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IMPACT OF ENVIRONMENTAL FACTORS ON THE DEGRADATION OF VARIOUS STEEL GRADES OVER TIME

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Abstract: The pace at which metals and other materials corrode is significantly influenced by atmospheric pollutants including SO_2, NO_2 and CO_2. The rate of corrosion in steels is determined by their chemistry. Studies conducted in numerous nations have shown that pollution has a significant impact on corrosion rate. When moisture combines with the acidic gases produced by factories, the atmosphere becomes acidic. The corrosion behavior of two steel types—plain carbon steel (PCS) and weathering steel (WS)—exposed to the atmosphere of Jharsuguda is described in this study. The exposure of the samples took place between 2014 and 2019. Compared to WS, PCS exhibits a higher rate of corrosion. This is explained by the development of protective, nonporous oxide layers on WS. Raman spectroscopies validate the findings. The mechanism of air pollutants has been ascertained by analyzing the dusts collected at Jharsuguda. Laboratory researches on exposed samples have been conducted in order to determine the mechanism and comprehend the causes. Raman spectroscopy and other techniques have been used to investigate the mechanisms behind the degradation of various steel grades.

Keywords: Plain Carbon Steel (PCS), Rust, Raman spectroscopy, Weathering Steel (WS)

Introduction

Steel is a crucial component used in the construction of buildings, bridges, roads and many other structures. Steels are used because of their strength, longevity and durability. The primary component of the earth that sustains any nation's economy is steel. Steels initially develop iron oxide on their surface when exposed to any kind of environment. The type of oxides determines the formation of the oxide layer [1–3]. Lepidocrocide (γ-FeOOH), goethite (α-FeOOH), akaganeite (β-FeOOH), and feroxyhite (δ-FeOOH) are among the oxides that form on the surface of steels during atmospheric corrosion [4-5]. The composition of the atmosphere and chemistry determine the type of oxide. When steel is exposed to concrete, a passive layer—a protective coating that contains adherent and nonporous oxides—forms on the surface. The development of passive layers prevents corrosion in concrete environments. The surface of these passive layers is primarily composed of goethite (α-FeOOH) and maghemite (γ-Fe2O3) [6]. Our goal was to conduct this study because steels exposed to open air developed various oxides that might be protective or unprotective and may be used to forecast the rate of corrosion and lifespan of steels. Because of its higher environmental air pollution, we have selected Jharsuguda.

Experimental details

In this study, two structural steel grades—WS and PCS—were used. Hot rolled plates were used to cut the 150 mm, 100 mm, and 4 mm steel coupons. Prior to being fixed to the exposure rack at Jharsuguda, the steels' surfaces were belt polished and degreased in acetone. Table 1 lists the chemical compositions of the steels employed in this investigation.

Table 1: Chemical compositions of structural steels used in the this study Wt% of alloying elements

Steels	C	Mn	Si	S	P	Ni	Mo	Cu	Cr	Al	Fe
WS	0.087	0.375	0.40	0.005	0.123	0.292	0.01	0.351	0.498	0.05	Balance
PCS	0.146	0.757	0.02	0.005	0.014	0.01	0.01	0.01	0.03	0.04	Balance

2 The identical steels were used for the laboratory tests as well. Different kinds of experiments were conducted to evaluate the corrosion behaviour of steels. Samples were exposed to the climate of Jharsuguda in the initial sets of trials. Jharsuguda is a dirty

industrial area. Table 2 displays the types of climates as well as the average annual statistics for SO_2, NO_2 and particulatematter (PM).

Table 2: Pollution data

Year	Pollution data (µg/m^3)		
	SO_2	NO_2	PM

2014-2016	44	56	100
2017-2019	35	48	153

All of the test samples were placed on steel racks that were angled 440 degrees and facing south. To prevent galvanic connections, the samples were fastened to the rack using brass nuts, bolts and porcelain insulators. Three sets of samples were removed from the racks and brought into the lab for various tests after the two-year exposure period. The ASTM G50-76[7] procedure was followed for the atmospheric exposure tests. As advised by ASTMG1-90, the rust on the exposed specimens was cleaned using an acid solution [8, 9].

From the steel surface, a few grammes of rust were scraped off and saved for the additional research. The publication now includes the average data for the three sets of specimens.This

solution, which is composed of 0.5%wt NaCl + 0.1%wt $CaCl_2$ + 0.25%wt $NaHCO_3$, is said to replicate a saline, humid atmosphere. In order to conduct the EIS investigations, a sinusoidal voltage of 10 mV (relative to the open circuit potential) was applied to the working electrode, and the frequency was changed from 100 kHz to 0.01 Hz. Rust was extracted from the samples and subjected to Raman spectroscopy using an Almega dispersive Raman Spectroscope. The materials were excited by a He–Ne laser beam with a wavelength of 529 nm. To prevent rusts from changing due to the laser's heating effect, the laser's power was kept as low as feasible at 0.14mW. However, the Raman spectra with substantial noise was recorded when the laser intensity was reduced below 0.15 mW. Thus, it was determined to keep the laser power at 0.14mW. Depending on the type of sample, the collecting duration was adjusted from 70 to 150 seconds. An Olympus microscope set to 50 magnifications was used to focus on the locations of the specimens to be examined. In order to fine-focus on a specific area of the sample, the sample holder featured a motorised platform with a Jokey. The grating had a pinhole of 26 µm and 671 lines/mm. The device was calibrated using pure silicon at the 522 cm-1 peak before samples were analysed.

Results and discussion

Raman spectroscopy was used to determine the type of rust that had developed on the steels. Goethite (α-FeOOH) and maghemite (γ-Fe_2O_3) are the primary iron oxide phases that form on the surface of WS, whereas lepidocrocite (γ-FeOOH) and haematite (α-Fe_2O_3) are formed on PCS. Iron oxide's goethite and maghemite phases are highly protective, non-porous, and surface- adhesive [6, 8]. Raman spectra display in figure and the table has embedded peaks. According to the majority of researchers, lepidocrocite (γ-FeOOH) forms on steels during the early phases of air corrosion [10].

Additionally, it is proposed that the chemistry of steels plays a major factor in the development of rust. This experiment revealed that while non-porous, adherent, and protective iron oxides, such as goethite and maghemite are formed on WS steel, porous, non-adhesive, and unprotective

oxides, including the strong haematite and lepidocrocite are formed on PCS steel. Cormell et al. have found that the formation of goethite on the steel surface protects the steel from further corrosion [11].

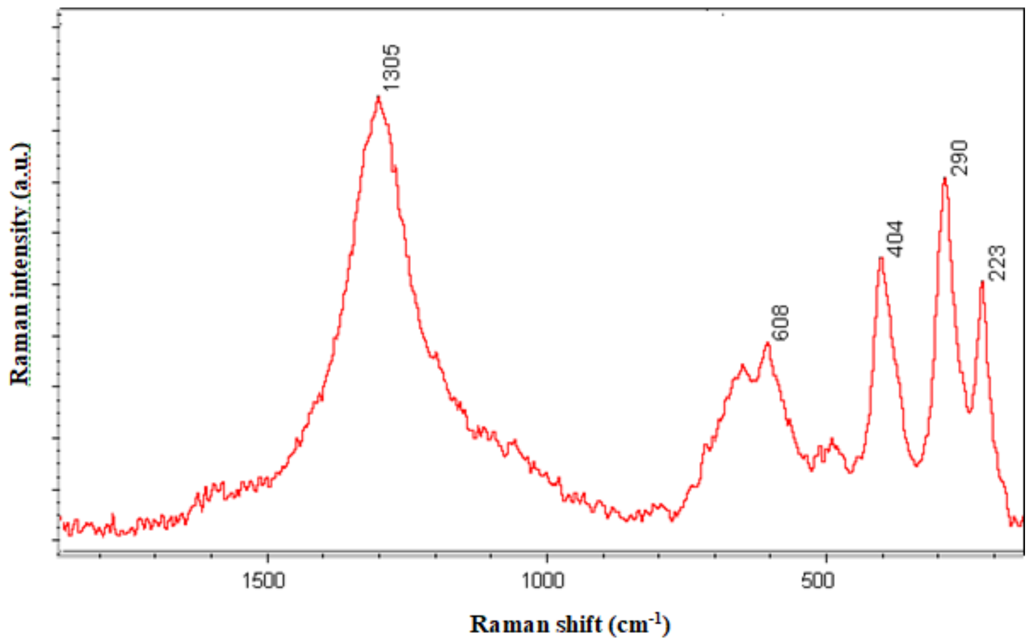

Fig 1: Raman spectra of rust formed on PCS

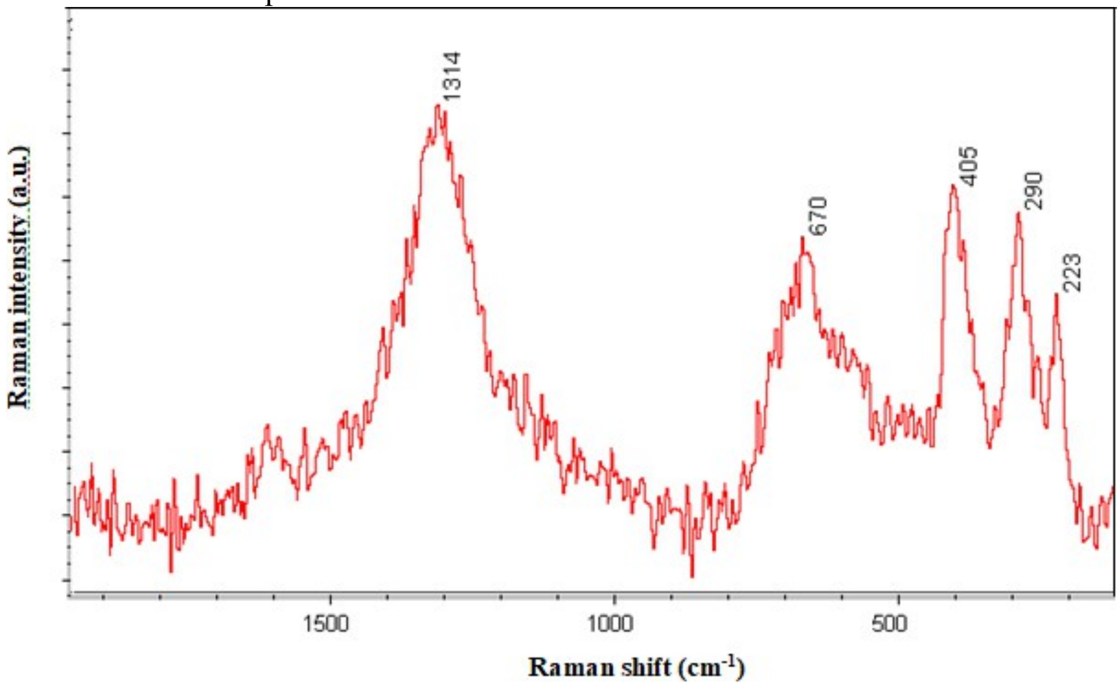

Fig 2: Raman spectra of rust formed on WS

Figure 1: Peaks Attribution (cm^{-1})		Figure 2: Peaks Attribution (cm^{-1})	
223	α-Fe_2O_3	223	α-Fe_2O_3
290	α-Fe_2O_3	290	α-Fe_2O_3
404	α-Fe_2O_3	405	α-Fe_2O_3
608	α-Fe_2O_3	670	γ-Fe_2O_3
1305	γ-FeOOH	1314	γ-Fe_2O_3

Conclusions

From the above studies it has been concluded that:

1. Corrosion rate of PCS is higher than WS during all period of exposure;
2. The corrosion rate of WS is less because of alloying elements i.e. Cu, Cr, P, Si and Ni are present;
3. On WS steel very protective, non-porous and adherent oxides (goethite and maghemite) while on PCS non protective, porous and non-adherent oxides (haematiteand lepidocrocite) are formed.

Bibliography

1. Schwartz N., 1965, Werkst. Korros. 16, p208,
2. Keller P., 1971, Werkst. Korros. 20, p32
3. Hiller J.E., 1966, Werkst. Korros. 17, p 943
4. Yamashita M., Mishawa T., 2000, Corros. Eng. 49, p159,
5. Dillmann Ph., Mazandier F., Hoerle S., 2004, Corros. Sci. 46, p1401
6. Practice for conducting atmospheric corrosion metals, ASTM G50-76, 1992
7. Practice for preparing, cleaning and evaluating corrosion test specimens, ASTMG1-90
8. Simpson, M.W., Linde, Van der, McCune, D.C., Townsend, H.E., License plate cosmetic corrosion tests automotive coated steel sheet CORROSION/98, paper No. 553 (Houston, TX, NACE 1998
9. Yamashita, M., Miyuki, H., Masuda, Y., Nagano, H., Misawa, T., Corros. Sci. 36 (1994) p283
10. Antunes, R.A., Costa, I., de Faria, D.L.A., Materia 8

(2003) p27 Cornell R.M., Schwertmann U., The Iron oxides, VCH, New York, 1996 @ Metainnovate March 2025