राष्ट्रीय
धातुकर्म
प्रयोगशाला
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जमशेदपुर – 831 007, भारत

ISO-9001:2000

National
Metallurgical
Laboratory
(Council of Scientific & Industrial Research)
JAMSHEDPUR - 831 007, INDIA

डा० देवेन्द्र देव नारायण सिंह
DR. D. D. N. SINGH
वरिष्ठ वैज्ञानिक
SR.SCIENTIST

No.NML/ACC/DDNS/SRMB-06
Date: 30.05.2006

To,
M/S S.R.M.B. Udyog Ltd, Kolkata

Dear Sir,

In reference to your letter of 10th March 2006, we have conducted the corrosion resistance tests of different types of rebars sent to us. The results are summarized as follows:

Types of tests	Type of rebars			
	Zinga	HDG	FBEC	CRS
(a) Corrosion rate, µmpy, (electrochemical polarization resistance technique), ASTM G - 59 (91)	19.6	38.6	34.5	99.6
(b) Pitting resistance tendency, ASTM G - 61(86)				
E_{pit}, mV (SCE)	- 315	- 750	- 450	- 400
Loop area	x	3.5x	2.5x	5x

Test electrolyte: Simulated concrete pore solution + 3.5 % NaCl

Findings: Amongst the tested bars, Zinga coated rebars exhibit superior corrosion resistance than the others.

Thanking you,

Yours truly,

(D. D. N. Singh)

Phone : 0657 - 2423544(R), 2271557(O); e-mail : ddns@nmlindia.org
Working Days : Monday to Friday (9.15 am – 5.45 pm)

BY COURIER

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डा० देवेन्द्र देव नारायण सिंह
Dr. D. D. N. Singh
वरिष्ठ वैज्ञानिक
Sr. Scientist

Date : 28.06.2006

No.NML/ACC/DDNS/SSP0289

To,

SRMB Udyog Ltd,46, B.B. Ganguly Street,Kolkata-700012

Subj: Performance report of Zinga coated bars vis-à-vis other bars

Please refer to your letter of March 10,2006 requesting us to study the corrosioin behaviour of Zinga coated bars vis-à-vis other types of bars. The data have been generated in the lab and the results / findings are given in the attached report.

Thanking you,

Yours faithfully

(DDN Singh)

Phone : 0657 - 2423544(R), 227155/101; e-mail : ddnsingh@nmlindia.org
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Interim Report on "Comparative corrosion resistance of Zinga coated vis-à-vis other rebars"

Project # SSP 0289

A Project Sponsored by

M/S S.R.M.B. Udyog Ltd,KOLKATA

National Metallurgical Laboratory
Council of Scientific & Industrial Research
Jamshedpur - 831007

Interim report on performance of ZINGA coated, MS , CRS , hot dip galvanized coated and Epoxy coated bars exposed in chloride contaminated simulated concrete pore solution

Summary :

The above study was taken up in the corrosion research laboratory of National Metallurgical Lab. Jamshedpur. In this programme , studies have been made for the corrosion resistance performance of ZINGA coated steel rebars, bare steel MS bar, uncoated CRS bar,Hot dip galvanized coated bars and Epoxy coated bars exposed in chloride contaminated simulated concrete pore solution. The kinetics of corrosion have been studied by using electrochemical impedance spectroscopy and DC corrosion techniques.The results indicate that ZINGA coated bars outperform the other types of bars. Possible explanations for the superior performance of ZINGA coated bars vis-à-vis others have been discussed.

Experimental Details :

All samples of bars were supplied by M/S SRMB Udyog , Kolkata. The chemistry of different types of bars are shown in Table I. The table shows that except CRS bar which was micro alloyed steel ,the others were having the composition of mild steel. Zinga coated bars had coating in the range of 50-60microns. HDG had 80-85 microns of coating. The coating thickness on FBEC bars ranged between 150-180 microns. CRS and MS bars were used after removing their scale and polishing the surface on polishing wheel. The diameter of bars was 16 mm. 10 cm of their length was taken to perform the studies. Electrochemical Impedance Spectroscopy (EIS) experiments were performed to have non-destructive assessment of coated as well as uncoted bars exposed in simulated concrete pore solution having chloride ion added as sodium chloride. Polarization Resistance experiments were performed to asses the change in corrosion rate of rebars with passage of time. The composition of simulated pore solution is given as follows:

0.06M potassium hydroxide (KOH),

0.2M sodium hydroxide (NaOH) and

0.001M calcium hydroxide [$Ca(OH)_2$].

Analytical grade chemicals and distilled water were used to prepare the solution..

Table I : Chemical composition of structural steels used in the present study

Steels	C	Mn	Si	S	P	Ni	Cu	Cr
CRS	0.11	0.33	0.44	0.013	0.01	0.05	0.44	0.48
MS barl	0.13	0.68	0.41	0.012	trace	00	00	0.05
HDG barl	0.12	1.21	0.23	0.09	trace	0	0	0.02
Zinga bar	0.13	0.68	0.51	0.012	trace	00	00	0.05
FBEC bar	0.23	0.78	0.47	0.012	trace	00	00	0.05

CRS: Corosion resistance steel,MS :Mild steel, HDG : Hot Dip galvanized ,FBEC :Fusion bonded epoxy coated

All the tests were performed as per the ASTM standard.

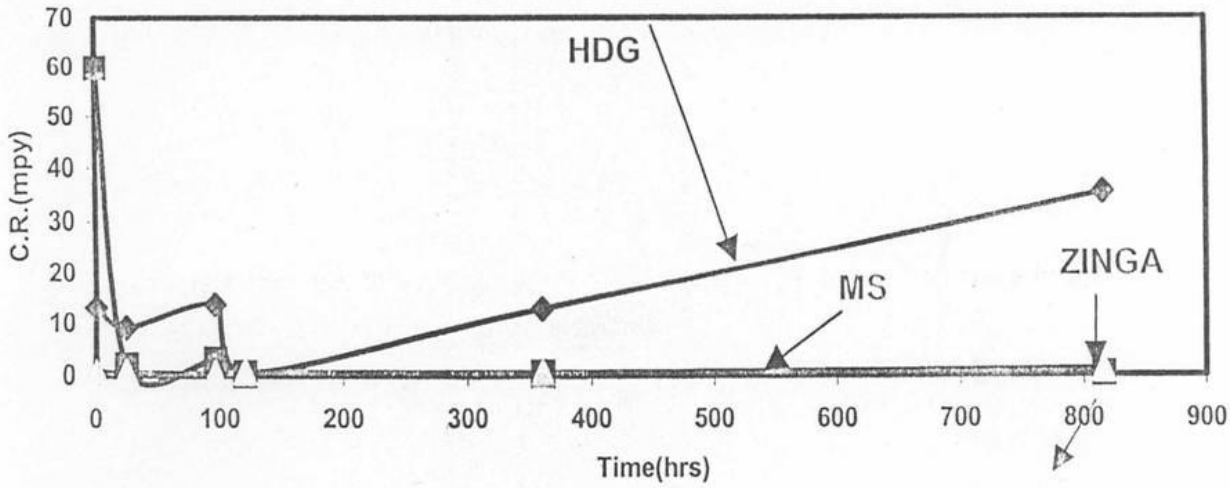
Experimental results:

Before the report is discussed in detail , it is pertinent to mention here that both zinga coated and hot dip galvanized bars protect the substrate steel by providing sacrificial protection. The FBEC, on the other hand provides the protection as barrier coating. The MS and CRS develop rust and suffer due to general and localized corrosion. It is therefore important that the properties of the bars should be described by taking in to account the above parameters. The results will be described under the following headings:

Uniform Corrosion.

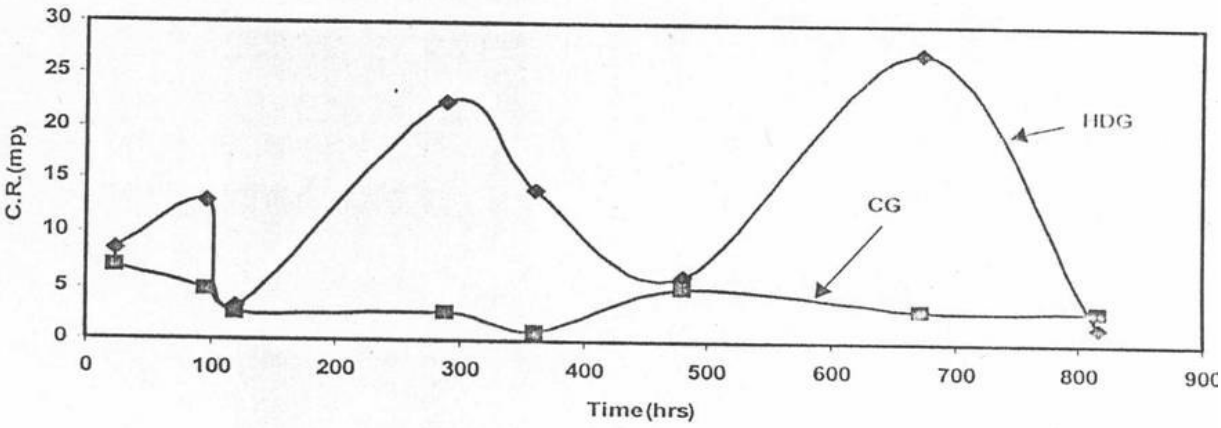
The uniform corrosion rate data generated for the zinga coated bar vis a vis hot dip galvanized and MS bars are shown in figures 1 and 2. These figures do not

incorporate the data for FBEC rebars as they suffer the corrosion losses in the form of pitting corrosion. Their properties vis a vis HDG and Zinga coated bars will be described while discussing the pitting aspects.



Corrosion rate of HDG, Zinga and MS exposed in SPS +1% Cl at RT.

HDG = Hot dip galvanized and GC = Zinga coated bars



C.R.of HDG and CG exposed in SPS +3.5% Cl at RT.

Table : Comparative study of pitting tendency of different types of rebars exposed in SPS + 1% Chloride ions at 30 ^{0}C

Type of rebars	Pitting parameters		
	Pitting potential (mv,SCE)	Comparative cyclic loop area	Remarks
ZINGA	-315	x	Higher E_{pit}, lesser L_a
HDG	-750	3.5x	Lowest E_{pit} Higher L_a
FBEC	-450	2.5x	Lower E_{pit} Higher L_a
CRS	-400	5x	Lower E_{pit}, Higher L_a
MS	-315	5x	LowerE_{pit} HigherL_a

E_{pit} = Pitting potential, L_a = area of cyclic loop, x = stands for area of cyclic loop recorded during the cyclic polarization of zinga coated bars in SPS + 1% chloride ions.

Findings : The results of the above table indicate that amongst all the types of bars studied for the pitting resistance, Zinga performs the best followed by MS<FBEC<CRS <HDG.

Why Zinga coated bars performed superior than the other types of studied bars ?

To understand the causes for showing superior performance of ZINGA coated bars than the others, exposed in chloride contaminated concrete environment, following studies were performed:

a. Raman spectroscopy of corrosion products,
b. Scanning electron microscopy ,
c. Electrochemical impedance spectroscopy and
d. Energy dispersive X-ray analysis.

Incorporation of detail results in this report are out of scope of this work. However, these results will be published shortly in the form of research papers. The findings may be summarized as follows:

- During the initial stages of exposure of ZINGA bars in corroding environments, its zinc component preferentially reacts and forms corrosion products such as simonkolleite (Zinc hydroxyl chloride ,ZHC). This product is also identified in the corrosion products of HDG . The SEM and EDXA shows that the binder material which is insoluble in test electrolyte and gets embedded with corrosion products (XZHC) forms a compact and impervious surface film. This is absent in case of the other rebars.

CONCLUSIONS

- ZINGA coated bars show 3 times higher corrosion resistance than HDG, twice to MS , CRS and FBEC bars.

- Pitting resistance of ZINGA coated bars are on an average two times higher than the other tested bars.
- This difference is expected to be higher with increase in testing time for bars embedded in concrete mortars.
- ZINGA provides superior performance due to embedding of its binder in the corrosion product of zinc which is primarily simonkolleite (Zinc hydroxyl chloride, ZHC). This embedding blocks the pores of simonkolleite and prevents diffusion of ions through the corrosion product.