Overview of Mechanical Behaviour of Corroded Steel Structures

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Abstract: The corrosion imposes significantly effect on the mechanical behaviour of steel material and steel members, which can reduce the safety of steel structures. This paper presents current key research findings to promote the following research. This paper sets out the preparation methods available to gain corroded steel specimens firstly, then summarizes the correlation between corrosion and mechanical behaviour of corroded steel members and material.

1. Introduction
With the advantages of spatial multiformity, high strength, light weight, fine seismic performance, high degree of industrialization and short term of construction period, steel structures have been extensively used in many constructions, including public buildings, industrial architecture, commercial buildings and residential buildings. However, many steel structures, especially in industrial atmospheric environment or marine atmospheric environment, are inevitably affected by corrosion damage, which are shown in Fig.1 and Fig.2. Therefore, it is essential to evaluate the remaining bearing capacity of steel structures with corrosion damage to decide whether to repair corroded steel members or change them.

Fig1. Corroded grid structure.  
Fig2. Corroded rigid frame.

Many literatures have studied the effect of corrosion damage on the mechanical behaviour of steel structures, and they found that corrosion reduces loading capacity of steel structures even leads to steel structures destroyed [1]. Therefore, the research on mechanical behaviour of corroded steel structures
is important. The corrosion of steel structures has been extensively discussed, but a comprehensive overview is currently lacking. Therefore, it is very necessary to overview mechanical behaviour of corroded steel structures.

2. Preparation method of corroded steel specimens

The preparation method of corroded steel specimens can be divided into three types mainly: outdoor-exposure method, indoor-artificial accelerated method and method of directly gaining specimens from practical corroded steel structures. Outdoor-exposure method matches the corrosion environment with the actual environment, so the corrosion morphology of specimens is proved consistently well with actual situation [2]. However, corrosion rate of outdoor-exposure method cannot be accelerated, which makes the period to gain the corroded specimen longer than other methods. Besides, the difference in air purity can lead to great difference in results. Indoor-artificial accelerated method includes hot-wet test [3], salt spray test [4], immersion method [5] and so on. Accelerated method can gain the corroded specimen in short term, so this method is used widely though it is always mismatching the results of outdoor-exposure tests. No single method can represent different types of atmospheric exposure, which is an inherent difficulty of indoor-artificial accelerated method. The specimens gained directly from practical corroded steel structures own the historical corrosion damage, and the corrosion morphology of specimens can reflect the actual situation. However, the specimens gained from actual engineering may own other damage, such as fatigue damage, plastic damage and so on. Moreover, because the actual engineering usually do not keep perfect members, so it is hard to gain the control group specimens.

In the literature [6], the following conclusions are reached: (a) to evaluate the anti-corrosion performance, wet/dry cyclic tests can be used to shorten the time in the laboratory; (b) the Cebelcor test can be used to simulate the rural-urban atmosphere with low sulfur dioxide pollution; (c) Kesternich tests can be used to simulate well with industrial atmosphere with high sulfur dioxide pollution; (d) the marine atmosphere can be simulated by Prohesion cyclic tests.

3. Mechanical behaviour of corroded steel structures

The effect of corrosion on the thickness of steel plates have been investigated by many researchers, and various models concerning thickness reduction were developed [7-8]. Meanwhile, attention was paid to the effect of corrosion on the mechanical behaviour of steel. They found that the corrosion not only reduces the cross-section area of the steel member but also can diminish the strength of steel, because the surface of steel plates becomes an irregular plane which causes stress concentration. Garbatov et al. [9] tested corroded plate specimens which were cut from a bod girder initially corroded in real sea water conditions, and they found that yield stress and tensile strength is reduced with corrosion. Sheng and Xia [10] analysed the multiple corrosion factors on mechanical properties of steel, and the results indicate that shape, depth and distribution of pit exert little influence on the ultimate load of tensile samples. Xu et al. [11-14] investigated the mechanical properties of corroded flat specimens and proposed constitutive model for corroded steel, and they conclude that all mechanical properties decrease significantly when the corrosion rate is over 15%. Additionally, many literatures have investigated the effect of corrosion on the mechanical behaviour of steel bars [15-17], and the conclusions were similar to those obtained for steel plates. The difference of the corrosion mechanism and corrosion ratio limits the application of these results. Therefore, some researchers proposed constitutive model which can concern the stochasticity of corrosion [18-19].

The aforementioned literate mainly studied the mechanical properties of corroded structural steel materials such as ultimate strength, yield point and elongation. Meanwhile, many researchers also investigated the remaining capacity of corroded steel members and corroded steel structures. Kayser et al. [20] developed a corrosion model for steel girder bridges concerning the location and corrosion rate. Based on the data obtained from actual corroded beams, Sarveswaran et al. [21] proposed a method which can calculate the component reliability of corroded steel members. Based on the measurements of a small sample of corroded beams obtained from a chemical work, a simplified method for
quantifying the initial visual inspection is proposed [22]. Assuming that corrosion wastage and position of corroded area are basic random variables, a stochastic model considering plate thickness and modulus of elasticity is suggested [23]. Through the regression analysis of the calculations, Jeom Kee Paik et al. [24] proposed a closed-form design formulae for ultimate strength of steel plates with pit corrosion wastage and under in-plane shear loads. Tatsuro Nakai et al. [25] carried out several tensile tests to study the effect of pitting corrosion on tensile strength of steel members, and the results show that degradation of the ultimate strength of members with local corrosion is greater than that with overall uniform corrosion, and the compressive buckling test results show that compressive buckling capacity of pitted members is smaller than or equal to that of members with uniform thickness. R. Rahgozar et al. [26] conducted load test for four samples of corrosion damaged beams, and developed minimum curves for various kinds of common beams. Based on the compressive buckling tests for twenty-four specimens, the effect of corrosion on the stability behaviour and resistance of corroded steel angle section members are studied [27]. The bearing capacity tests for two groups of welded H-section beams are carried out, and the results show that the plate thickness is an essential factor influencing the mechanical behaviour of H-section beams [28]. Based on the bearing capacity tests for five H-type corroded steel members and 2 H-type steel members without rust, and results show that the corrosion at flange exert significantly effect on ultimate capacity of corroded H-type steel members [29]. Bearing capacity tests show that the section size, span and corrosion rate are the main factor to affect the ultimate capacity and deflection of corroded channel steel beams [30]. The axial compression tests for sixteen angle members and eight uncorroded members are carried out, and some recommendations are drawn [31]. The stability of tubular members which bear high temperature together with local corrosion are studied in literature [32].

4. Conclusion
The corrosion damage have an effect on the mechanical behaviour of steel material and steel members, which can reduce the safety of steel structures even lead to steel structures destroyed. This paper summarizes and analyses the preparation methods available to gain corroded steel specimens. Then, based on the existing research results, this paper sums up the mechanical properties of corroded structural steel and the remaining capacity of corroded steel members and corroded steel structures. The results show that sufficient attention must be paid to the effect of corrosion on the performance of steel members and steel structures.

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