NUMERICAL INVESTIGATION ON SHEAR BEHAVIOR OF RC BEAMS WITH LOCAL BOND DETERIORATION

Nagoya University Student Member ○ Cong Luyen Nguyen
Nagoya University Regular Member Hikaru Nakamura, Yoshihito Yamamoto, Taito Miura

1. INTRODUCTION

It is obvious fact that when rebars in concrete structures are corroded, the structural performance can probably be changed due to losses of cross-sectional area of reinforcement as well as losses of bond strength. A number of researches have widely investigated on shear behavior of RC members with bond deterioration. However, it has yet to be made clear due to the various situations of corrosion such as corrosion location, corrosion level, crack pattern, etc. In order to deeply understand the effect of many factors, analytical investigation would definitely be useful based on powerful numerical tools. In this study, shear behavior with bond deterioration including shear strength, crack pattern and shear mechanism based on beam and arch actions in beams is investigated by using 3-D Rigid-Body-Spring-Model (3-D RBSM).

2. ANALYTICAL MODEL BY USING 3-D RBSM

In 3-D RBSM, concrete is modeled by an assemblage of rigid particles interconnected by means of springs along their boundary surfaces. A random geometry of rigid particles is generated by Voronoi diagram to avoid mesh bias. The applicability of RBSM to ultimate behavior of RC members is confirmed and the results show the realistic cracking behavior (Yamamoto et al. 2008).

In order to observe explicitly the effects of bond deterioration on shear behavior, RC beam is modeled with a/d=3.14 and stirrups are arranged in one shear span to prevent shear failure while bond between concrete and rebars in other shear span is reduced. This model is named as SS beam, as shown in **Fig.1a**. Other model is made with 200mm reduced bond length in the middle of objective shear span in order to take into account the effects of length of bond deterioration. This model is named as MSS200 beam and shown in **Fig.1b**. Analytical model was shown in **Fig.2**. The average element size is 20 mm. All reinforcement are modeled by beam elements. The bond between concrete and reinforcement is modeled by zero-link element and bond stress-slip relationship is introduced. In this study, degree of bond deterioration were expressed by changing the maximum bond strength τ_{max}, as indicated in **Fig.3**.

3. SHEAR BEHAVIOR IN BEAM WITH LOCAL BOND DETERIORATION

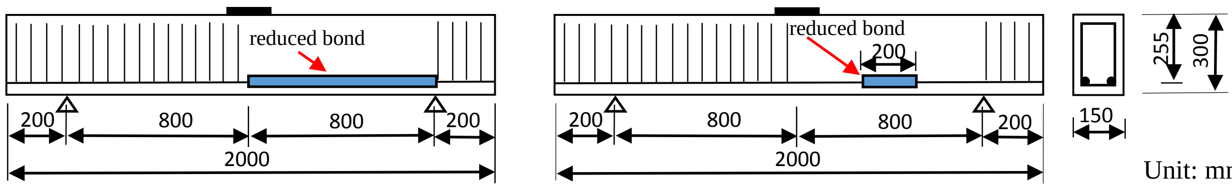
By changing the bond strength between concrete and longitudinal bars corresponding to each level of bond deterioration, specifically 20%, 40% and 60%, the load-displacement relationship, failure mode and principal stress distribution have finally been obtained.

3.1. Beams with bond deteriorated entire shear span (SS beams)

The results of load-displacement relationship, crack pattern and stress distribution at peak loads in SS beam are shown in **Fig.4** and **Fig.5b-d**, respectively. The shear strength increases significantly as bond strength reduces higher level and all of cases are recognized higher shear capacity in comparison with normal bond beam. Observed crack pattern shows that as bond strength reduces lower, crack location is shifted toward loading point and there is observed that no diagonal crack occurred in high bond reduction cases. In term of stress distribution, it is notice that the lower bond strength is, the larger area of arch stress flow is created. (**Fig.5b-d**).

3.2. Beams with bond deteriorated in 200mm middle shear span length (MSS200 beams)

The results of MSS200 beam are shown in **Fig.5e-g** and **Fig.6**. It is indicated that there are explicit increases in shear strength as bond becomes weaker, but it is lower than that of SS beam with the same level of bond deterioration.



Unit: mm

a) SS beam b) MSS200 beam

Fig.1 Specimen outline

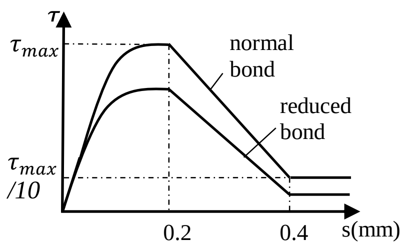


Fig.3 Bond stress-slip relationship

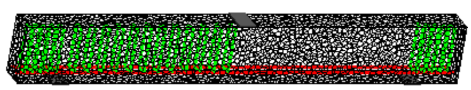


Fig.2 Analytical model

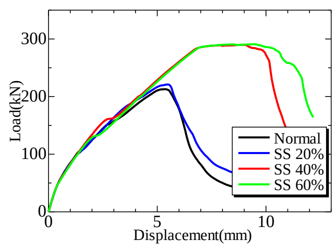
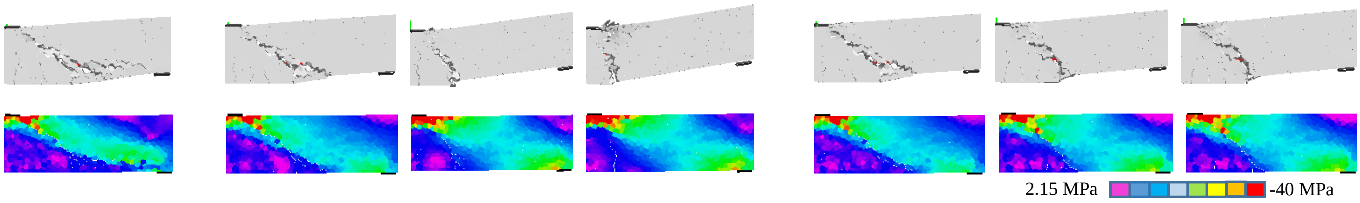


Fig.4 Load-displacement relationship in SS beams

Keywords: shear behavior, bond deterioration, shear resistant mechanism, beam action, arch action, 3-D RBSM
Contact address: 〒466-8603 Nagoya University, Chikusa, Nagoya, Tel: 052-789-5690



(a) Normal (b) SS 20% (c) SS 40% (d) SS 60% (e) MSS200 20% (f) MSS200 40% (g) MSS200 60%

Fig.5 Crack pattern at failure and axial stress distribution at peak load in shear span in beams with bond deterioration

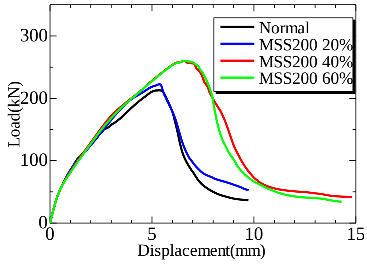
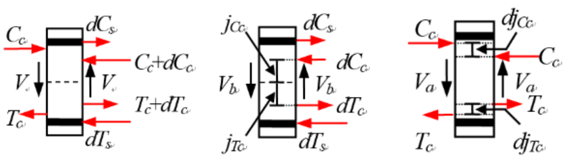


Fig.6 Load-displacement relationship in MSS200 beams

Crack patterns appeared absolutely similar trend with those of SS beam case, such as shifting toward loading point. However, in this case, due to the reason that bond is only reduced in 200mm middle shear span and bond in other parts is probably good, diagonal crack, therefore, occurred in sections near bond reduction area and is not steeper than that of SS beam. Stress distribution also presented the same shape as that of SS beam but stress concentration near the support is slightly weaker (**Fig.5e-g**).

4. EVALUATION OF TRANSITION OF SHEAR RESISTANT MECHANISM BY DECOUPLING METHOD

It is well-known that shear resistance consist of beam and arch actions. With the use of local stress results obtained by 3-D RBSM, by considering the equilibrium of a small segment *dx* which is 100mm between two adjacent beam cross section, the beam action V_b and arch action V_a were decoupled (**Fig.7**) for all segments in objective shear span (Iwamoto et al. 2015). The average decoupling results of shear resistant mechanisms for all segments *dx* corresponding to each displacement condition were shown in **Fig.8** and **Fig.9**.



(a) Equilibrium (b) Beam action (c) Arch action

Fig.7 Mechanical interpretation of shear resistant components

It is confirmed that for all cases, the sum of beam and arch action agrees well with analytical load-displacement curve. Figure 8 and 9 show that beam action is recognized the punctual trend while arch action experiences the dramatic increases as bond strength reduces lower. Stress distribution in **Fig.5** is an evidence that can explain why arch action in both cases is significantly huge. As the bond strength decreases, the load from tensile rebars could not transfer to concrete but to the support and consequently resulting in the dramatic increase in arch action due to the formation of strong arch stress flow starting from both loading point and the support. Nevertheless, there is considered that arch action in SS beam is higher than that of MSS200 beam with the same bond deterioration level, which is the main reason for the differences in their shear capacity. In MSS200 beam, stress concentration near the support is smaller than that of SS beam due to the far distance between bond reduction area and the support.

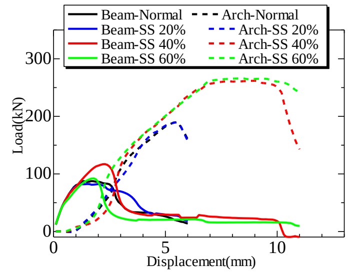


Fig.8 Beam and arch actions in SS beams

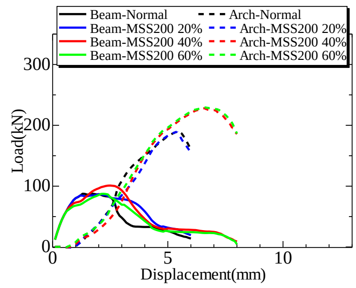


Fig.9 Beam and arch actions in MSS200 beams

5. CONCLUSIONS

It is concluded that bond strength between rebar and concrete plays a key role in shear behavior of RC beams. In case of beam with a/d = 3.14, by reducing bond strength into various levels, the changes in shear strength, crack pattern and shear carrying mechanism are observed. Using local stress distribution obtained from 3-D RBSM and decoupling shear resistant mechanism into beam and arch actions, it is clear that deterioration in bond strength may result in the transition in shear resistant mechanism – dramatically build-up arch action because tensile force in longitudinal bars could not be transferred to concrete but to the support.

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