Corrosion behavior and mechanical degradation of weathering steel in simulated environment

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1. Abstract

This study focuses on the investigation of corrosion behavior and mechanical degradation of weathering steel exposed in the simulated corrosive environment. The stabilization of weathering steel rust layer is identified by rust appearance, hardness, and corrosion products. An influence of rust quality on the yield and ultimate strength are discussed by conducting a uniaxial tensile test and morphology study of weathering steel's rust layer.

2. Introduction

The weathering steel (WS) is a type of carbon steel with an additional certain amount of alloying elements and it is widely used in infrastructure construction due to its benefits in reduction of maintenance costs. In general, weathering steel resist the environmental effects by producing self-protective rust layer when material electrochemically reacts with water and oxygen from the environment. The rust layer of weathering steel composes of loose and compact rust layer and the base layer is considered as a protective one. The alloying element added in the weathering steel manufacturing process can displace the Fe ions in the corrosion products, which can give a stable chemical property as well as a certain ion selective permeability to the base rust layer. However, the protective performance of weathering steel is typically influenced by the corrosive ambient in the atmosphere. A stable and dense rust layer can only provide a good protection for the base material, and it can also make changes to the mechanical properties after corrosion. In this study, microstructural and mechanical analyses were conducted on the corroded weathering steel specimens to understand the chemical and mechanical degradation under simulated corrosive environment.

3. Experimental procedures

The weathering steel (SMA 490) exposed in Gifu Prefecture for about 16 years were exposed in the laboratory accelerated corrosive environment according to JIS K 5600-7-9 [1] to satisfy an enough rust layer for evaluation. The test periods are set up at 0h, 300h, 600h, 900h and 1200h. The chemical and mechanical evaluations were carried out using simulated specimens. Since the corrosion process of weathering steel generates a variety of iron oxides and iron hydroxides, the determination of physical phase in the rust layer is analyzed by the XRD analysis. The quantitative analysis of goethite (α-FeOOH), akageneite (β-FeOOH) and lepidocrocite (γ-FeOOH) was performed based on the characteristics of diffraction pattern. The morphology of rust surface is analyzed by SEM-EDS analysis. The mechanical degradation of weathering steel is investigated by conducting a uniaxial tensile test of specimen with different rust layer thicknesses.

4. Results and discussion

From the analysis results from XRD patterns, the rust composition contains goethite (α-FeOOH), akageneite (β-FeOOH) and lepidocrocite (γ-FeOOH) are observed as the main components of the rust layer. The transformation of lepidocrocite generated in the earlier stage into goethite has confirmed under the suitable conditions and this transformation is considered as the stabilization of the chemical properties of rust layer. Figure 1 shows the SEM image and XRD patterns of rust layer at 0h and 900h exposure time. In the SEM images, variations in the structure of rust layer can be seen at different corrosion times. The rust layer of corrosion test at 0h mostly contains the laminar plate-like lepidocrocite, and goethite in the form of needle-like morphology can be seen in the rust layer of 900h of corrosion test.

Key words weathering steel, corrosion, chemical composition, mechanical degradation.
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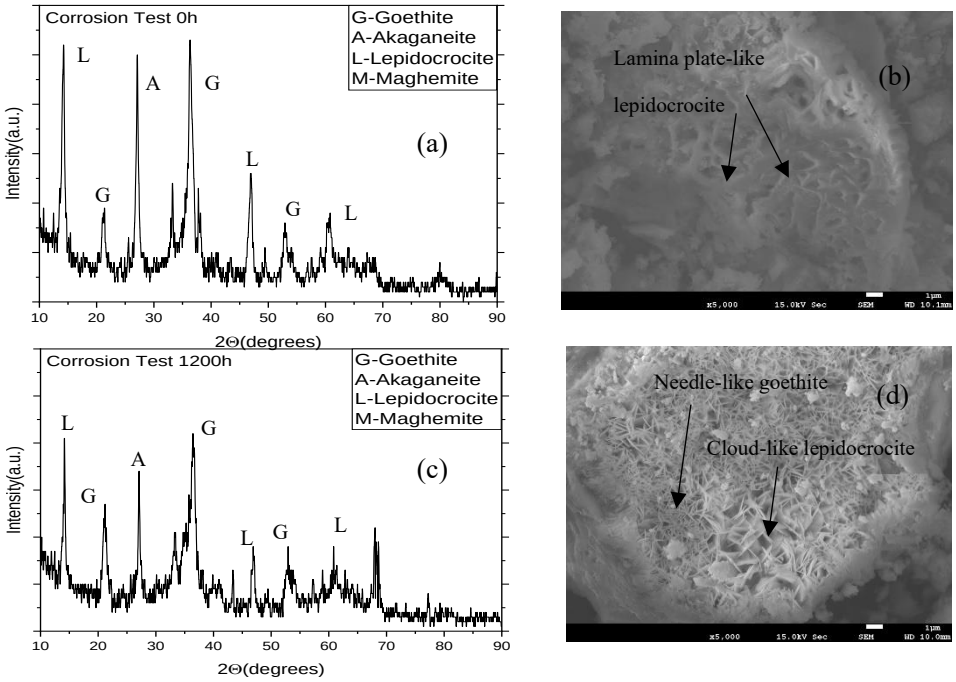

Fig. 1 The XRD patterns and SEM photographs of rust layer at 0h (a, b) and 900h (c, d)

The tensile test results of weathering steel are almost similar in behavior with carbon steel with distinct elastic stage, upper yield point, lower yield point, yield plateau, and strengthening period as shown in the figure 2.

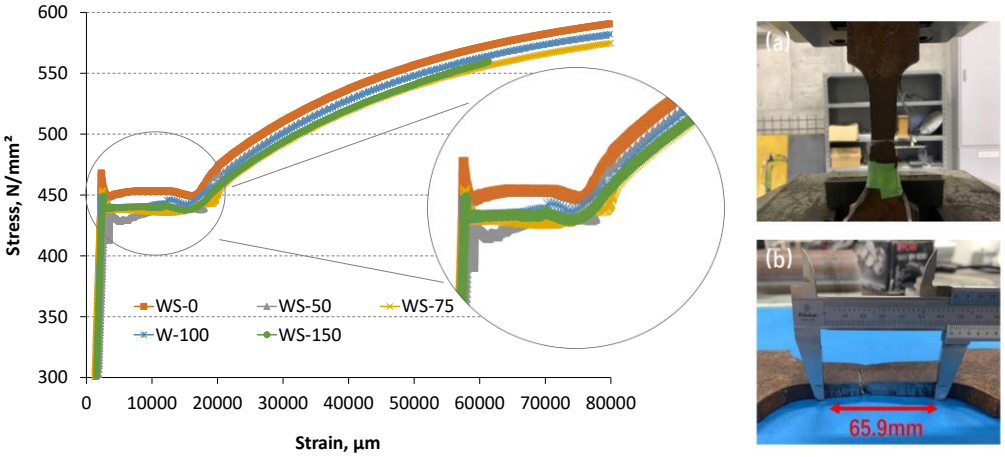

Fig 2. Mechanical degradation of weathering steel and test conditions

Although the tensile strength of weathering steel after corrosion degrades with the testing time, the rate of degradation gradually slows down to the deacceleration of corrosion rate as of chemical stabilization of rust layer. It is also confirmed that the degradation of yield and ultimate strength at the initial stage of corrosion test is relatively higher than the stabilization stage.

5. Conclusion

The results of this study confirm that the mechanical degradation of weathering steel is related to the chemical composition of rust layer. Although yield and ultimate strength of weathering steel degrade with corrosion progress, the rate of degradation slows down as the rust layer becomes more stable while the major component of rust layer is akaganite. An influence of micro-structure of rust layer on mechanical properties of weathering steel after corrosion was investigated from this approach.

6. References

[1] JIS K 5600-7-9. 2006. Testing Methods for Paints − Part 7: Determination of Resistance to Cyclic Corrosion Conditions − Section 9: Salt Fog/ Dry/ Humidity. Japan: Japan Standard Association (JSA)