CHROMISING OF MILD STEEL (REBARS)

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It has been observed that electrodeposited chromium often lacks the required resistance at higher temperature applications, because of lower thickness of the coating and also of its higher porosity. Coatings formed by diffusion, have been found to result in better adhesion of the coating to the substrate and substantial reduction in porosity. However, long duration chromising processes sometimes result in the formation of heat cracks and thermally activated defects. Short duration chromising techniques, could be an answer to this problem.

In this paper, short duration chromising of mild steel has been carried out and the coated panels are studied. The influence of addition of particulate materials, has also been studied.

EXPERIMENTAL

Paint or Slurry Chromising using Ethyl Silicate as Binder

This technique has been first patented by Wallace Johnson [1]. The steel article is coated by a brush or by dipping it in a slurry made of chromium powder in a solvent like ethyl silicate. The coated steel is then heated to a temperature of 800-900°C for a period of 30-45 minutes in muffle furnace under controlled atmosphere.

M.S.rod specimens of 1.8 cm dia and 5 cm long have been cleaned, surface pretreated and used for chromising. 10 gms of electrolyte chromium powder (-250 mesh) is ground with 50 ml ethyl silicate in a mortar for 1/2 hour and applied on pre-treated mild steel rod with a brush. The sample is dried in hot air oven at 40° for 10 min. This is then transfered from the oven to a vertical muffle furnace, maintained at 800-900°C left at this temperature for 30 - 40 min and cooled. This process is repeated thrice to improve the coating.

RESULTS

Slurry-chromising of steel results in better diffusion of chromium into the steel surface with considerable increase in microhardness (Table 1). Multiple metalliding further enhances the diffusion of chromium, resulting in an increase in coating thickness from 20μm to 130 μm. It has been seen from the table that the potential of the mild steel in 3% NaCl becomes more noble with the extent of metalliding. Treble metallided mild steel shows less negative potentials than the single or double metallided mild steel. This table clearly shows the beneficial influence of chromising. Treble metalliding most probably seals all the pores in the coating and also increases the diffusion layer thickness, thereby improving the corrosion resistance of rebars.

The diffused chromium specimen was dipped in 0.04 M NaOH containing chloride ion and polarised anodically at 300μA/cm^2 ; the potential is nearly constant with time for 10 mts. The results are given in the Table.

The coating formulations corresponding to the composition of Cr powder and TiO_2 in the ratio 1:1, and Cr powder and Al_2O_3 in the ratio 1:1 are also used separately to ascertain the effect of these filler materials on the coating performance. It has been observed that addition of Al_2O_3 enhances the hardness and corrosion resistance after annealing.

Paste Chromising with Reactive Flouride Pastes

A reactive paste prepared by mixing chrome ore and aluminium oxide in the ratio 1:1 with 3% by weight of NH_4HF and water is applied onto the surface of the mild steel. The coated specimen is dried at 30°C in an oven for 5 minutes, followed by charging in the furnace at a temperature of 1000°C for 45-60 minutes. Stainless steel trays are used as the containers for the metalliding reaction. The process can be made continuous. Stainless tube filled with the paste may be used as the container. The polished and degreased steel specimen may then be inserted through the centre of the pasty mass in the tube. The tube may then be kept in a tube furnace for a known time, after which, the specimen is removed from the tube and cooled.

It is seen from Table 2 that reactive paste chromising results in the diffusion of chromium into metal substrate. Multiple metalliding results in the increase of chromium content, thereby loading to more thickness of

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TABLE 1

PROPERTIES OF MILD STEEL AND METALLIDED REBARS
(Microstructure of metallided rebars show precipition of carbides and intermetallics, but no grain formation)

Sample	% Cr (micron depth)	Micro hardness distribution case to core (Kg/mm^2)	Thickness (microns)	Potential in mV vs SCE specimens dipped in 3% NaCl for different periods (days)						Potential in alkali medium #
				0	10	15	20	25	30	
Uncoated mildsteel	-	-	-	-550	-600	-610	-610	-610	-650	-
Single metallided	0.62	333-303 365-340	20	-300	-350	-400	-410	-410	-420	-30
Double metallided	0.94	-	75	-300	-350	-400	-410	-410	-410	-15
Terble metallided	1.30	335-346 366-340	130	-250	-300	-350	-350	-370	-380	+140 to +143

Specimens dipped in 0.04 N NaOH + 1000 ppm Cl^- and anodically polarized at 300 $\mu A/cm^2$. Potential is nearly constant with time (10 mts).

TABLE 2

PROPERTIES OF METALLISED MILD STEEL REBARS OBTAINED BY PASTE CHROMISING METHOD USING REACTIVE FLUORIDE PASTES
(Micro structure of metallised surface revealed smaller grain formations with no intermetallic constituents)

Sample	% Cr in the top 100 μm layer	Thick-ness of coatings (microns)	Hardness of Coat-ing BHN Kg/mm^2	O.C.P in mV vs SCE in 3% NaCl	Corro-sion rate # $g/cm^2 \times 10^{-5}$	Potential (mV) vs SCE in 3% NaCl after					
						0 d	10 d	15 d	20 d	25 d	30 d
Mild Steel	-	-	-	-400	6.9	-550	-600	-610	-	-	-680
Single metallised	0.83	25	300	-200	1.16	-300	-350	-400	-420	-420	-420
Double metallised	1.02	40	325	-50	0.69	-250	-300	-350	-380	-400	-400
Treble metallised	1.4	40	350	-50	0.59	-200	-250	-300	-330	-350	-380

Corrosion rate in concrete saturated with brine

the coating. Paste chromising results in diffusion of chromium with the formation of very little intermetallic constituents. Multiple metalliding results in the increase of hardness and thickness of the metallided coating. It is clear that multiple paste chromising leads to superior coatings, with better corrosion resistance properties.

The surface exhibits less negative potential, with treble metallizing compared with single and double metalliding. It is seen from Table 3 that increase in the concentration of chloride ion makes the potential of the coated specimen less positive[3]. For a concentration of 16000 ppm chloride ion, the potential change in 10 minutes is of the order of 20 mV only.

Chromising by Plating Followed with Annealing

Electrodeposition of chromium followed by heat treatment at high temperatures in the hydrogen atmosphere in vacuum, forms a diffusion layer

TABLE 3

POTENTIAL OF TREBLE METALLIDED STEEL SPECIMENS IN 0.04 N NaOH CONTAINING DIFFERENT CONCENTRATION OF CHLORIDES AND ANODICALLY POLARISED BY IMPRESSING A CURRENT OF 300 $\mu A/cm^2$.

(Potentials are nearly constant in a given medium for 10 mts. In high chloride media, there is a tendency for a potential drift to less positive values at the end of this period.)

$[Cl^-]$ ppm	1000	5000	7000	16,000
Potential mV Vs SCE	+ 925	+ 750	+ 675 to + 650	+ 650 to + 630

of chromium and thus enhances the corrosion resistance. Electrodeposited coatings normally reveal residual stress. After diffusion anealing treatment, the tensile stresses are transformed into compressive stresses, which are less harmful from the point of view of corrosion. Hydrogen embrittlement, resulting from plating process, is effectively reduced by the thermally activated annealing process. A flash coating of chromium of 0.45μm and 0.9μm chromium is given on the polished and degreased rebar surface from a conventional chromic acid bath, at a current density of 144 amp/sq.ft using H_2SO_4 as the catalytic agent. It has been observed that plated and diffused annealed specimen reveals more positive potential in 3% NaCl. A coating of chromium and nickel is also used for obtaining diffusion coatings on mild steel.

From the above account it is found that paste chromising appears to be the best technique from the point of view of corrosion resistance. However, from the economic point of view, multiple chromising using ethyl silicate and chromium powder, may be recommended for suitable commercialisation.

ACKNOWLEDGEMENT

Authors are thankful to Prof. K.I. Vasu, Director, CECRI, for his kind permission to publish this paper.

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