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Comparison of corrosion resistance of material; Brief summary of an experiment

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Abstract

The aim of this research was to assess the corrosion resistance of three types of steel under different conditions. The results demonstrate that MMFX steel exhibits a notably longer lifespan due to its enhanced corrosion resistance. Specifically, the corrosion rates for carbon steel range from roughly 25 to 35 miles per year, while MMFX steel experiences a rate of only 0.1 to 0.5 miles per year. Based on these findings, we estimate that structures made from carbon steel last about 50 years, those made from stainless steel around 100 years, and MMFX steel can last 120 years or more. As a result, we recommend MMFX steel for large-scale structures like bridges.

Keywords: Comparison, Steel Structures, Immersion, Salt Spray, Experiment.

INTRODUCTION

Corrosion is the most significant form of deterioration that impacts the performance of large steel structures, such as bridges and building foundations, leading to high maintenance costs. As a result, there is considerable interest in developing methods to mitigate corrosion-related damage. One approach involves slowing the corrosion process by increasing the time between the onset of corrosion and the structure's end of service life. Another common method focuses on delaying the penetration of chloride ions to the steel reinforcement. To understand the properties of different types of steel, it is essential to examine their chemical composition, such as that of Thermo-Mechanically Treated (TMT) bars. Aluminum, for example, makes up about 4.8% of the Earth's crust, making it widely available (Angst & Vennesland, 2008). The diverse chemical properties of steel are influenced by its various alloying elements, such as tungsten, chromium, sulfur, nickel, aluminum, molybdenum, phosphorus, silica, manganese, and carbon, which contribute to the production of high-quality steel. Steel comes in various forms, including tool steel, electroplated steel, galvanized steel, stainless steel, wootz steel, Damascus steel, and carbon steel, each with its specific applications. This study primarily focuses on structural steel, stainless steel, and MMFX steel, as these are commonly used in large steel structures and are therefore the main subjects of investigation in this research..

MATERIALS AND METHODS

Steel, primarily composed of iron and approximately 1% carbon, is essential in construction. This study analyzed three different types of steel to meet its research objectives. Carbon steel and stainless steel, both commonly used in the construction sector, are classified as structural steels (Scully, Hurley, & Sharp, 2007). In contrast, MMFX steel, recognized for its enhanced strength, is utilized in demanding applications such as coastal construction, steel bridges, and skyscrapers. The table below presents the properties of these three steel types.

Table 1

Steel Types and Properties

Name	C%	CR%	MN%	Si%	S%	P%
Carbon Steel	0.29	9.1	1.1	0.03	0.03	0.03
Stainless Steel	0.02	15.5	2.9	0.05	0.03	0.01
MMFX Steel	0.07	9.5	0.73	0.02	0.02	0.04

The table reveals the following differences in the composition of the three types of steel:

Carbon content (C%): Carbon steel has the highest carbon content at 0.29%, followed by MMFX steel at 0.07%, and stainless steel at 0.02%.

Chromium content (CR%): Stainless steel leads with 15.5%, followed by MMFX steel at 9.5%, and carbon steel at 9.1%.

Manganese content (MN%): Stainless steel ranks highest at 2.9%, followed by carbon steel at 1.1%, and MMFX steel at 0.73%.

Silicon content (Si%): Stainless steel has the highest silicon content at 0.05%, followed by carbon steel at 0.03%, and MMFX steel at 0.02%.

Sulfur content (S%): Both carbon steel and stainless steel share the same sulfur content of 0.03%, while MMFX steel has 0.02%.

Phosphorus content (P%): MMFX steel has the highest phosphorus content at 0.04%, followed by carbon steel at 0.03%, and stainless steel at 0.01%.

These variations in composition highlight the differences in the qualities of the three types of steel across various elements.

For our methodology, we assessed the corrosion resistance of steel samples through two primary tests: a salt spray experiment and immersion in a sodium chloride solution. The salt spray test followed ASTM B117 standards, which specify a controlled environment where specimens are exposed to a continuous mist of sodium chloride in a chamber (Ji, Darwin, & Browning, 2005). The specimens are positioned within the chamber, where compressed air maintains the salt fog.

In the immersion test, specimens were regularly observed to monitor the initial appearance of rust (Gong, Darwin, Browning, & Locke, 2004; Nadh & Vasugi, 2014). The samples were continuously immersed in a sodium chloride solution to determine the time required for complete corrosion.

RESULTS

The equipment used in this experiment was monitored on an hourly basis to track the results. The steel specimens were exposed to corrosion under different salt spray conditions to observe varying degrees of rust formation.

Carbon Steel

Carbon steel specimens underwent corrosion testing, with the initial signs of rust appearing after 15 hours of exposure. Full rust formation was observed after 24 hours of continuous exposure. Based on the carbon steel composition, the results showed that 2% of the carbon content was consumed after 24 hours of testing.

Table 2
Results

Carbon Steel	Test Conducted	Initial Rust Hours	Final Rust Hours
Specimen 1	• Salt Spray Test • Immersion Test	25	32
Specimen 2	• Salt Spray Test • Immersion Test	23	30
Specimen 3	• Salt Spray Test • Immersion Test	25	30

Stainless Steel
Stainless steel is prone to intergranular corrosion, which starts at the grain boundaries. Consequently, it was crucial to focus specifically on testing for this type of corrosion.

Table 3
Results

Time Interval	I	II	III	IV
Initial Weight	24.55	24.55	24.55	24.55
Final Weight	24.43	24.46	24.47	24.43
Difference in Weight	0.12	0.09	0.08	0.12
Corrosion rate/mm/month	0.011	0.012	0.03	0.04
Corrosion rate/miles/year	9.58	8.64	9.99	10.23

The sample was observed for approximately 300 hours. The results indicated that the first cycle started after around 46 hours. The second cycle began at about 1%, while the third cycle showed a range from 2% to 30%. The final cycle started with a rate exceeding 30%.

MMFX Steel
MMFX 2, a low-carbon steel, features a patented steel matrix that is almost free of carbides, which reduces the formation of micro-galvanic cells. The testing was conducted following the AASHTO MP 18 standard, which defined the chloride threshold level for the material.

Table 4
Results

Corrosion Performance Measurement under ASTMA 1035	Test Time Length	Test Sample
Percent weight loss ratio	28 weeks	0.29
Southern Exposure Test	85 weeks	0.49
Time to corrosion ratio	39 weeks	3.1
Time to corrosion initiation ratio	31Weeks	4.9
Chloride threshold ratio	29 weeks	3.9

The results demonstrate that the chloride threshold ratio for MMFX steel is approximately six times higher than that of black bars and more than twice that of other steel types.

CONCLUSION

This study aimed to evaluate the corrosion resistance of three types of steel under various conditions. The findings indicate that MMFX steel offers a considerably extended lifespan due to its superior corrosion resistance. Specifically, the corrosion rates for carbon steel range from about 25 to 35 miles per year, while MMFX steel experiences only 0.1 to 0.5 miles per year. Based on these results, we conclude that structures made of carbon steel have an estimated lifespan of around 50 years, those made of stainless steel around 100 years, and MMFX steel can last 120 years or more. As a result, our study recommends the use of MMFX steel for large-scale structures, such as bridges.

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