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Effect of corrosion on the tension behavior of painted structural steel members

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ABSTRACT

The long-term structural performance of steel structures can be directly related to corrosion. In this study, tensile tests were conducted on corroded steel members to examine the effect of corrosion damage on their tensile behavior. For this purpose, tension specimens were manufactured using the members of a 75-year-old painted steel bridge exposed to the marine environment. The corroded surfaces of the tension specimens were measured using an optical 3D digitizing system to obtain their residual thicknesses. After the tensile tests were performed, the characteristics of the tensile behavior of the corroded steel plates such as the yield load, ultimate load, and elongation were evaluated quantitatively. An effective thickness has been suggested using the mean and standard deviations of the residual thicknesses of the specimens. This can be used to evaluate the tensile strength of a structural steel member with an irregularly corroded surface. The practical measurement intervals for taking the various thickness measurements of the corroded steel members are also presented.

1. Introduction

Painting is a useful and effective way to maintain steel structures and to prevent corrosive damage in them, which can affect their structural behavior. Moreover, painting is preferred because of its easy applicability and economic feasibility. Therefore, the methods of application and the deterioration of paint coatings have been researched with respect to corrosion damages in steel structures. Repainting periods are provided for the maintenance of steel structures such as bridges because the deterioration of the paint coat can cause cross-sectional damage in the steel members [1]. However, corrosion damage occurs on painted steel surfaces because of the deterioration of the paint film and owing to various painting defects such as pinholes and scratches. This corrosion damage will lead to loss of cross-sectional area of the steel structures if they are not maintained or repaired at regular intervals [2,3].

Severe corrosion can result in irregular stress distribution and stress concentration on the surfaces of a steel member. Corrosion also results in reduced and irregular cross section of the steel member, which can affect its structural performance. Recently, there have been reports on the incidents of structural failure caused by corrosion damage. For example, in Japan, a diagonal member of a truss bridge had to be cut off (failure) because of corrosion [4]. Similar cases of failure were also detected in the remaining diagonal members of the bridge and their damaged sections were repaired and strengthened. In addition, hanger cable failures have also been reported in Japan [4]. Several steel structures that were damaged owing to corrosion were identified during the maintenance process [4]. These cases explain the need for rational corrosion assessment techniques and adequate maintenance procedures to prevent severe corrosion damage in aged steel structures. Several studies have been conducted to estimate the damage in steel structures that are exposed to a corrosive environment, and various corrosion assessment techniques have been proposed [5–7]. Furthermore, researches have been conducted on the structural performance of corroded steel structures [8–11]. The structural behavior and residual strength of the steel bridge members exposed to localized corrosion have been evaluated in terms of the tensile strength, compressive strength, and local buckling strength. The residual structural performance or the corrosion estimation is used to calculate the reliability of steel bridges [12–16].

A corrosive environment can cause different forms of corrosion in a steel structure. Diverse studies are required to evaluate the performance of steel structures under a variety of corrosive conditions. This study is a fundamental research on the performance of corroded steel structures. In this study, the tensile behaviors of corroded steel members were examined using samples with varying levels of corrosion. To perform this study, corroded specimens were prepared using the members of a 75-year-old painted bridge that had been exposed to a marine

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Table 1
Chemical composition of steel plate (wt%).

C	O	Na	Si	Cl	Fe
4.76	6.3	0.81	0.43	0.45	87.25

environment. Tensile tests were performed and the tensile behaviors of the specimens were analyzed quantitatively.

2. Tensile test program

2.1. Tensile test specimens

To examine the effect of corrosion damage on the tensile behavior such as the yield load, ultimate load, and elongation of steel members, the tensile test specimens were procured from a demolished steel bridge that had a service life of approximately 75 years (1934–2009). The bridge had been erected in a coastal area with high salinity. The steel plate was made of structural steel and was 400 mm long and 60 mm wide. The chemical composition of the steel is shown in Table 1. As per ISO 12944 [17], the corrosivity category of the steel bridge is classified as very heavy (C5-M), which represents the highest level of corrosion.

Fig. 1(a) shows the steel bridge before demolition and its dismantled members. The specimens for the tensile test were selected from the stringers and connection plates of the dismantled steel bridge members as shown in Fig. 1(b).

In this study, the tensile specimens that were originally taken from the Yeongdo Bridge were reprocessed according to KS B0801 [18]. Fig. 2 shows the dimensions of a typical specimen. In addition to the seventeen corroded tensile test specimens, three non-corroded

(a) Before and after demolition of the 75-year-old Yeongdo Bridge.

(b) Pictures of the corroded members of the Yeongdo Bridge

Fig. 1. Location, environment, and corroded members of the Yeongdo Bridge.

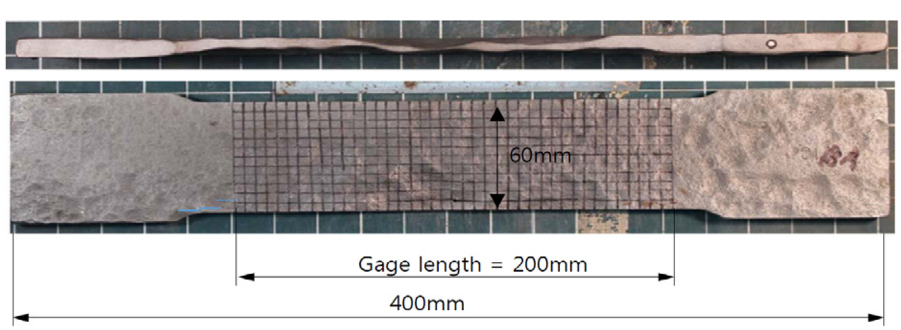

Fig. 2. A typical tensile test specimen.