Investigation on Corrosion Pit Characteristics of Severe Corroded Weathering Steel

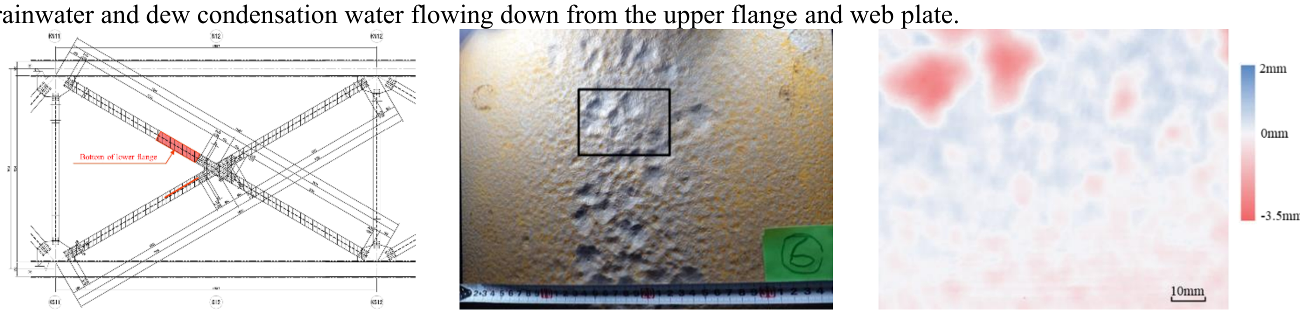
Kyushu University Student Member ○Qidi WANG
Kyushu University Fellow Member Shigenobu KAINUMA
Kyushu University Regular Member Muye YANG

1. Introduction Steel structure usually suffers from corrosion problems because of the long-time exposure in the atmosphere environment. In our previous study, it has been found that the most common shape of the corrosion pits that occurred at common steel in the atmosphere environment are cone-shaped rather than a sphere, which is inconsistent with some research assumptions mentioned by Nakai[1]. Weathering steel structures, especially those exposed to high-salt environments, are also meeting severe corrosion problems. However, there is less research about the corrosion pits' characteristics of weathering steel. It is necessary to investigate the characteristics of corrosion pits of weathering steel, to summarize the shape and distribution of corrosion pit of severe corroded weathering steel in different parts of the steel bridge. In this study investigated a weathering steel bridge located in Kagoshima, Kyushu, Japan which has been serviced for 20 years. The surface profile of the corrosion pits is obtained by using 3D LED scanner. The conclusion can provide a reference for the evaluation of corrosion levels of severely corroded steel structures.

2. Field test method The field test performed in a weathering steel bridge, which is located at Kagoshima in the mountainous area, the straight-line distance from the west coastline is about 5km. All target steel components used the weathering steel according to SMA490AW (JIS G3106) without coating. Due to airborne sea salt coming from both north and south along the valley from the coast. According to previous investigation[2], due to the influence of precipitation, fog and condensation, the wetting time of steel components more than 80%. Because of the high humidity environment, significant corrosion damage has occurred about 10 years after construction. Besides, the stagnant rainwater after heavy rainfall and the use of antifreeze during winter also help the causes of pitting corrosion.

During this investigation, scanned the shape of the corrosion pits on the upper flange, the web, and the lower flange as shown in Fig1(a), and summarized the characters of the corrosion pits of weathering steel. The surface parameters of the corrosion pit are measured by the 3D LED scanner (decomposition energy as 0.01mm) based on the structured projection phase shift method[3,4]. The measured scanning step is 0.2mm. The chosen scan area is the center of the corrosion area with 100mm in length and 80mm in width. The scanned area is shown in Fig.1(b), and the scan result is the spatial coordinates of the corroded surface, drawn as a 2D image as shown in Fig.1(c).

The corrosion pits of weathering steel are almost independent pit and do not overlap with each other, as shown in Fig.1(b). The most severe corrosion occurred at the bottom of the lower flange plate, mainly in the middle of the flange, where rain and dew are always concentrated. The width of the lower flange plate of the steel bridge is 360mm, and the width of the corroded area is about 120mm, accounting for 1/3 of the entire lower flange plate. The corrosion degree of the inner side of the upper flange plate of the lateral bracing is lower only by the bottom of the lower flange plate, and the corrosion pits are also in the middle part of the flange, but more concentrated in the area close to the web, which is caused by the flowing tendency of water. On the web, obvious corrosion pits only be found in the upper part. The corrosion pits at the web should be formed by the rainwater and dew condensation water flowing down from the upper flange and web plate.

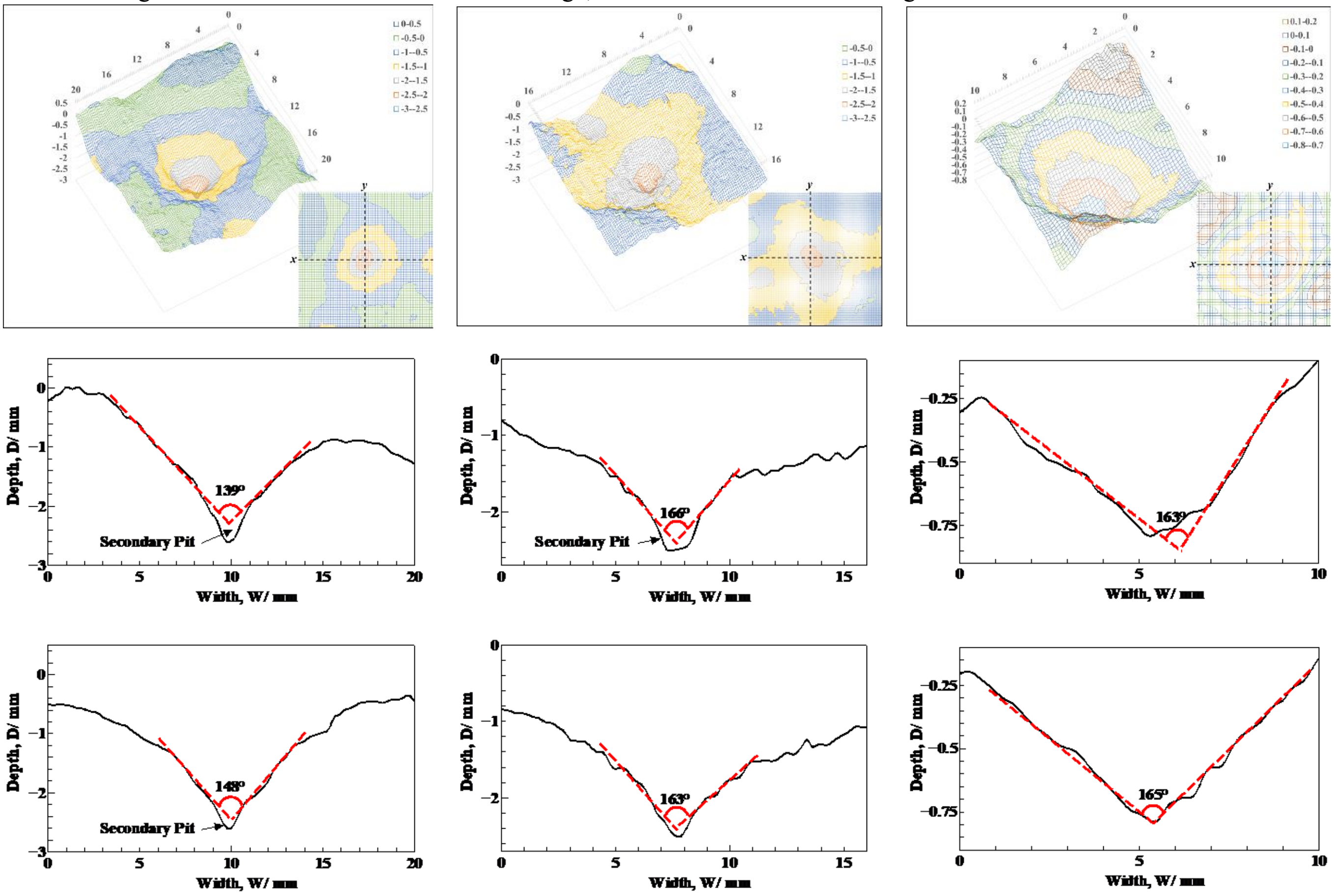


(a)Scan area of the steel bridge (b) Corrosion pits on the lower flange (c) Mapping of the corrosion area

Fig.1 Corrosion pits of weathering steel structure

3. Test results In the investigation of the lower flange, scanned the middle part of the bottom side of the lateral bracing, where the corrosion pit mainly concentrated, and chose 19 independent corrosion pits for analysis. The depth of these corrosion pits ranged from 0.85mm to 4.15mm. Secondary corrosion is found at the bottom of eight corrosion pits, and the corrosion depth of these corrosion pits all over 2mm. As shown in Fig.2(a), it is a corrosion pit with a secondary pit and has a cone shape like the corrosion pit of ordinary steel. The relationship between the depth and angle of the corrosion pits as shown in Fig.3, it is found that the cone angle of the weathering steel corrosion pit has no relationship with the corrosion depth, and the average cone angle is 156°.

In the investigation of the upper flange, scanned the surface of the inner side of the upper flange of the lateral bracing, chose 16 corrosion pits from this area for analysis. The corrosion depth of these pits is from 1.10mm to 3.39mm, smaller than the pits on the lower flange. Among these corrosion pits, only five of them have secondary corrosion pit. The corrosion depth of these corrosion pits also exceeds 2mm. As shown in Fig.2(b), corrosion pits of the top flange are also cone shape, and their average corrosion angle is the same as that of the bottom flange, which is 156° as shown in Fig.3.



(a) Corrosion pits of the lower flange plate (b) Corrosion pits of the upper flange plate (c) Corrosion pits of the web

Fig.2 Characteristics of corrosion pit

The corrosion pits on the web are significantly smaller than the flange. Scanned the upper part of the web and chose 14 corrosion pits for analysis, the maximum corrosion depth the chosen pits is 1.14mm, and no secondary corrosion pits in them. As shown in Fig.2(c), the corrosion pits on the web are also cone shape. The average angle of the corrosion pits on the web is 166° as shown in Fig.3, larger than the pits on the flange.

The previous research analyzed 27 corrosion pits from two corroded components from a common steel bridge in Kitakyushu expressway[5]. These corrosion pits appear on the upper side of the steel beam, and most of them overlap each other. The average cone angle is around 145° like shown in Fig.3.

It can be seen that the corroded position, distribution also shape of corrosion pits of common steel and weathering steel are different, so that need to be studied separately.

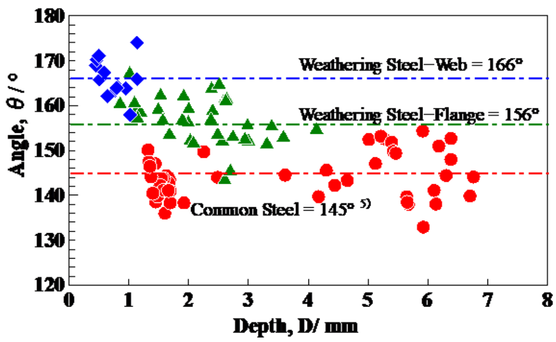


Fig.3 Relationship between pits' angle and depth

4. Summary of Findings 1) The severe corrosion pits' shape of weathering steel is the cone, and its cone angle is larger than common steel corrosion pits, on the flange is about 156° and on the web is about 166°;

2) The severe corrosion of weathering steel is mainly caused by the long wetting time and the most severe corrosion occurs at the water condensed part and is accompanied by secondary corrosion pit.

References 1) Nakai, T, Matsushita, H, Yamamoto, N, & Arai, H : Effect of pitting corrosion on local strength of hold frames of bulk carriers (1st report), Marine structures, Vol.17, No.5, pp.403-432, 2004. 2) Fujioka, Y, Warashina, A, Takaki, S, Naka, K, Kainuma, S, Michino, S& Yamamoto, Y: Estimating the causes of corrosive damage and assessing corrosiveness in unpainted weathering steel truss bridges in highly corrosive environments (Part 1) Investigation of corrosive damage, Rust prevention management, Vol.60, No.7, pp.264-272, 2016. 3) Liu, K, Wang~~ANG~~, Y, Lau, D: Dual-frequency pattern scheme for high-speed 3-D shape measurement, Optics express, Vol.18, No.5, pp.5229-5244, 2010. 4) Zhang, S, and Shing-Tung, Y: High-resolution, real-time 3D absolute coordinate measurement based on a phase-shifting method, Optics Express, Vol.14, No.7, pp.2644-2649, 2006. 5) Wang, Q~~D~~, Kainuma, S, Yang, M~~Y~~: Investigation of the relation between rust characteristics and corrosion degree of common carbon steel, Collected Papers on Steel Construction, Vol.28, p.267, 2020.