EVALUATION OF DAMAGE CONDITIONS IN ASR-AFFECTED STRUCTURES

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1. INTRODUCTION

For structures with ASR progressing notably, the fracture of rebar has been confirmed to easily occur in the bent part of stirrups. In this paper, one bridge pier suffering great deteriorations and fractures of stirrups was evaluated. Firstly, general deteriorations including the fracture and the external crack conditions for the pier were studied. After that, through cut of cross sections in beam part of the pier, the interior damage conditions due to ASR was analyzed. As a result, the general deformation forms of the cross section and the correlating effect on bent part of rebar were estimated.

2. FRACTURE AND EXTERNAL CRACK CONDITION

Fig. 1 shows the objective pier from the bridge located in the Hokuriku Region of Japan. The ASR deterioration becomes obvious in this bridge after 17 years of services. During 5 years after the maintenance of surface coating, cracks appeared again on the surface coating materials, which indicates the great deteriorative degree. As shown in Fig. 1, the objective pier is an oval shaped overhanging RC type structure with the length of beam part as around 14.0m and the width as 3.0m. The section A and B in the overhanging part of beam is the cutting position for investigating interior cracks (refer to next chapter).

Herein, the fracture conditions are stated. Fig. 2-(a) illustrates the reinforcements of the cross section. The bent part of stirrup is named like TU, KU for the following descriptions. Three damage types are defined based on the visual observations. As shown in Fig. 2-(b) (viewed from the right side, refer to Fig. 1), along with the beam axis, many rebar are confirmed to surfer damages. There are rebar damaged continuously as illustrated in (1) of Fig. 2; while there are also rebar damaged individually as in (2) of Fig. 2. As for the damage ratio (ratio of number for damaged rebar to the total number), 69%, 46%, 25% and 20% is counted for the KU, TU, KL and TL side, respectively. The upper side of beam has greater damage ratio relatively. In general, the total damage ratio of this pier is around 46%, from which, great deterioration is confirmed to occur.

Fig. 3 illustrates the crack conditions in the right profile. The data was recorded on the surface coating material. The general crack density in profile is 3.38m/m^2 and the maximum crack width is around 2.0mm. In the web part of the profile, it is observed that cracks are notable in horizontal direction. Though after the surface coating, crack with width greater than 1.0mm generated. The notable crack in horizontal direction is located in around 1500mm below the upper surface; while the maximum thickness of covering layer is 300mm. Thus, it is known that the bent part of stirrup has roughly 1000mm height difference with the horizontal cracks. It is difficult to conclude that the occurrence of great cracks is correlated with the damage of rebar. For studying the connections with cracks in profile, the interior crack conditions are evaluated in the next chapter.

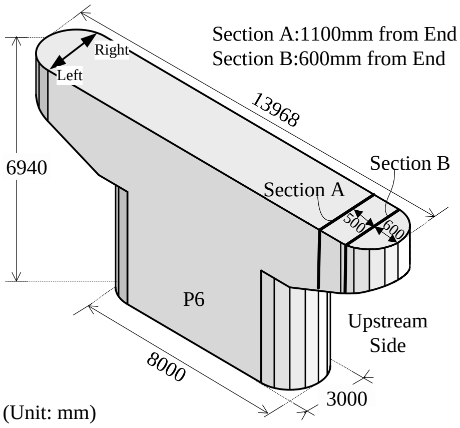
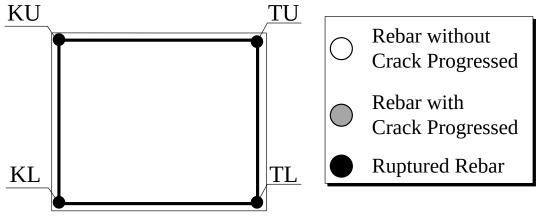
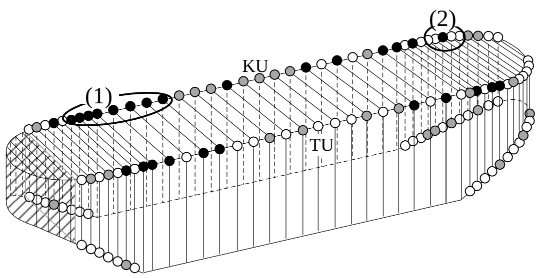


Fig. 1 Objective Bridge Pier



(a) Sectional View and Graph Legend



(b) Fracture Conditions

Fig. 2 Fracture of Stirrups in P6

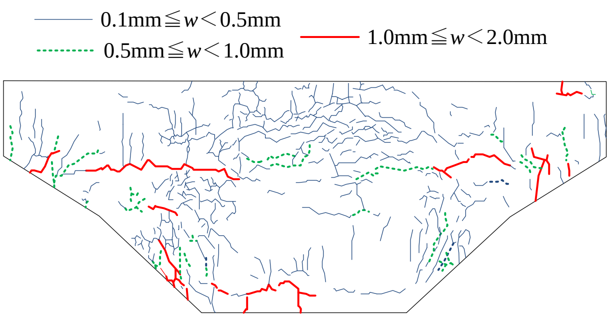


Fig. 3 Cracks in Profile

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3. INTERIOR CRACK CONDITION

As illustrated in the former Fig. 1, two sections were cut in the overhanging part of the beam. As representative, the interior crack conditions of section A is evaluated in Fig. 4. The maximum crack width is near 2.0mm, being similar to that in profile. However, the average crack density in the section is 6.13m/m^2 being greater than the 3.38 m/m^2 in profile. Thus, it is found that the interior section has suffered enough deterioration. Cracks in inner of the section seem to have smaller width than those in outer. In peripheral central area of the section (*a* of Fig. 4), cracks have the trend to stop at the position of stirrups. However, in the corner area (*b* of Fig. 4), cracks are much like to spread across the stirrups. By general view, it is considered that cracks in different areas have different trends. Therefore, the crack directions in the section are evaluated in the following.

Fig. 5 and Fig. 6 present the vectors of cracks considering the crack density for the part *b* (Fig. 4) and the general section. 10 divisions are conducted for the two directions with the mesh size as 282mm×190mm. Cracks with widths greater than 0.2mm in each mesh are divided into two types by their positions as in 1, 3 quadrants and 2, 4 quadrants. Thus, by compositions, the direction is obtained.

As illustrated in Fig. 5, the crack in corner area has the rough trend to progress at around 45˚. Great density near 10m/m^2 occurs in this area. Further, as shown in Fig. 6, this trend can also be found in other corner areas. When cracks in corner progress deeper, directions become along with the stirrup as illustrated in (1) of Fig. 6. Due to greater restrains, the crack density is smaller in the inner of the section. As presented in (2) of Fig. 6 (corresponding to *a* of Fig. 4), cracks in peripheral central area have trends to progress perpendicularly to profile.

For studying the differences of crack directions, Fig. 7 shows estimation of the mechanisms. Cracks in peripheral central area of the section have smaller length and progress vertically from the profile. This type of crack is considered to be caused by bending effect together with the general circular deformation of the section (Fig. 7-(a)). Besides, for cracks in corner area, the development length is relatively greater and the direction is around 45˚. This type of crack is considered to be caused by the uniform tension due to ASR expansion and accompanies with the uniform movement (Fig. 7-(b)).

As also estimated in the former research, general circular deformation of the section has correlation with opening deformation of stirrup in corner (angular increment of bent part in stirrup). The opening deformation of stirrup is also considered to induce the progress of initial damage in stirrup. From the evaluation of internal cracks herein, the opening deformation of stirrup can be estimated further.

4. CONCLUSIONS

(1). The interior section has suffered enough deterioration with maximum crack width as 2.0mm and average density as 6.13m/m^2;

(2). The height difference between great crack and bent parts of stirrup is around 1000mm. Relationship between great external cracks and damage of stirrups is not confirmed;

(3). By observation of cracks in interior section, cracks in peripheral central area is estimated to be correlated with the general circular deformation. This deformation is associated with the opening deformation of stirrup.

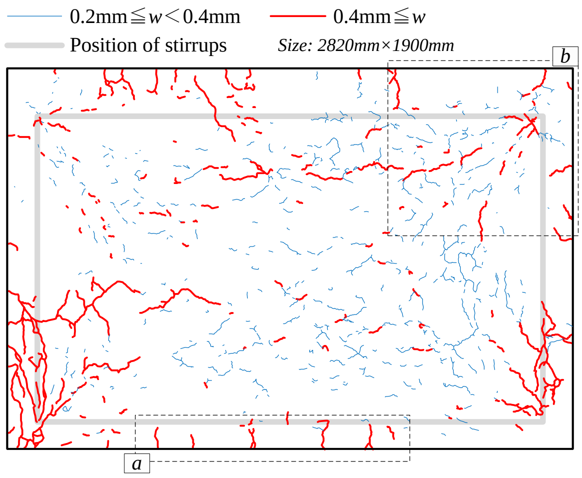

Fig. 4 Inner Cracks in Section A

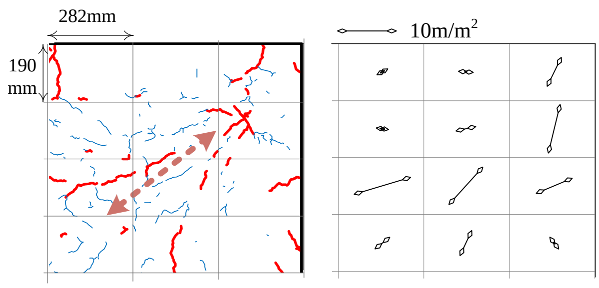

Fig. 5 Detail of Cracks in Part *b*

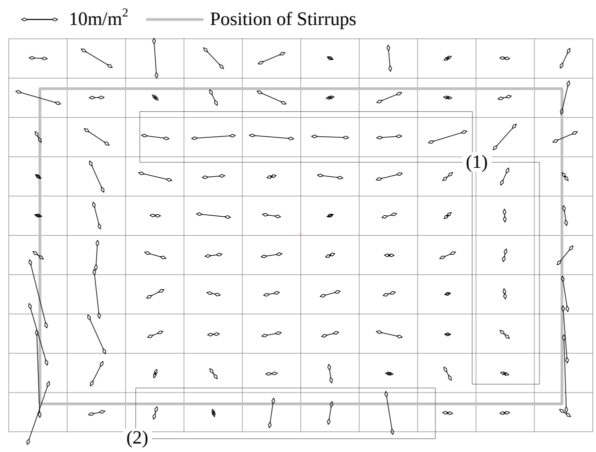

Fig. 6 Crack Density and Directions

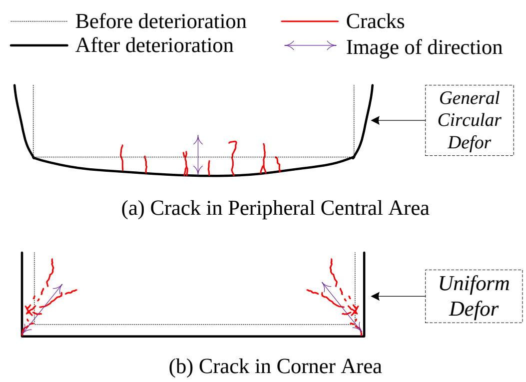

Fig. 7 Image for Mechanism of Cracks