EVALUATION FOR FRACTURE OF REBAR DUE TO ASR EXPANSION

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1. INTRODUCTION

For the structures with ASR progressing notably, the fracture of rebar has been confirmed to easily occur in the bending part or joint part of the stirrups. Experiments to investigate the influence from the ASR expansion on the damage or fracture of rebar are few. This study is to check whether rebar in structures will fracture and the easiness degree to fracture due to the ASR. The authors conduct the simulation tests with 1/4 scale of the actual structure by using different amount of expansive mortar, different type and ratio of rebar as parameters.

In this paper, the external damage condition of the specimen will be introduced firstly. Thus, the time depended variation of strain in measuring line will also be explained. For discussing the mechanism of fracture, the authors will give observations to the inner condition of the specimen. Lastly, based on the inner condition, the fracture mechanism of rebar due to ASR will be evaluated.

2. EXTERNAL DAMAGE CONDITION

Fig. 1 illustrates the specimen condition (size as 916mm×916mm×1600mm). For simulating the expansion, expansive mortar with the area as 456mm×456mm is used in the square surrounded by normal concrete. The steel ratio of stirrup is 0.22% being same as the actual structure with rebar fractured. Further, the stirrups are constituted by three types as current type and B, C types (rebar extracted from actual structures). The joints of different rebar are welded by flare. As illustrated in Fig. 1, among all the 8 stirrups, the No. 3 stirrup from the upside of the specimen fractured due to the expansion in the experiment.

The external damage condition of concrete surface is summarized in Fig. 2. Referring to Fig. 1, the side 2 which contains the fracture place and the side 1 which doesn't are used for observations. The cracks with their width smaller than 0.2mm and greater than 0.2mm are divided. It is known that cracks occurred overall in both these two sides. In the left corner of the side 2, which includes the fracture place A, there is a trend that the cracks with great width of about 3mm developed intensively. Further, taking the cracks with widths greater than 0.2mm into account, the density of crack is 3.51 m/m^2 and 3.27 m/m^2 for side 2 and side 1 with relatively small difference.

In addition, the authors will discuss another factor (strain in the measuring line) to evaluate the external damage condition. As shown in Fig. 3, 15 measuring lines with the interval as 100mm have been drawn in the transverse direction to the main rebar. The cracks are measured and sketched by each 0.5h when the expansion pace is great and by each 1~2h when the expansion pace is small. The measuring objects are the 4 sides and the upside of the specimen. By calculating the overall crack width in the intersections of measuring lines and cracks, the strain in measuring line is calculated by the following Eq. (1):

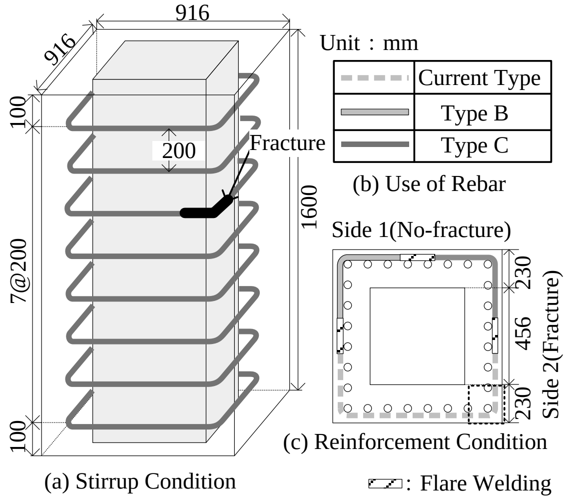

Fig. 1 Shape of Specimen & Fracture Position

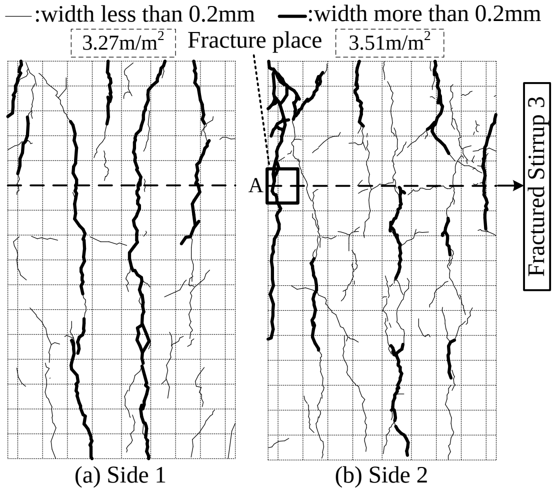

Fig. 2 Ultimate Crack Condition (Side 1, 2)

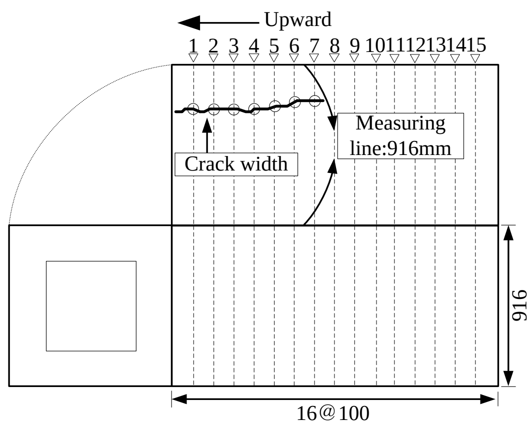

Fig. 3 Measurement of Strain

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$$\text{strain} = \frac{\text{Overall crack width}}{\text{Length of measuring line(916mm)}} \qquad (1)$$

To check whether there is more notable damage in the section with stirrup fractured, the strain in 4 sides of the section containing No. 3 stirrup and the general average strain of the sections containing other stirrups are illustrated in the Fig. 4. The time 0 is the point when crack began developing on the surface. It can be known that both the strains of section with fracture and general average are in small level before the point A (1.8h). From point A to point B (3.25h), due to the acceleration of ASR, the strains of them increase in relatively great paces. In general, no great difference is found before the point B between the section with fracture and the average. After point B, the increasing pace becomes smaller and small difference between the two strains occurs before point C (4.75h). After point C, both strains become no longer to increase. For the general conditions, variations of the two kinds of strains are in similar trends and the difference between them is relatively in small level with 13% (373μ) in the ultimate state.

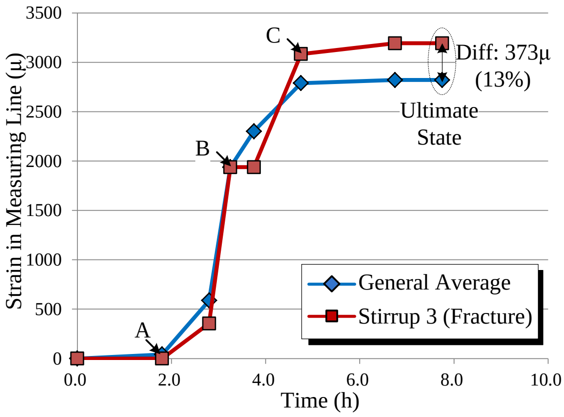
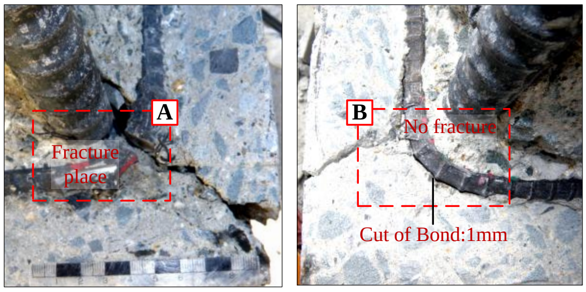
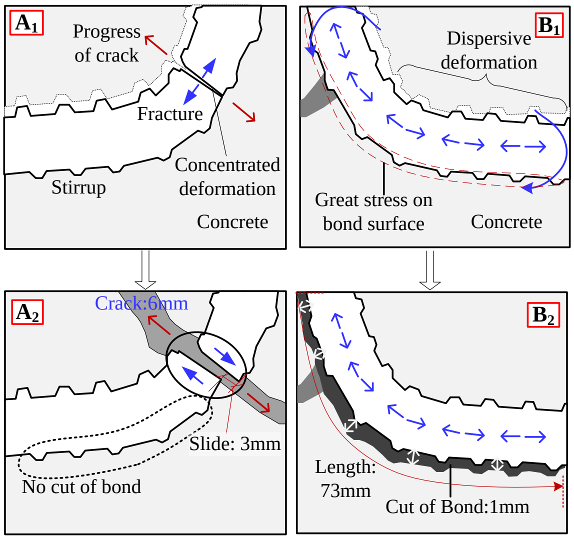


Fig. 4 Comparison of Strain in Measuring Line



(a) Section with Fracture (b) Section without Fracture

Fig. 5 Fracture Part & Non-fracture Part



(a) Section with Fracture (b) Section without Fracture

Fig. 6 Image of Mechanism

3. INTERIOR DAMAGE CONDITION

As described in the last chapter, no great difference can be found between the external damages of section with fracture and the general average. That is to say the expansion energy in the section with fracture is similar with the average. Thus, to check the reason resulting in the fracture, the interior damage conditions around the corner of stirrups are concentrated for discussion.

Fig. 5 illustrates the actual conditions of section with and without fracture. From Fig. 5 (a), it is known that the corner of the stirrup is fractured with great cracks of the concrete developed through the fracture surface; while the bond between stirrup and the concrete is maintained well. However, as shown in Fig. 5 (b), it is confirmed that no fracture of stirrup occurred while the cut of bond generates with the width about 1mm.

For investigating the reason of this difference occurred in the section with and without fracture, the derivation of the mechanism is illustrated in Fig. 6 by concentrating on the A and B areas in Fig. 5. From A_1, it is considered that the initial crack in the corner of the stirrup caused the fracture with the development of expansion. Thus, with the further expansion, concentrated deformation will occur on the fracture surface. This leads to the great slide of 3mm (A_2 of Fig. 6) occurred between the fracture surface. The crack of the concrete with width of 6mm developed through the fracture surface. Further, also due to the concentrated deformation, the stress between stirrup and concrete is small, which leads to the no cut of bond between them.

On the other hand, the section without fracture is presented in the B of Fig. 6. From B_1, the stirrup is not fractured which caused the dispersive deformation of the stirrup with the development of expansion. This further induces the relative motion and the great stress between concrete and stirrup on the bond surface. As a result, cut of bond occurred with the length as 73mm which is even greater than the length of bending work (50mm).

As a conclusion, fracture which is caused by the initial crack induced the concentrated deformation on the fracture surface. This further leads to great cracks occurred through the fracture surface and the maintaining of bond.

4. CONCLUSIONS

(1). Through the simulation test of ASR expansion, we find 1 among the total 8 stirrups in the specimen fractured;

(2). From the comparison of strain in the measuring line of section with fracture and the general average of other sections, relatively small difference with only 13% occur in the ultimate state;

(3). The initial crack in the stirrup is considered to cause the fracture and then due to the concentrated deformation in the fracture surface, no cut of the bond occurs.