

SEM-EDX and FTIR Studies of Chlorinated Rubber Coating

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Summary: Anticorrosive performance of chlorinated rubber coating has been investigated by visual examination, Scanning electron microscopy (SEM)/Energy dispersive X-ray (EDX) analysis and Fourier transform infrared (FTIR) spectroscopy. After surface preparation, commercially available coating system based on chlorinated rubber (primer)/chlorinated rubber (topcoat) formulation was applied on mild steel test panels (10cm x 15cm sizes). Prepared coated panels were exposed at marine, industrial and urban test sites located in Karachi, Pakistan according to ISO 8565 norm. Accelerated testing was performed by using a salt spray chamber (ASTM B117 norm). Accelerated weathering methods are the methods in which the factors responsible for the degradation of coatings are artificially intensified in order to achieve the rapid degradation of coatings. Visual examination of blistering and rusting as well as SEM micrographs indicated a more severe degradation of the coating surface characteristics at natural exposure testing sites (particularly at marine test site) than for accelerated (salt spray) testing. EDX determination of the Oxygen/Carbon (O/C) ratios also indicated increased degradation at natural test sites compared to the accelerated (salt spray) testing. Photooxidation of the binder results in the formation of carbonyl compounds as revealed by FTIR spectroscopy which also indicated dehydrochlorination.

Keywords: Anticorrosive performance; Scanning electron microscopy (SEM)/energy dispersive X-ray (EDX); Fourier transform infrared (FTIR) spectroscopy

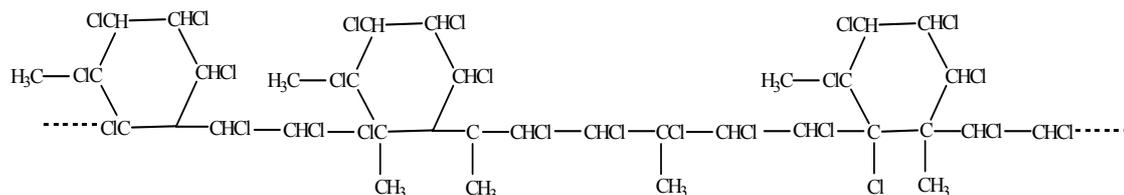
Introduction

Corrosion issues are of great importance particularly in Karachi's environment where they cause a colossal economic damage. Corrosion can lead to economic costs, technological delays and structural failures that have remarkable consequences for humans and the surrounding environment [1]. Different countries have carried out the studies related to the estimation of cost of corrosion. It has been found that corrosion can cost a country between 3 and 6 % of its Gross development products (GDP) [2-3]. Thus anticorrosive protection is immensely important in order to reduce harms to human safety, valuable property and machinery caused by corrosion. Among different anticorrosive protection methods, use of coatings is the most widely used method [2, 4-5]. Consequently, for a good long-term protection it is very important to assess the performance of a coating before using. The most extensively used methods for evaluation of the performance of coatings are natural weathering and accelerated methods [1, 6-10].

Chlorinated rubber coatings are considered as effective anticorrosive materials because of good chemical, mechanical, fungicidal and fire-retardant properties [11]. The molecular structure shown here is ascribed to chlorinated rubber [12].

Many examples are available in literature in which researchers have used chlorinated rubber coatings for corrosion protection. F.X. Perrin, *et al.* tested the chlorinated rubber paint by five standard artificial tests. They concluded that the chemical degradation of chlorinated rubber paint mainly occurred through dehydrochlorination [12]. S. Feliu, *et al.* studied the loss of adhesion of chlorinated rubber coating which was applied over pre-rusted steel [13]. B. del Amo, *et al.* studied the performance of chlorinated rubber paint containing zinc molybdenum phosphate as an anticorrosive pigment [14]. D. de la Fuente, *et al.* evaluated the performance of chlorinated rubber coatings applied on zinc substrates by accelerated and natural exposure testing [15]. Zinc substrate was contaminated with soluble salts chiefly chlorides and sulphates and their effect on the performance of chlorinated rubber coating was determined. In a study reported by C. Perez, *et al.*, barrier properties of the three paints were analyzed over galvanized steel and in the ranking chlorinated rubber coating was most effective than alkyd and water borne acrylic resin [16]. A. Sakhri, *et al.* compared the anticorrosive performance of chlorinated rubber coating by salt spray test and immersion in 3.5 % NaCl solution [17]. They incorporated polyaniline emeraldine salt or zinc phosphate as active pigments in the chlorinated rubber coatings.

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The issue of testing and qualifying coatings requires significant attention. Evaluation of the anticorrosive behavior of different coatings has been carried out all over the world but the results cannot explain the global durability of a coating. This is because of the fact that the service life of a coating is significantly influenced by the nature of environment which in turn vary across the world. Karachi, the city of industries, is considered as the backbone of the economy of Pakistan is facing the problem of atmospheric corrosion. Karachi can be safely considered as one of the most suitable sites for carrying out a study related to corrosion protection because of a combination of factors including marine, industrial and urban environments.

An important domain of natural exposure testing is the atmospheric corrosivity of different environments (marine, industrial and urban). Severity of atmospheric corrosion is significantly influenced by the type of environment and usually marine environments are highly corrosive. In view of the above, the present study reports the effect of natural exposure (at marine, industrial and urban test sites) and accelerated testing on the anticorrosive performance, structure and microstructure of chlorinated rubber coating.

Results and Discussion

Visual Examination

Table-1 presents the results of visual examination of the anticorrosive performance of chlorinated rubber coating systems exposed at different test sites. Natural exposure testing at marine site (L_1) indicated the formation of blisters and rust after 3 months of exposure. With the passage of time rapid increase in degree of blistering and rusting was observed. Coating system completely failed after 12 months. Coating system failure appeared to be associated with blistering and rusting along the scribed lines.

Natural exposure testing at industrial site (L_2) showed the appearance of blisters and some rust after 3 months of exposure. Development in degree of blistering and rusting was observed with time subsequently. Further exposure was stopped after 15

months (Table-1). Surface rust staining was also observed. Blistering and rusting along the scribed lines were the major modes of failure.

Natural exposure testing at urban site (L_3) indicated no detectable signs of degradation even after 15 months of exposure. Thus more exposure was stopped after 18 months for further studies (Table-1).

Table-2 presents the main results of accelerated (salt spray) testing of chlorinated rubber coating system. Accelerated (salt spray) testing showed the formation of blisters and some rust after 96 hours of testing. Further exposure resulted in increase in degree of blistering and rusting. After 408 hours coating system was removed due to severe blistering and rusting along the scribed lines.

Fig. 1 shows state of the scribed region of chlorinated rubber coating systems applied on mild steel: a) unexposed, b) after natural exposure testing at marine test site, c) after natural exposure testing at industrial test site, d) after natural exposure testing at urban test site and e) after accelerated (salt spray) testing.

It was apparent from the results obtained in this study that the natural exposure testing (particularly at marine test site) caused extremely high degradation of the coating systems tested as compared to accelerated testing. In addition to this, the major modes of degradation in the coating systems were entirely different in accelerated and natural exposure testing.

The performance of chlorinated rubber paint system applied on rusted steel substrate was evaluated after 14 years of atmospheric exposure tests at three different test sites [18]. M. Morcillo, *et al.* tested the chlorinated rubber paints at marine, industrial and urban test sites [19]. The paint was applied over uncontaminated rusted steel. They found that the signs of degradation increased with the corrosivity of the atmospheric exposure test sites. Results obtained in this study are consistent with their findings. High degradation of the coating system was observed in most corrosive marine environment.

Table-1: Results of Visual Examination of the Anticorrosive Performance of Chlorinated Rubber Coating Systems Exposed at Different Test Sites.

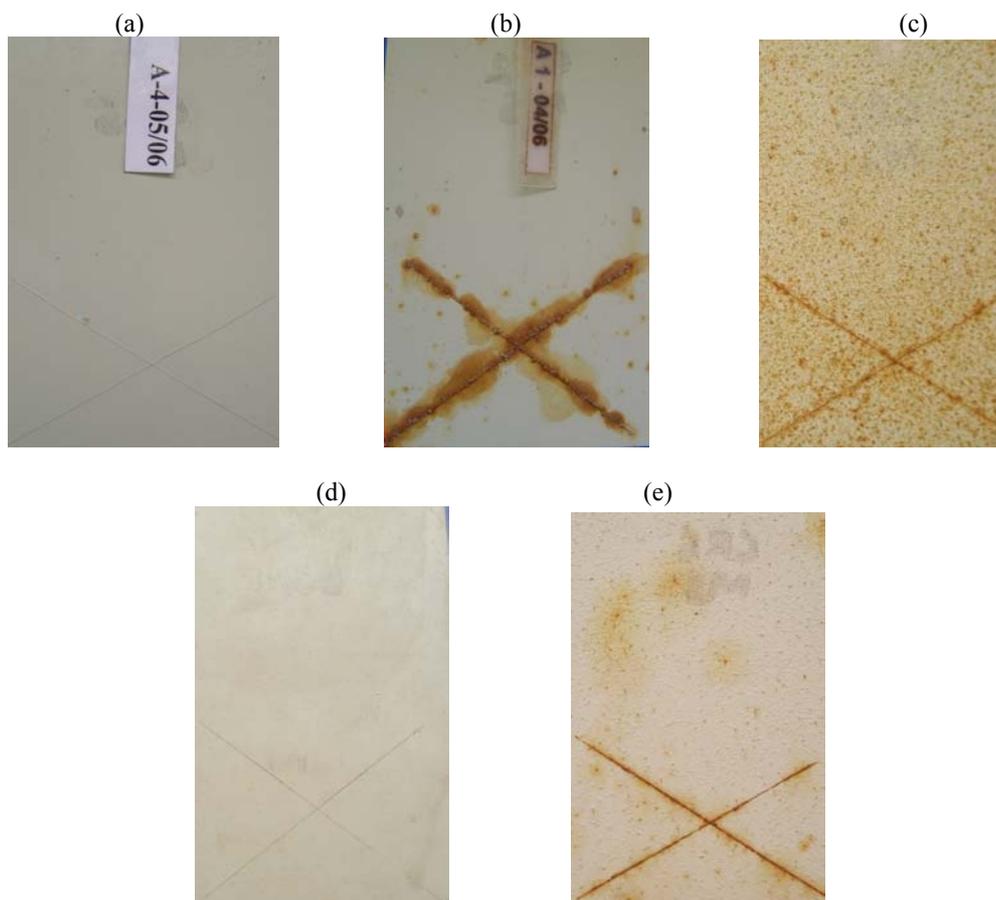
Test sites	Coatings defects after																				
	3 months			6 months			9 months			12 months			15 months			18 months			19 months		
	(May2006-Aug2006)			(May2006-Nov2006)			(May2006-Feb2007)			(May2006-May2007)			(May2006-Aug2007)			(May2006-Nov2007)			(May2006-Dec2007)		
	B	R	Cr	B	R	Cr	B	R	Cr	B	R	Cr	B	R	Cr	B	R	Cr	B	R	Cr
L ₁	2S ₂	1	0	3S ₂	1	0	4S ₂	3	0	ND	5	0	d	d	d	d	d	d	d	d	d
L ₂	2S ₂	1	0	2S ₂	1	0	3S ₂	2	0	4S ₂	4	0	5S ₂	5	0	d	d	d	d	d	d
L ₃	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	d	d	d

L₁: Marine test site; L₂: Industrial test site and L₃: Urban test site
 B: blistering; R: rusting; Cr: Cracking
 ND: Blisters were not detected because of severe corrosion along the scribe
 0: No detectable paint defect
 d: Panels were removed after exposure

Table-2: Main Results of Accelerated (Salt Spray) Testing of Chlorinated Rubber Coating System.

Coating defects	Time duration in hours						
	48	72	96	240	320	408	
Blistering	0	0	2S ₂	2S ₂	4S ₂	5S ₂	
Rusting	0	0	1	2	3	5	

0 = No detectable paint defect



a) unexposed, b) after natural exposure testing at marine test site, c) after natural exposure testing at industrial test site, d) after natural exposure testing at urban test site, e) after accelerated (salt spray) testing

Fig. 1: State of the Scribed Region of Chlorinated Rubber Coating systems.

Gloss Measurement

Fig. 2 shows the comparison of the gloss of chlorinated rubber coating systems. It was found that after natural exposure testing maximum reduction in gloss was observed for the coating system exposed at marine test site. Minimum reduction in gloss was observed for the coating system exposed at urban test site.

Comparison of the gloss of chlorinated rubber coating systems after accelerated (salt spray) and natural exposure testing indicated that the former induced less reduction in gloss of the coating system.

Severe reduction in gloss was observed after natural exposure testing at marine site indicating high degradation of the binder in natural marine environment. Reduction in gloss of the chlorinated rubber coating was noticed by F.X. Perrin, *et al.* [12]. They concluded that due to the degradation processes in the binder small organic units formed and were eliminated from the polymer matrix. In this way loss of organic material resulted in loss of gloss of the coating system.

Scanning Electron Microscopy (SEM)/Energy Dispersive X-ray (EDX) Analysis

In this work the surface characteristics of unexposed and exposed coating systems were studied

by SEM-EDX analysis. SEM-EDX is considered as a powerful tool to study the changes that occur in the surface characteristics of coatings as a result of weathering [20]. SEM has been used to study the behavior of chlorinated rubber coating applied on zinc substrates contaminated with soluble salts [15].

Fig. 3 shows the scanning electron micrographs of the surface of chlorinated rubber coating systems. The surface of the unexposed coating system contained no defects (Fig. 3a). SEM micrograph expressed that after natural exposure testing at marine site (L_1) coating's surface was roughened and the pigments were eroded on the surface (Fig. 3b). Cracks were not observed. Natural exposure testing at industrial site (L_2) demonstrated very bad conditions of the coating surface characteristics (Fig. 3c). Surface was smashed and some depositions on the surface were noticed. Natural exposure testing at urban site (L_3) indicated degradation of the coating surface characteristics (Fig. 3d). Rough surface was observed in the micrograph. Cracks were not observed during natural exposure testing at industrial (L_2) and urban (L_3) test sites. Accelerated (salt spray) testing showed little destruction of the coating surface characteristics (Fig. 3e).

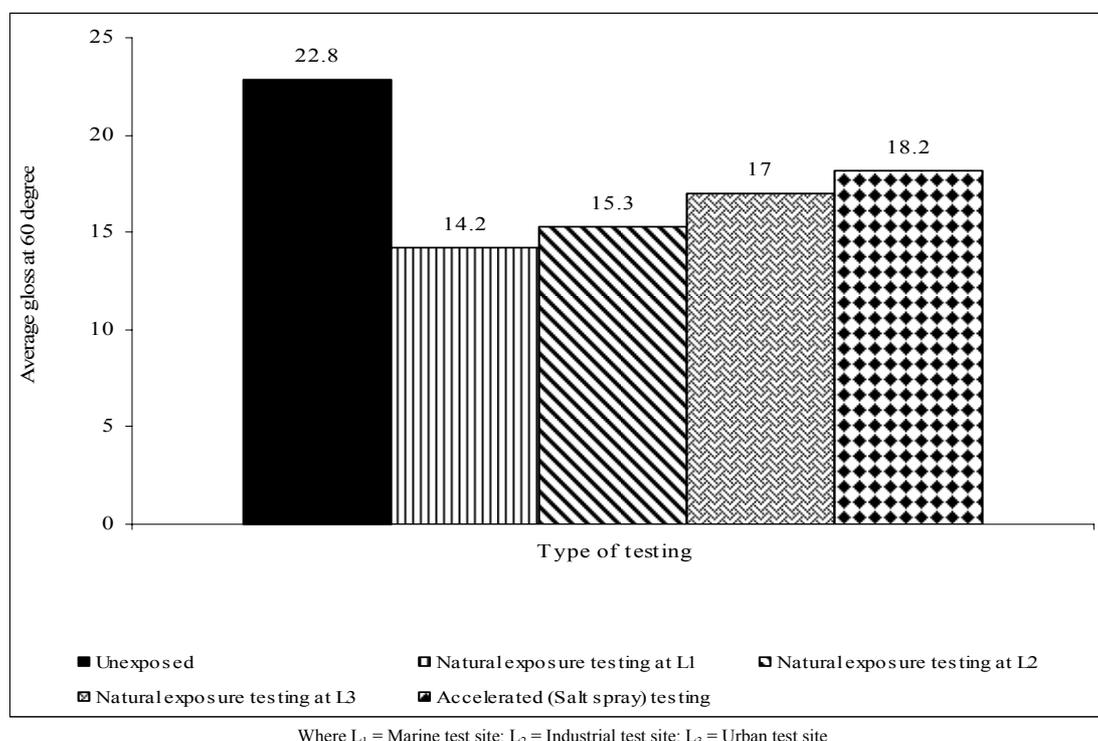
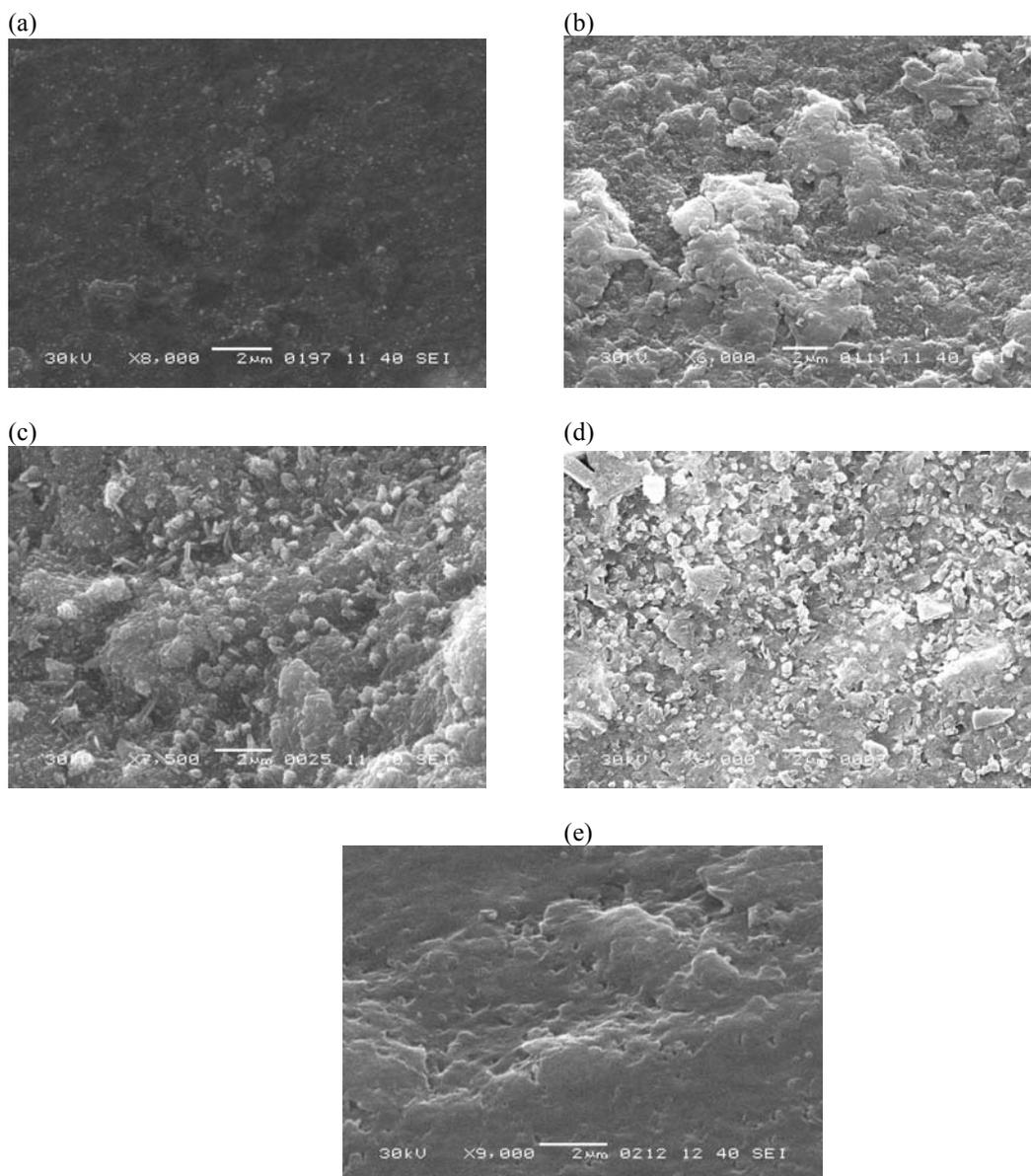


Fig. 2: Comparison of the Gloss of Chlorinated Rubber Coating Systems.



a) unexposed, b) after natural exposure testing at marine test site, c) after natural exposure testing at industrial test site, d) after natural exposure testing at urban test site, e) after accelerated (salt spray) testing

Fig. 3: Scanning Electron Micrographs of the Surface of Chlorinated Rubber Coating Systems.

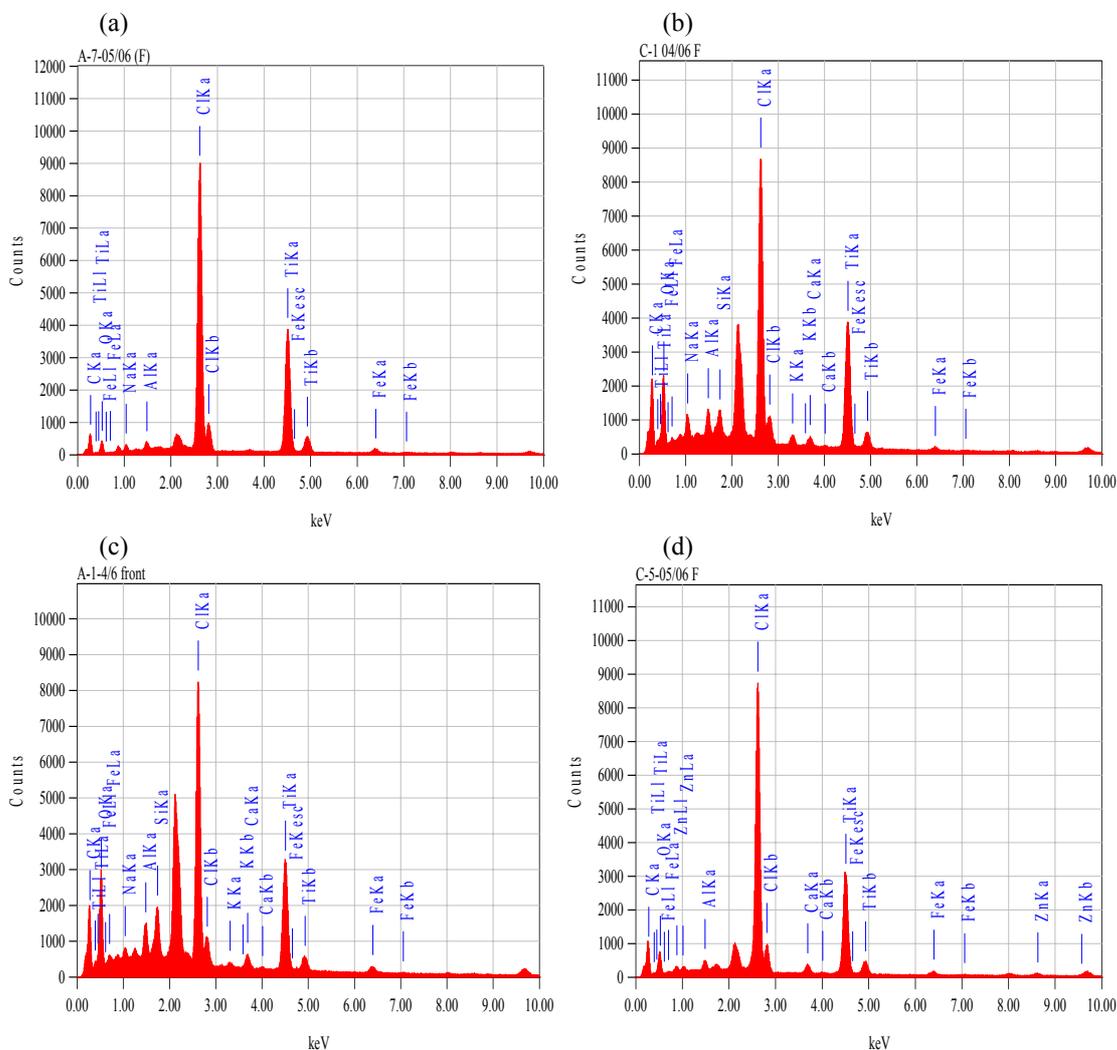
Fig. 4 shows the energy dispersive X-ray (EDX) spectra of the surface of chlorinated rubber coating systems, while Table 3 presents the surface composition data of chlorinated rubber coating systems as determined by EDX analysis. EDX analysis shows the presence of C, O, Na, Al, Cl, Ti, and Fe in the unexposed coating system (Fig. 4a; Table-3). Natural exposure testing at marine site (L_1) illustrated the presence of C, O, Na, Al, Si, Cl, K, Ca,

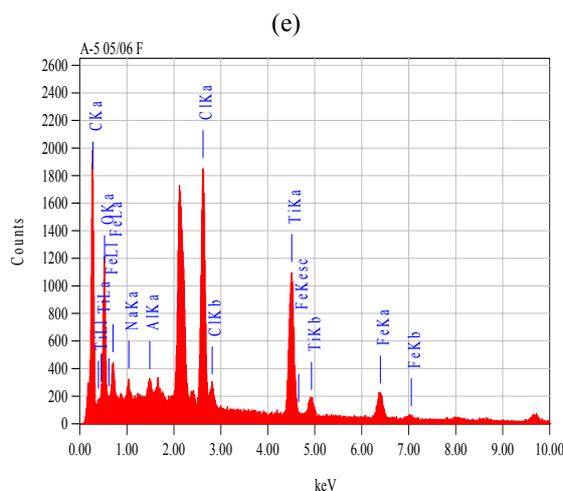
Ti, and Fe (Fig. 4b; Table-3). Natural exposure testing at industrial site (L_2) indicated the presence of C, O, Na, Al, Si, Cl, K, Ca, Ti, and Fe with different mass % (Fig. 4c; Table-3). Natural exposure testing at urban site (L_3) verified the presence of C, O, Al, Cl, Ca, Ti, Fe and Zn (Fig. 4d; Table -3) while C, O, Na, Al, Cl, Ti, and Fe were found after accelerated (salt spray) testing (Fig. 4e; Table-3).

Table-3: Surface Composition Data of Chlorinated Rubber Coating Systems as Determined by EDX Analysis.

Element	BindingEnergy kev	Unexposed	Natural exposure testing at L ₁	Natural exposure testing at L ₂	Natural exposure testing at L ₃	Salt spray testing
		mass%	mass%	mass%	mass%	mass%
C	0.277	42.94	24.62	27.12	47	40.7
O	0.525	20.23	29.32	24.26	30.09	27.17
Na	1.041	1.36	0.91	1.9	-	0.85
Al	1.486	0.7	1.62	1.33	0.6	0.57
Si	1.739	-	2.05	1.04	-	-
Cl	2.621	18.78	19.35	19.92	12.72	10.22
K	3.312	-	0.45	1.05	-	-
Ca	3.69	-	1.37	0.97	0.53	-
Ti	4.508	15.12	17.92	21.11	8.12	14.28
Fe	6.398	0.87	2.33	1.31	0.45	6.21
Zn	8.63	-	-	-	0.5	-
Total		100	100	100	100	100

L₁= Marine test site
 L₂ = Industrial test site
 L₃ = Urban test site





a) unexposed, b) after natural exposure testing at marine test site, c) after natural exposure testing at industrial test site, d) after natural exposure testing at urban test site, e) after accelerated (salt spray) testing

Fig. 4: EDX Spectra of the Surface of Chlorinated Rubber Coating Systems.

Results obtained from EDX analysis indicated that a common major change occurred during natural exposure testing at all the test sites as well as after accelerated (salt spray) testing. There was an increase in oxygen content and when O/C (Oxygen/Carbon) ratio was calculated, an increase in this ratio was observed after natural exposure testing at all the test sites as well as after accelerated (salt spray) testing. Fig. 5 shows the comparison of O/C ratios in unexposed and exposed chlorinated rubber coating systems. Maximum O/C ratio (1.19) was found after natural exposure testing of the coating system at marine test site (L_1). O/C ratio for the coating system exposed at industrial test site (L_2) was less than the coating system exposed at marine test site (L_2) but it was higher than the O/C ratio for the coating system exposed at urban test site (L_3). Comparison of O/C ratio obtained for the coating system after accelerated (salt spray) testing with the O/C ratios obtained for the coating system after natural exposure testing at marine (L_1) test site illustrated that increase in O/C ratio was little after accelerated (salt spray) testing.

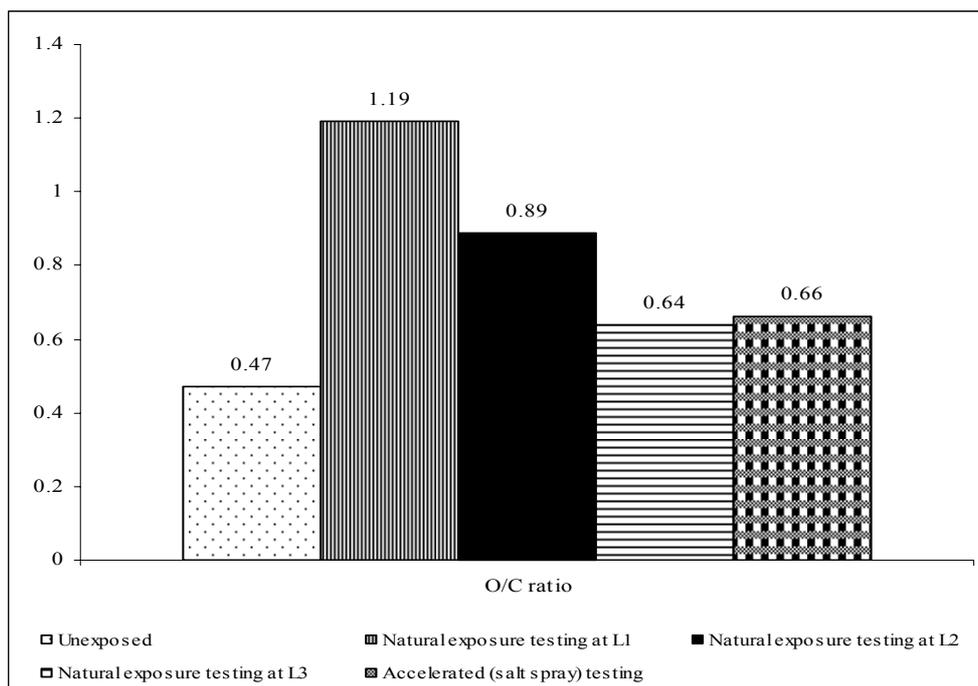
B.S. Skerry, *et al.* explained the reason for the smooth and featureless surface of the unexposed coating system [21]. They explained that this could be attributed to the formulation of topcoats as a gloss finish systems with a relatively low pigment volume concentration. According to their examination accelerated (salt spray) testing not showed surface features similar to those noticed after natural exposure testing. Also they correlated the surface roughening with the decrease in gloss. Results of the

present study confirm these findings. Accelerated (salt spray) testing revealed less degradation of the coating surface characteristics. In contrast, natural exposure testing caused drastic degradation of the coating surface characteristics particularly with the samples exposed at marine test site. Thus because of high degradation more reduction in gloss was observed for the naturally weathered sample.

X.F. Yang, *et al.* in their study [22] used SEM and they found that due to the degradation of the binder two major changes occurred on the surface.

1. Pigments raised on the surface
2. Formation of cracks on the surface

In another study X.F. Yang, *et al.* used SEM in combination with EDX [23]. They identified that in addition to the formation of cracks and erosion of pigments on the surface, the degradation of the binder resulted in some depositions on the surface. EDX analysis revealed that the depositions were actually the oxidation products formed due to the degradation of the binder. For the first time oxygen/carbon (O/C) ratio was used to prove the photodegradation of the coating as a result of weathering by these authors. Similar to their findings it was noticed that the weathering of the chlorinated rubber coating systems caused an increase in oxygen contents and as a result oxygen/carbon (O/C) ratio also increased. Comparison of the oxygen/carbon (O/C) ratios indicated that maximum photodegradation of the coating system occurred as a result of natural exposure testing at marine test site.



Where L₁ = Marine test site; L₂ = Industrial test site; L₃ = Urban test site

Fig. 5: Comparison of O/C Ratios in Chlorinated Rubber Coating Systems.

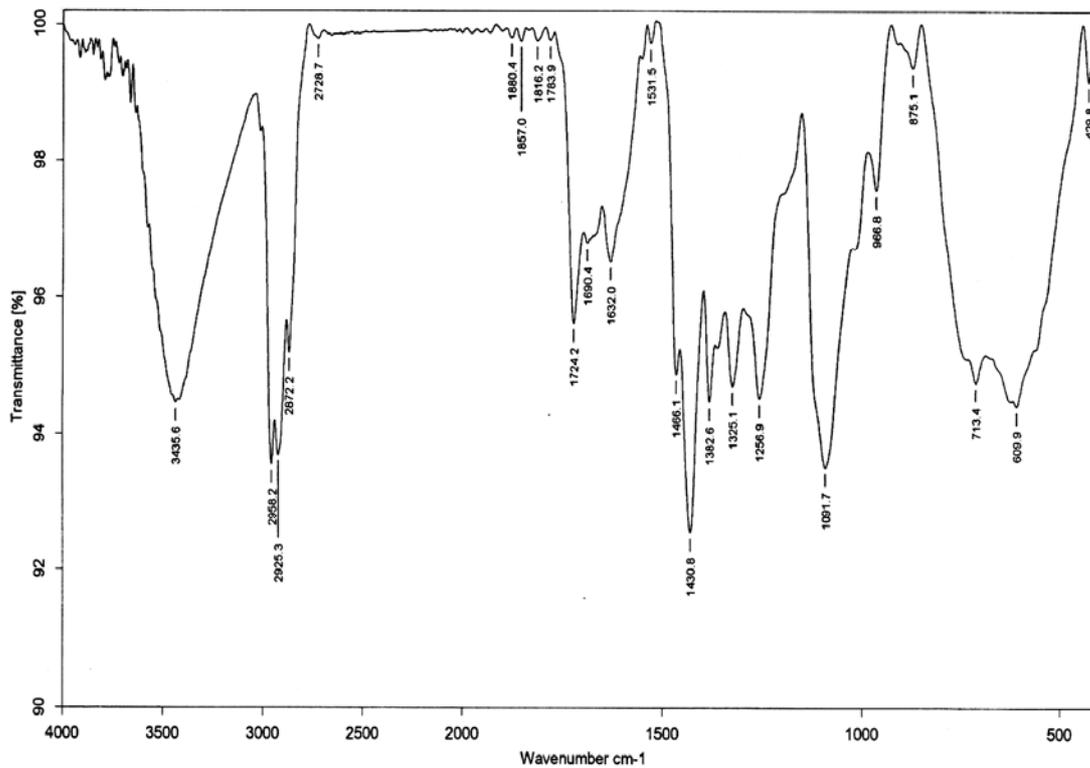
Fourier Transform Infrared (FTIR) Spectroscopy

Fourier transform infrared (FTIR) spectroscopy is considered as a useful analytical tool to study the extent and types of chemical degradation that takes place in coatings during accelerated and natural exposure testing [24-26].

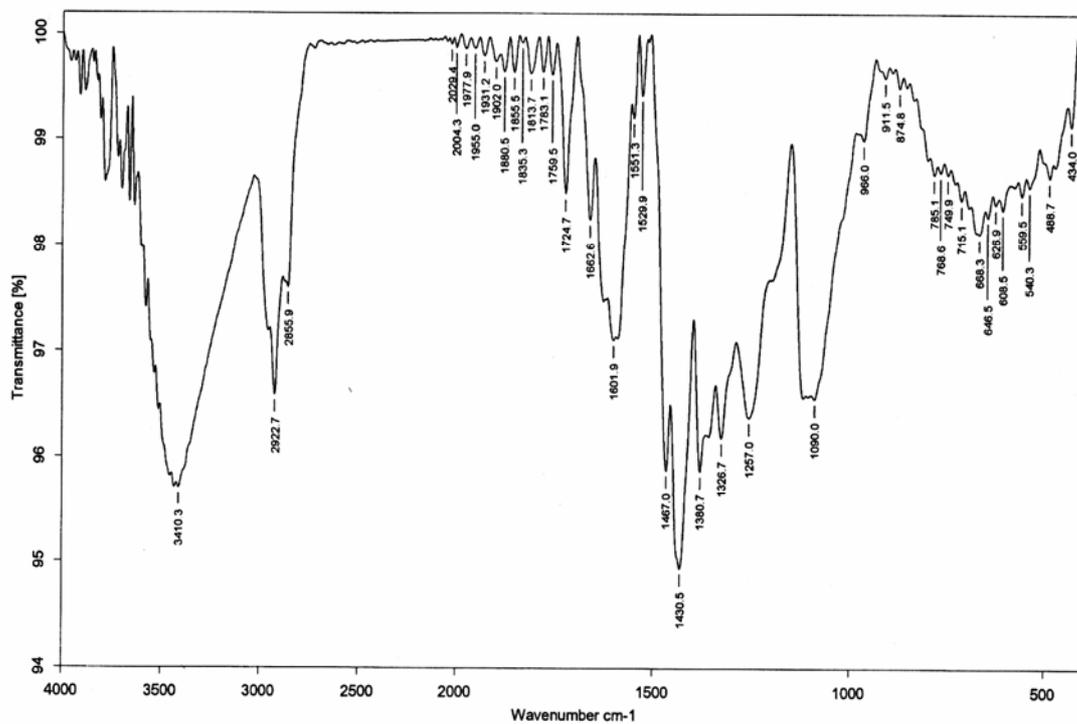
The IR spectrum of unexposed chlorinated rubber coating system showed a band due to asymmetric stretching of CH of CH₃ at 2958 cm⁻¹ (Fig. 6a). Band present at 2925 cm⁻¹ was due to asymmetric stretching of CH₂ (saturated). The band observed at 2872 cm⁻¹ was due to symmetric stretching of CH₂ (saturated). Stretching of the C=O of acrylic resin was observed at 1724 cm⁻¹. Band present at 1632 cm⁻¹ was an indication of C=C stretching of olefinic unsaturations. C-H bend due to symmetric deformation of CH₂ and asymmetric deformation of CH₃ was present at 1450 cm⁻¹. Band at 1430 cm⁻¹ correspond to CH₂ wag of the chloride substituted methylene. Symmetric deformation of CH₃ was noticed at 1382 cm⁻¹. Band at 1256 cm⁻¹ was associated with C-H bending in CH-Cl and stretching of C-O-C of ester [12].

FTIR spectra obtained for chlorinated rubber coating systems after natural exposure testing at marine, industrial and urban test sites as well as after accelerated (salt spray) testing showed changes in the similar regions independent of the type of testing (Fig. 6b, 6c, 6d, 6e). Following changes occurred on weathering:

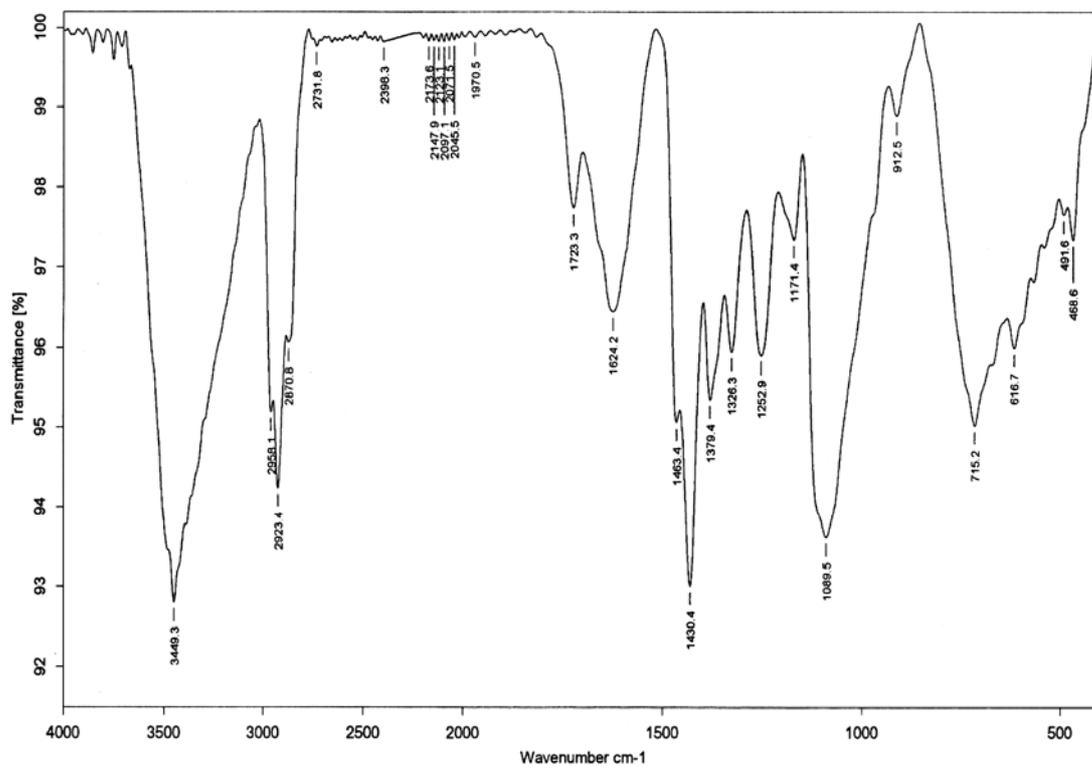
1. Decrease in the peak intensities of the vibrations at 2958 cm⁻¹, 2925 cm⁻¹ and 2872 cm⁻¹.
2. Decrease in the peak intensity of the vibration at 1450 cm⁻¹.
3. Some decrease in the intensity of band due to CH₂ wag of the chloride substituted methylene at 1430 cm⁻¹.
4. Decrease in the relative intensity of the band due to C-H bending in CH-Cl at 1256 cm⁻¹.
5. A strong rise and broadening of the absorption in carbonyl region occurred i.e in the region between 1650 cm⁻¹ and 1800 cm⁻¹.



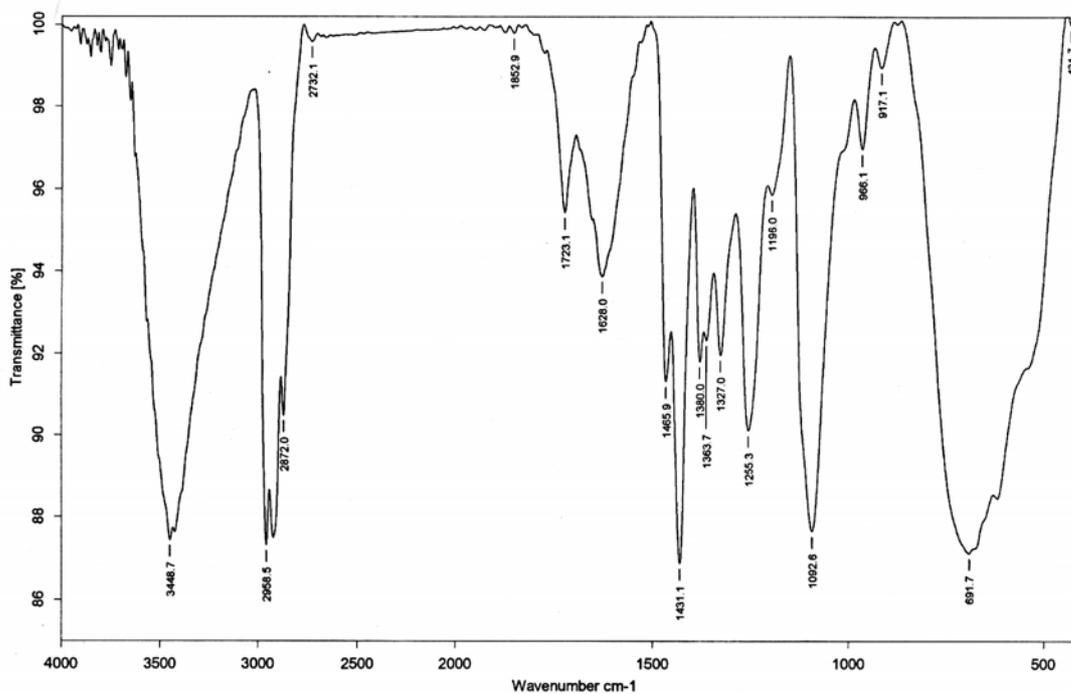
(a)



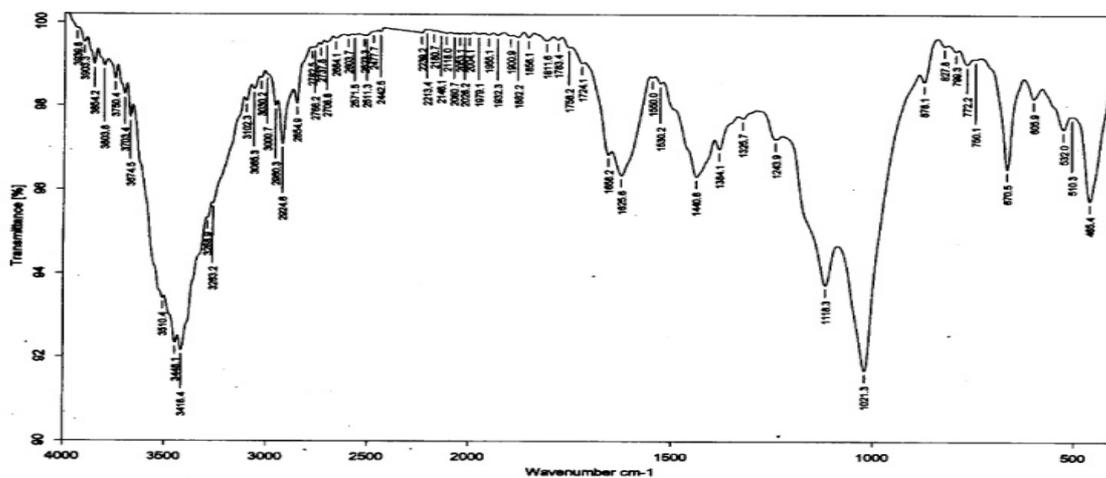
(b)



(c)



(d)



(e)

a) unexposed, b) after natural exposure testing at marine site, c) after natural exposure testing at industrial site, d) after natural exposure testing at urban site, e) after accelerated (salt spray) testing

Fig. 6: Infrared Spectra of Chlorinated Rubber Coating Systems.

Following conclusions can be drawn from the results obtained for chlorinated rubber coating system using FTIR spectroscopy:

- Point 1 to 4 provided information that a dehydrochlorination process occurred in the chlorinated rubber binder. Appearance of peak at 1600 cm^{-1} confirms the process of dehydrochlorination. This peak is due to C=C bond that arise in the binder as a result of removal of hydrogen chloride molecules [12].
- Point 5 suggests the formation of carbonyl compounds as a result of the photooxidation of the binder [12].

The major weathering factors which are responsible for the degradation of coatings are: sunlight, moisture, heat and chemical damage [27, 28]. The UV component of the sunlight has the energy required for the breaking of the bonds present in polymeric backbone of coatings. Degradation of coatings as a result of exposure to sunlight is commonly known as photodegradation of coatings [28-31]. Photodegradation is responsible for the loss in physical and mechanical properties of coatings and ultimately coatings become brittle, cracks and sometimes holes are formed on the polymer surface due to evaporation of the monomers/ products formed by depolymerization/degradation process [31]. The FTIR results obtained in this study are in good agreement with the conclusions of earlier study [12].

Besides showing changes in similar regions, comparison of the results indicated that after natural exposure testing maximum degradation of the coating systems occurred in marine environment (Fig. 6b) while less degradation of the coating systems was observed in urban environment (Fig. 6d).

Comparison of the results of accelerated and natural exposure testing indicated that the former induced less degradation of the coating system (Fig. 6).

Experimental

Mild steel panels with a size of 10cm x 15cm were cut from 1.2 mm thick mild steel sheet provided by Hino Pak Motors Limited (Body Operation Plant). The panels were subjected to a surface degreasing process using a suitable detergent. This was followed by rinsing and drying. For the surface preparation each panel was pre-treated with $\text{Zn}_3(\text{PO}_4)_2 + \text{H}_3\text{PO}_3$ solution. After surface preparation, commercially available chlorinated rubber coating was applied on the panels following the manufacturer's recommendations. The coated panels were left for drying and curing of the coating system. Then the dry film thickness (DFT) was measured according to ASTM D1186 [32] norm using Elcometer 456 digital coating thickness gauge. The data presented are the average of the measurements. Table-4 presents the main composition and the dry film thickness (DFT) of the chlorinated rubber coating system.

Table-4: Main Composition of Chlorinated Rubber Coating System Tested.

Primer		Topcoat		Generic Type	Total Average DFT* (μm)
Resin or binder type	Pigments	Resin or binder type	Pigments		
Chlorinated Rubber	Titanium dioxide and others	Chlorinated Rubber	Titanium dioxide, Carbon black and	Chlorinated Rubber	165

* = Dry film thickness.

Table-5: Characteristics of Natural Exposure Test Sites.

Test sites	Latitude	Longitude	Elevation [m]	Climatic type
L ₁	24°51' 02.63" N	66°53'08.26" E	4.27	Marine
L ₂	24°54' 12.08" N	67°00'34.21" E	19.51	Industrial
L ₃	24°56' 40.37" N	67°00'34.21" E	45.72	Urban

In order to identify the coated panels, tags were used. The bottom of each dried and cured coated panel was scribed with an X, in the coating, reaching through to the base mild steel. To prevent premature coating failure, the backside and edges of the coated panels were protected with a tape. One set of prepared coated panel was kept as control.

The natural exposure testing was performed at the marine, industrial and urban test sites located in Karachi, Pakistan. Table-5 presents the main characteristics of the atmospheric exposure test sites. Atmospheric exposure testing was carried out according to ISO 8565 norm [33]. At the test sites, coated panels were mounted on exposure stands facing south at an angle of 45° from the horizontal. During the exposure of coating at three test sites, visual examination of the anticorrosive performance in the scribed region was done from time to time. The degree of blistering, rusting and cracking were assessed periodically according to ISO norms [34-36].

In addition to natural exposure testing, accelerated testing was performed in salt spray chamber (T = 35 °C, NaCl concentration = 5% and relative humidity 95-98%) according to ASTM B117 norm [37]. Samples were removed from the salt spray chamber at regular intervals and degree of blistering and rusting were assessed.

Photographs of the panels were taken before and after natural exposure and accelerated testing. Gloss measurement for control and tested panels (after complete testing) was done according to the standard ISO 2813 [38]. Horiba IG-330 Gloss checker was used for this purpose.

SEM micrograph was taken by using a Scanning electron microscope (JEOL 6380A), equipped with an X-ray detector for energy dispersive X-ray (EDX) analysis. The microscope was operated at 10⁻⁷ Torr vacuum and a 30 kV voltage was employed for imaging and EDX analysis.

Infrared spectra were also taken for unexposed (control) and exposed coating systems. KBr discs were made. The spectra were obtained using a Shimadzu 8900 Fourier transform infrared spectrophotometer running with Omnic software, in the 4000-400 cm⁻¹ range. The spectrophotometer was operated in transmission mode. Spectra were recorded at a resolution of 2 cm⁻¹ and 20 scans.

Conclusions

Currently the manufacturing of chlorinated rubber using CCl₄ is being phased out due to ozone layer destruction. Newer grades have recently appeared in the market that does not use chlorinated hydrocarbons as starting materials. This study explored following noteworthy observations related to the anticorrosive performance, structure and microstructure of commercially available chlorinated rubber coating after accelerated and natural exposure testing which are useful for the coating's manufacturers as well as for users.

1. Visual examination showed severe blistering and rusting as a result of natural exposure testing (particularly at marine test site) compared to accelerated testing.
2. SEM micrograph indicated that the surface of the unexposed coating system was even and featureless.
3. SEM micrographs suggested that the accelerated (salt spray) testing revealed less degradation of the coating surface characteristics. In contrast, natural exposure testing caused drastic degradation of the coating surface characteristics particularly with the samples exposed at marine test site.
4. Comparison of the O/C ratios as determined by EDX analysis also indicated that all the tested coating systems degrade more in natural testing as compared to accelerated testing (O/C ratio is high for all the coating systems tested by natural

testing particularly for those tested at marine test site) and hence the two types of testing cannot be correlated.

5. Gloss measurement and SEM results cooperatively revealed that natural exposure testing (particularly at marine test site) indicated high degradation of the surface of the coating system as compared to accelerated testing. This surface roughening explained the high decrease in gloss for the naturally weathered coating system.
6. Results of FTIR spectroscopy proved that a dehydrochlorination process occurred in the chlorinated rubber binder. Formation of carbonyl compounds as a result of the photooxidation of the binder was also observed.
7. Results of FTIR spectroscopy and EDX analysis collectively indicated high photodegradation of the chlorinated rubber coating system as a result of natural exposure testing at marine test site.

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