

**CORROSION RESPONSE OF LOW CARBON STEEL IN TROPICAL ROAD MUD****A.N.Enetanya**Department of Mechanical Engineering, University of  
Nigeria, Nsukka, Nigeria**ABSTRACT**

*Corrosion damages in Steel and Cast- Iron frequently occur in automobile and other vehicle undercarriage parts as a result of regular road mud and other dirt deposits on those components on those vehicles operating on the poorly maintained roads in the developing countries. These ultimately result in Deposit and Pitting Corrosion damages which perforate the metal structure if left unattended. Cathodic Protection and the use of Corrosion Inhibitors are not practical in this problem. Other steel structures, as buildings, petroleum, gas, water and sewage pipelines exposed to soil and mud are frequently attacked and extensively damaged by corrosion; however these can be protected using Corrosion Inhibitors or Cathodic Protection. This report presents a summary of experimental investigations on Corrosion Mitigation efforts using readily available anti- corrosion coatings to protect low carbon steel test coupons against the corrosive effects of tropical road mud and dirt deposits. The following protective coating devices were effective: aluminization by hot-dipping, zinc galvanization by hot- dipping, hand brush-painting using special enamel paints, and special coatings with thermosetting phenol-formaldehyde and fibre re-inforced resins. The results show that provided the coatings are carefully applied without cracks or openings, they provide excellent protection against corrosion due to road mud and dirt deposits.*

**Keywords:** *Corrosion Mitigation; Anti - Corrosion Coatings Deposit; Pitting Corrosion Perforation; Corrosion inhibitors; Cathodic Protection*

**1,0 INTRODUCTION**

A major corrosion damage on steel occurs in those automobiles and other vehicles operating on the poorly maintained roadways of the African and other developing countries. These damages can be observed on those automobiles and other body parts located beneath the vehicle frequently subjected to intermittent road mud and dirt deposits. Similar corrosion damages occur on other steel structures regularly or intermittently in contact with mud, soil and dirt. Such structures may be part of buildings or they may be petroleum, gas, water supply or sewage pipeline.

The contact with mud, soil and dirt results in deposit and pitting corrosion with subsequent perforation of the steel material. Corrosion is caused by a combined reaction of the media surrounding the corroding metal and the constituents of the metal. With low carbon steel in tropical road mud, beneath the mud and dirt deposits the oxygen supply is very much reduced, resulting in the formation of differential aeration cells [1]\* The metal surface covered by mud and dirt deposits acts as the Anode in each cell and is attacked by corrosion while those areas which receive a better supply of oxygen become the Cathode /1,2/. This is ultimately very damaging to these steel components and is largely responsible for the rapid depreciation in the values of those structures regularly exposed to these environments. Cathodic Protection [3] or the use of corrosion inhibitors 14, 51 can effectively protect stationary steel structures. These are not practical for protection of moving automobile or other vehicle body parts. Detailed information on the combined effects of the environment and the constituents of individual materials on their responses is available in specialised texts for designers [6]

On account of their low price, high strength and relatively high rigidity steel and cast-iron continue to be widely used as structural materials in various environments. With the wet road mud and dirt deposits on steel a possible iron-water environment reaction is



This may result in fluid being trapped over the steel surface and in the absence of adequate vapour or oxygen and since there are no dissimilar metals in the entrapped space, a film of hydrogen forms to hinder further corrosion. On the other hand, continued replacement of water by any means could void the corrosion preventive products. Complex microbial consortia are now known for contributing to destructive corrosion media as a result of the activities of certain sulphate - reducing bacteria commonly found in the soil surrounding some petroleum and gas pipelines [7]. These activities call for improvements in the corrosion mitigation plans for those buried structural components continually in contact with soil and water. Special chemicals are used to solve bacterial corrosion problems [8] of particular interest is the pattern of the chemical structure involved in the mechanism of bacterial adhesion to certain metals and other structural Materials subjected' to bacterial corrosion. This was extensively studied by Gaylarde and Beech [ 9];

Recent developments in the search for corrosion resistant pipeline materials for the petroleum and gas industries include certain composite materials, which are corrosion resistant. Among these are the Glass Reinforced Epoxy (GRE) Composites [3] which are resistant to many forms of corrosion, including Deposit and pitting corrosion. However GRE has a low strength in addition to low rigidity and can only be used for low

strength applications. More recent developments in the petroleum and gas industries have produced the so called steel strip laminated Glass Re-inforced Epoxy (SSL-GRE) pipeline materials with acceptably higher strength and rigidity (tensile strength =31MPa). These new materials appear to be very corrosion resistant but their performance has not yet been fully explored.

Until these new corrosion resistant structural materials are conveniently available for applications steel and cast-iron will continue to be widely used as structural materials. Consequently appropriate easily available corrosion mitigation measures are sought for a range of situations and environments to which these materials may be subjected. All recommended corrosion protection techniques must therefore be conveniently available to and easily applicable by the steel structures fabricator.

Several methods of corrosion mitigation are presently available to protect steel and cast-iron materials exposed to corrosive media [ 6], The corrosion engineer may choose to eliminate, the corrosion-causing agents from the corrosive medium. He can also choose to separate the corroding metal from the corrosive agents, or he can change the characteristics of the corroding metal so as to prevent it from corroding. Cathodic Protection is very effective if the corrosive medium forms an adequate covering over the corroding metal so as to constitute an electrolyte in which the protected metal can be made a Cathode in the subsequent electrochemical cell [3]. A more active metal, lower in the galvanic series than the protected metal is made the Anode and corrodes away. For Cathodic Protection of Steel, Magnesium Anodes are commonly used. Corrosion inhibitors [4,5,10] if the situation permits can react with the corrosive medium to put a protective barrier shielding the metal from the corrosive agents. This is impractical in the present problem.

Coatings and wrappings provide a barrier to prevent or reduce contact between the steel surface and the corrosion medium; frequently these prove to be the most convenient and practical corrosion protection for steel. This is true in the present investigation. Coatings may be metal, organic, inorganic, plastic or paint. The individual responses of some of these coatings are studied in the present investigation, which involves alternate suspension in tropical road mud and intermittent exposure to the atmosphere daily.

## 2.0 INVESTIGATION PROCEDURE

### 2.1 coupon test specimens

Several low carbon steel test coupons were cut, each measuring 100mm long, 25mm wide and 3.00 to 4.00mm thick. These were grouped and labeled A, B, C, D, E, F, G, and H, and were carefully cleaned with sand-paper and finally with fine emery cloth, to remove all dirt and grease. Each group consisted of six coupon

specimens which were prepared for special corrosion coatings as described below.

#### Group A Coupons

These coupons in group A were primed with zinc chromate ( $ZnCrO_4$ ) to create a reliable vapour barrier on each side of the steel surfaces. Each of the six coupons was then aluminized by Hot Dipping to a thickness of 0.10mm on each side.

#### Group B1 Coupons

Chopped stand E-Glass fibre in catalysed and Accelerated Polyester Resin (30% fiber volume content) were prepared and used to coat each of the six coupons on both sides.

Hand Lay-Up GRP production method was used. This is the production method used in developing countries (as Brazil). Rollers were used to consolidate the lining on each side of the coupon to a thickness of 0.20mm.

#### Group B2 Coupons

These six coupon specimens were used to replace group B1 coupons when three weeks into the test two of Group B1 coupon sample were observed to be corroding due to some cracks in these two coupons. The application of the GRP coatings in B2 coupons was more carefully done to prevent production defects. These Group B2 coupons were also tested for 150 days.

#### Group C Coupons

These six coupon specimens were zinc Galvanized to a thickness 0.05mm on each side of each coupon by Hot Dipping.

#### Group D Coupons

These coupons were each covered with a thin layer of "Homalux Enamel Paint" to a thickness of 0.10mm on each side. "Homalux Enamel Paint" is the brand name of a metallic paint manufactured at Onitsha (Nigeria). This paint is ash-coloured grey and is abundant in the market; it is conveniently applied by hand brush,

#### Group E Coupons

"Seniorlux Enamel Paint" was used to give a thin covering to these coupon specimens on each side using a hand brush, to a thickness of 0.10mm; this paint is abundant in the market; it is manufactured in Lagos (Nigeria) and gives a leaf green colour to the steel surface.

#### Group F1 Coupons

These were coated with thermosetting Phenol-Formaldehyde to a coating thickness of 0.15mm on each side which was carefully measured. The thermosetting resins were applied at resin temperatures slightly above 40° C; below 40° C temperature the coating set on the coupons.

#### Group F2 Coupons

These six coupons were used to repeat Group F1 coupon tests when one coupon in that group showed some corrosion on account of some openings on the sides during the application of the thermosetting Phenol

- Formaldehyde. The coatings in F2 coupons were more carefully applied. These Group F2 coupons were also tested for 150 days.

**Groups G and H Coupons**

Coupon specimens in Group G were left uncoated, subsequently to be subjected to the same mode of exposure to tropical road mud as were the coupons in Groups A-F. The six coupons in Group H were kept away from the corrosive media to which Groups A - G coupon samples were exposed. A summary of these specimen Groups with their protective corrosion coatings, test conditions and responses is shown in Table 2. During testing the coupons in Groups A - G were alternately suspended for twenty four hours and then removed and kept outside mud for another twenty hours for a period of 150 days.

**2.2 Important Constituents of Tropical Road Mud**

Chemical analysis of samples of the tropical road mud showed that it had an average Ph level of 5.5 and contained small amounts of Fe<sub>2</sub>O and Fe<sub>2</sub>O<sub>4</sub> and the following metals: Magnesium, Aluminum and Zinc. The non-metals present were Phosphates, Carbonates and Nitrates. The acid water in combined reaction with iron- oxides and abundant oxygen could promote corrosion.

**2.3 Important Constituents of Homalux Enamel Paint**

Chemical analysis showed the following major components of the Homalux Enamel Paint.

Ethylmethyl Ketone (Solvent)	82%
Drying Oil - Linseed Oil	7.2%
Bodying Agent (Fillers) and Colourant	6.0%
Tungsten	3.8%
Cobalt	1.0%

**2.4 Important Constituents of Seniorlux Enamel Paint**

Following a chemical analysis, the major constituents of the Seniorlux Enamel Paint as used for corrosion protective coating are:

Ethylmethyl Ketone	80%
Bodying Agent and Colour (Adds Strength and Bulk)	9.4%
Drying Oil-Linseed Oil	0.6%
Lead	

**2.5 Chemical Composition of the Low Carbon Steel**

Chemical analysis of samples of the low carbon steel showed the important constituents as shown in Table I.

Table 1: chemical composition of the low carbon steel coupons

Elements	F <sub>e</sub>	C	S <sub>i</sub>	N <sub>i</sub>	C <sub>u</sub>	M <sub>n</sub>	S	P	C <sub>r</sub>
Composition %	98.25	0.20	0.24	0.15	0.18	0.44	0.05	0.05	0.10

**3.0 RESULTS**

Following the 150 days of 24 - hour alternate suspension in mud and removal of coupon specimens in Groups A- G these specimens were carefully removed rinsed in clean water, dried, weighed and examined for corrosion damages group by group. The responses of the various Coupon Sample Groups are detailed below and summarized in Table 2.

**3.1 Responses of Group A Coupons Primed With Zinc Chromate and Aluminized by Hot-Dipping**

After careful examination all six coupon samples in Group A were found in excellent condition. There were no signs of blisters, rust, pits, or any form of corrosion on any of the six coupon samples.

**3.2 Responses of Group B1 Coupons Lined With Fibre Re-Inforced Resins**

During the test period, after three weeks of 24 - hour alternate suspension in mud and removal some evidence of the usual Hand Lay-Up Production Defects were observed in two of the six samples in this group.

Moisture penetration and subsequent corrosion were noticeable on the two coupon samples. These defects allowed moisture migration and subsequent pitting and deposit modes of corrosion on both steel surfaces of these two coupon samples. Over the 150 days of the test period, pitting depth in one coupon was about 0.08mm in a number of locations, while in the second corroded sample pitting depth was as much as 0.10mm in several spots. These corrosion attacks were the result of undetected production defects in these coupon samples.

The other four samples exhibited excellent corrosion resistance, with no signs of corrosion attack.

**3.3 Response of Group B2 Coupons More Carefully Lined with Fibre Re-Inforced Resins**

All six coupons without the production defects of B1 coupons showed excellent corrosion resistance.

### 3.4 Response of Group C Coupon Samples which Were Zinc-Galvanized by Hot-Dipping

All six coupon samples in this group showed excellent resistance to corrosion following 150 days of 24-hour alternate suspension in Tropical Road mud and removal. There were no signs of any form of corrosion.

### 3.5 Responses of Groups D And E Coupons Brush-Painted with Homalux and Seniorlux Enamel Paints Respectively

All six coupon samples in each of Groups D and E showed excellent resistance to corrosion following 150 days of the test. There were no signs of any form of corrosion.

### 3.6 Responses of Groups F1 And F2 Coupons Coated With Thermosetting Phenol-Formaldehyde

Two to three weeks into the test period, evidence of some corrosion was observed on one of the coupons in group F1. Further observation showed some corrosion damages on this one sample. Possible production defects were thought to have caused this. Consequently another set of six coupons, Group F2, were more carefully coated with the thermosetting phenol-formaldehyde and exposed to 150 days of alternate 24-hour suspension in and removal from mud.

The other five coupon samples in Group F1 showed excellent corrosion resistance. Also the carefully coated Group F2 coupon specimens showed excellent corrosion resistance in all coupon samples.

### 3.7 Response of the Uncoated, Unprotected Group G Samples

All six coupon specimens in this Group were covered with patches of reddish brown rust on both sides. Pitting Corrosion pits and Patches of Deposit Corrosion

were observed on all six coupon samples on both sides. The pits were spread all over the brown rust patches. Deposit corrosion pits were limited to an average of 0.02mm whereas the pitting corrosion pits averaged 0.12mm.

### 3.8 Response of the Uncoated, Unprotected Group H Samples Suspended in the Warm Humid Tropical Environment, away from Rain

After 150 days in which these coupon samples were suspended in warm humid Tropical Atmosphere but protected from rain, there were signs of slow degradation on all samples. Clusters of light brown corrosion patches were observable on all samples.

A summary of specimen groups, sample group coatings, test conditions and the responses is given in Table 2 below

## 4.0 DISCUSSION

This study shows that coupon Groups A, B2, C, D, E AND F2 which were carefully covered with anti corrosion coatings performed excellently in resisting corrosion due to exposure to tropical road mud. However some of the coatings are easier to apply than others. Aluminum and Zinc metallic coatings when available are very convenient and easy to apply by hot dipping as shown by coupon Groups A and C. Also hand-brush-painted coupon Groups D and E protected with Homalux and Seniorlux Enamel paints respectively showed excellent corrosion resistance in the same corrosion medium. It does appear that GRP resin and Thermosetting Phenol- Formaldehyde coatings are not quite easy to apply even though when carefully applied (as shown by coupon Groups B2 and F2) these coatings could also provide excellent corrosion protection for low carbon steel parts exposed to tropical road mud.

**Table 2: summary of test coupon sample groups and responses**

Sample group	Corrosion protective coating	Sample group test condition	Response to test.
A	Zinc chromate (ZnCrO <sub>4</sub> ) Priming; Aluminized Coating by Hot Dipping to a thickness of 0.01mm on each side	Alternately soaked and suspended in tropical road mud for 24hrs, then removed and suspended in laboratory atmosphere for 24 hrs for 150 days of test	All six coupons in excellent condition. No rusts, pits or any other sign of corrosion
B1	Chopped Strand E-Glass Fibres in Catalysed and Accelerated Polyester Resin (30% Fibre Vol. Cont) coating to 0.2mm thick on each side.	Ditto Group A	Two coupons were observed to be corroding, three weeks into the test period. After 150 days of test. Pitting and deposit modes of corrosion were observed on these two coupons. Other four coupons showed excellent corrosion resistance
B2	Ditto Group B I. the coatings	Ditto Group A	All six coupons in excellent condition.

Sample group	Corrosion protective coating	Sample group test condition	Response to test.
	were more carefully applied to Prevent production defects common with this coating method.		No rusts, pits or any other sign of corrosion
C	All (six) coupons zinc galvanized by Hot-Dipping to a thickness of 0.05 mm on each side.	Ditto Group A	All six coupons exhibited excellent corrosion resistance
D	Hand-brush-painted with Homalux Enamel paint to a thickness of 0.10mm on each side	Ditto Group A	All six coupon samples Showed excellent corrosion resistance.
E	Hand-brush-painted with Seniorlux Enamel paint to a thickness of 0.10mm each side	Ditto Group A	All six coupons exhibited excellent corrosion resistance
F1	Coated with Thermosetting Phenol-Formaldehyde to a coating thickness of 0.15mm each side	Ditto Group A	2 to 3 weeks into the test one of the coupons corroded because of openings in the coating. Some pits were observed in this corroded sample. The other five coupons showed excellent corrosion resistance.
F2	More carefully Coated with Thermosetting Phenol-Formaldehyde to a thickness of 0.15mm each side	Ditto Group A	Excellent corrosion Resistance in all six coupons
G	Uncoated; Unprotected against corrosion.	Ditto Group A	All samples covered with patches of reddish brown rust. There were pitting corrosion pits and patches of Deposit corrosion.
H	Ditto Group G	Suspended in warm humid tropical atmosphere but protected from rain.	Clusters of brown corrosion patches on both sides of all six coupons samples.

## 5.0 CONCLUSION AND RECOMMENDATIONS

This investigation shows that low carbon steel can be carefully protected from the destructive corrosion damages due to frequent contact with tropical road mud, especially on those automobile and other vehicle undercarriage parts frequently travelling on the poorly maintained roadways in tropical developing countries. It is observed that Cathodic Protection is not practical in dealing with this class of corrosion problems. The appropriate corrosion protection here involves careful application of metallic or polymer coatings, taking care to prevent any cracks or openings in the protective coating. Cracks or other openings could occur as a result of accidental scratches. These anti-corrosion coatings are therefore recommended for periodic applications on vehicle body undercarriage parts for all those automobiles, motorcycles, and other vehicles operating on the poorly maintained roadways in tropical developing countries where pot-holes and similar roadway damages are frequently filled with rain water to

create the Road Mud. The overall contributions from these periodic coatings in retarding the rapid devaluation in the values of these vehicles far exceeds the cost of labour and materials for application of these coatings.

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