination of steel shot and grit. As the bars pass through the blast, they are mechanically rotated to assure that the entire surface area of the bar is subjected to the blast. The mill scale and rust have to be removed and a near white steel surface has to be obtained. The abrasive blast cleaning is advantageous in that it produces a moderately rough surface thereby enhancing the adhesion of the epoxy coating to the bar surface. The cleaned bars have to be coated before re-oxidation of the surface occurs.

The bars have to be heated to a temperature in the range 200-275°C after cleaning, in a non-contaminating and even heat source, before the epoxy powder is applied. This can be done in a gas-fired furnace or an electrically heated furnace. More commonly, induction heating has been employed. The bars can be allowed to pass into the coating chamber as soon as they are heated by the induction coils. This can be accomplished by controlling the rate at which the bars pass through the induction coils and coating chamber. It is important to maintain a constant even heat to assure the proper coating of the epoxy. This can be done by using heat sensors in suitable positions to monitor the bar temperature, before the bar enters the coating chamber.

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The coating chamber may be equipped with a suitable coating unit, such as an electrostatic powder spray coating system. The clean, heated bar has to be grounded and passed through the coating chamber. The guns from the spray unit dispense the charged fusion bonded epoxy resin through air pressure. The resin particles being charged, would be attracted to the grounded bar. When the resin contacts the hot bar, it melts instantly, flows around the bar surface, gels and solidifies within seconds. The coating thickness can be controlled. It has to be optimized to offer sufficient corrosion protection and still maintain the bonding with concrete.

After the bars are coated, they have to be water quenched. As the coating would have semi-set by now, it has to be cured by slowly passing over wet, sponge rollers, for a few more seconds. This would ensure complete curing of the coating, after which water can be directly sprayed on the coated bars to cool them down for handling.

Quality control for the coated bars is an essential step before they are embedded in concrete. Thickness, continuity and adhesion are some of the important factors to be checked. Thickness is measured with a magnetic pull-off gauge and it has to be ensured that the coating thickness does not vary more than $\pm$ 2% of the average thickness on any bar.

Bars can be visually inspected for continuity and patching can be done where necessary. Holiday detectors can also be used to locate flaws not visible to the naked eye. Such flaws can be also manually patched. The adhesion of the coating can be evaluated by bending the samples of coated bar by 120°. around a suitable bending mandrel. Any cracking or disbonding of the coating observed, is considered a cause for rejection.

SPECIFICATIONS

Steel reinforcement bars have been coated with epoxy powders and embedded in structures after being subjected to various tests. Based on the test results different specifications, such as American [3], British, and Japanese [4] have been evolved. Some of the specifications are listed in appendix I.

From the table it is seen that the standards for American and Japanese specifications are varying in different conditions. The coating thickness is of the same range in both the specifications upto a thickness of 200 microns. The Japanese conditions, as observed, accomodates an additional 50 microns The impact strength required is relatively greater for the American conditions While the American conditions do not tolerate cracking or disbonding on bending the rebar through 120°, the Japanese conditions can accept upto 20% peeling/cracking on bending the rebar through 180°. In both the systems the bond strength to concrete has to be greater than 80%. Regarding corrosion resistance, the American system considers the duration of the test as a criteria for acceptance while the Japanese system considers the percentage of area affected on exposure for acceptance. Both the systems accept coated rebars with a maximum of 2 holidays/foot.

APPENDIX I

SPECIFICATIONS

I	AMERICAN:	
	Thickness of film	150–200 Microns
	Mechanical Properties	
	Impact ASTM A775–81 A1.2.7	Pass 80 in. lb., No cracking Direct and reverse,
	Erichsen Indentation	8.0 mm [minimum]
	Erichsen pencil hardness	Pass 2H
	DIN 53–157 Sward rocker hardness	160 SEC
	Taber abrasion resistance ASTM A775-81 A1.2.6	Weight loss less than 25mg/1000 cycles
	Adhesion bend test ASTM A775-81 A1.2.4.1	No cracking or disbonding, 120°, 3 inch mandrel
	Bond strength to concrete ASTM A775-81	Greater than 80% compared with uncoated bar
	Corrosion Resistance	
	Hot salt spray	2000 hr – passed
	Humidity	2000 hr – passed
	Film continuity 75 $\pm$ 5 V DC detector	less than 2 holidays/ft
II	BRITISH:	
	Same as ASTM A775-81	
III	JAPANESE:	
	Thickness of film	200 $\pm$ 50 microns
	Impact strength	30 Kg. Cm.
	Bend test	180°, inner bending radius is 2 to 2.5 times the diameter of steel bar–cracking peeling caused must be less than 20%
	Bond strength	Greater than 80% compared with uncoated bar
	Corrosion resistance	Average corroded area less than 1%

PERFORMANCE

The performance of powder epoxy coated rebars have also been evaluated [5-8]. Some of the results are listed in appendix II. From the table, it can be seen that powder epoxy coatings of thickness 150 microns or greater offer excellent protection against corrosion as compared to the protection offered by liquid epoxy coatings. The bond strength with concrete of powder epoxy coated steel bars is also superior as compared with that of liquid epoxy coated rebars.

It can be seen from the table that as the thickness of the coating is increased to about 250μ the bond-strength decreases. In general, the powder epoxy coated rebars have been observed to perform better than other epoxy coated rebars.

APPENDIX II

PERFORMANCE OF POWDER EPOXY COATED REINFORCEMENT STEEL

Material	Test	Result
Powder epoxy coated, 80μ	Accelerated corrosion	Reddish brown rust in specific regions
150μ		No rust
250μ		No rust
Liquid epoxy coated, 150μ	Accelerated corrosion	Corrosion observed extensively
250μ		-do-
Plain steel	Bond strength	250 Kg/m^2
Powder epoxy coated, 80μ		224 Kg/m^2 [Good]
150μ		208 Kg/m^2 [Good]
250μ		150 Kg/m^2 [Poor]
Liquid epoxy coated, 150μ	-do-	112 Kg/m^2 [Poor]
250μ		110 Kg/m^2 [Poor]
Powder epoxy coated	Potential measured Field after 720 days exposure Sea-water	-0.20V
		-0.26 V
Powder epoxy coated	Corrosion of reinforcing steel in pre-crack concrete after 720 days	0.05-0.08 mm No corrosion
		[crack width] 0.15-0.20mm No corrosion

AVAILABILITY OF POWDER EPOXIES

Appendix III gives a list of powder epoxies employed for coating reinforcing steels and their manufacturers [9]. It can be seen that all the firms are from USA. Presently there is not a single manufacturer for these epoxy powders in India. Therefore the application of powder epoxy coating to reinforcing steels would require importing the powder epoxy material. Indigeneous production of powder epoxies for coating steel rebars has to be extensively studied and attempted.

APPENDIX III

SUPPLIERS

Epoxy powder	Suppliers*
Scotchkote 202,	Minnesota mining and manufacturing.
213 and 214	company, Inc.
Flint flex 531-6080	El du pont de nemours company Inc.
Epoxy powder 720-A-009	Cook paint and varnish company.
Corvel ECA-1440-J-green-2779	Polymer corporation.
Epoxy plate 346 to 349	Armstrong products company.
Mobiloxy 1004-R-2	Mobil chemical company.
Nap-Guard 7-2000	Napco corporation.
Oxyplast El-704-P-9	Fuller-o'brien corporation.
Hy-Sol DK 23-0602	Dexter corporation.

* All from USA

COST/BENEFIT RATIO

The cost of coating for employing powder epoxy coatings to steel rebars has been worked out (appendix IV). Two factors have been considered, one based on the material and the other from experience [7, 10]. Both calculations yield the cost of coating/m^2 in the same order.

So far, powder epoxy coated rebars have not been tested for their durability according to the Indian conditions. To evaluate the cost/benefit ratio for our application, the durability factor for powder epoxy coatings have to be evaluated, since cost/benefit ratio is given by, durability factor divided by cost of coating per m^2 of the rebar.

APPENDIX IV

COST OF COATING/M^2

I	Cost of powder required for coating 1 M^2 of steel surface	=	Rs. 112.50
	Contribution from equipment cost/M^2	=	Rs. 7.50
	Cost of power consumed/M^2 (Furnace + Spray Unit)	=	Rs. 30.00
	Depreciation cost/M^2	=	Rs. 1.00
	Cost due to wastage/M^2	=	Rs. 28.75
	So, cost of coating/M^2 (1+2+3+4+5)	=	Rs. 179.75
		Say,	Rs. 180.00

II It has been reported that the cost of coating Epoxy powder increases the overall cost of reinforcing steel, by about 65%, based on US experience.

Cost of reinforcing steel/Ton	=	Rs. 8000.00
Cost of Epoxy powder coating/Ton (65% of the cost of steel)	=	Rs. 5200.00
Surface area of steel/Ton	=	$20M^2$ (approx)
Therefore, cost of coating/M^2	=	5200/20
	Rs.	260.00

LIMITATIONS

Even though powder epoxy coatings have been observed to offer considerably good corrosion protection to steel rebars, there are several limitations associated with their application. First, as there is not a single manufacturer in India for powder epoxies that can be coated for steel rebars, the powder epoxy material has to be imported, presently. As the coating is a factory process and involves high temperature, the process control becomes vital, and extra costs arise due to transportation to factory and to site, power, equipment, etc. Handling the coated rebars also becomes crucial and has to be monitored. After coating the rebars, their performance in tropical (Indian) environments has to be studied and we have to establish standards for our application. Finally, the cost/benefit ratio has to be worked out for our Indian conditions before it is accepted for large scale utilisation.

CONCLUSIONS

In USA, UK and Japan, powder epoxy coatings for reinforcing steels have been successfully employed and have been found to offer excellent corrosion protection as compared to others. The suitability of powder epoxy coatings to our Indian conditions has to be thoroughly studied and evaluated before being employed in structures. Also, indigenous production of such promising powder epoxy materials, for coating reinforcing steels, has to be attempted.

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