Shear behavior of RC beams containing vertical penetrating pre-cracks

The University of Tokyo Student Member PIMANMAS Amorn
The University of Tokyo Student Member HOSODA Akira
The University of Tokyo Regular member MAEKAWA Kohichi

1. INTRODUCTION

Research in shear of RC to date has been primarily focused on a member with very few initial defects as underlying assumption [1]. In fact real RC members in severe environments are attacked by pre-cracks, which can, to a certain extent, affect the shear behavior. This paper aims to elucidate the influence of these pre-cracks.

2.EXPERIMENTAL PROGRAM

2.1 TEST SPECIMENS AND LOADING SETUP

Four reinforced concrete beams were tested. The size and dimension of beams and reinforcing bars used are shown **Fig.1**. The top and bottom main reinforcements were provided for the reversed flexural loading. The main reinforcement ratio was designed to be 1.14 %.

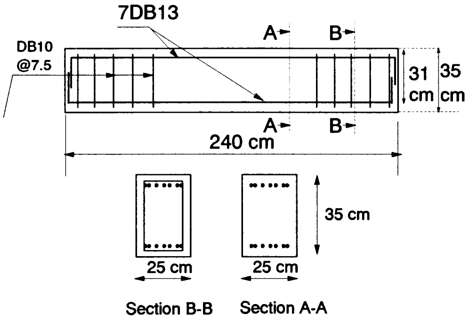


Fig. 1: Beam dimension

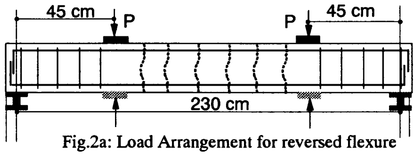


Fig.2a: Load Arrangement for reversed flexure

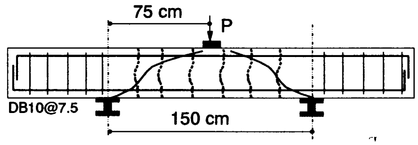
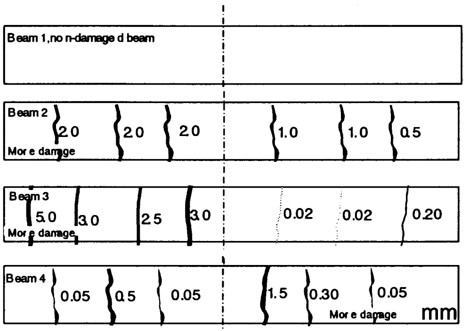


Fig.2b: Load Arrangement for shear

Loading set up was composed of two steps (Fig.2a and 2b). First reversed flexural loading was applied to the beams to introduce vertical penetrating pre-cracks. After reversed flexural loading, pre-crack conditions were carefully recorded and graphically displayed in Fig.3. In the second step shear loading was applied to the beam. Supports were moved towards beam mid-span to cause shear span to effective depth ratio equaling 2.41(Fig.2b). Beams were designed to fail by shear before yielding of main bars. The ratio of yielding load to shear failure load was designed to be 1.5.

3 TEST RESULTS AND OBSERVATION AFTER SHEAR LOADING

Load – center-span deflection relationships of all beams are shown in **Fig.4** along with corresponding failure crack patterns. Summary of test results for each beam is given in **Table 1,** which shows the load capacity of each beam, percent increase in loading capacity and the side of the beam where shear failure took place in the experiment.



Note: 1. Numbers along cracks are residual crack width measured by crack gage after reversed flexural loading in mm

2. The side of the beam that was more severely cracked in indicated in the figure

Fig.3: Initial pre-crack conditions of beam after reversed flexural loading

4. DISCUSSION

4.1 NON-DAMAGED BEAM

Non-damaged beam containing no pre-cracks was used as the reference test. Once diagonal crack formed, it suddenly failed the beam. The failure zone was narrow and localized. **Fig.4a** shows the failure crack pattern in the non-damaged beam.

4.2 DAMAGED BEAMS

In damaged beams, discontinuous diagonal cracks formed around vertical pre-crack without penetrating through it as shown in **Fig.4** and **Fig. 5**. The propagation of diagonal cracks was stopped due to low traction transfer along pre-crack as shown in **Fig.5a**

Table 1:Summary of loading capacity

Beam	Loading capacity(KN)	Percent load increase(%)	Side at which shear failure took place
Non-damaged beam	156.96	0.0	Left
Beam 2	233.48	48.75	Right
Beam3	184.92	17.81	Right
Beam4	217.29	38.44	Left

Key words: Cracking damages, Crack Interaction, Z-crack, Crack stoppage and diversion

113-8656 Concrete Laboratory, Dept. of Civil Eng., The University of Tokyo, Bunkyo-ku, Hongo 7-3-1,Tokyo

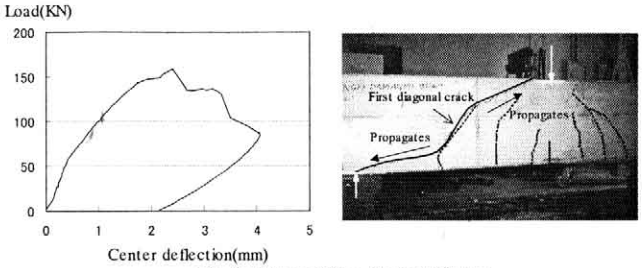


Fig. 4a: Beam 1:Non- damaged beam

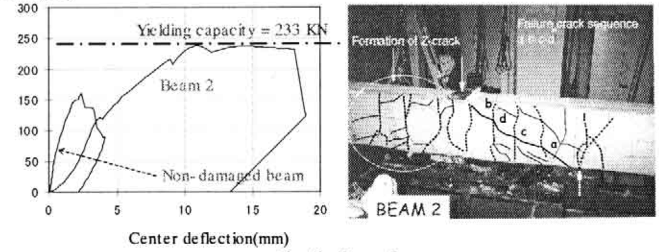


Fig. 4b: Beam 2

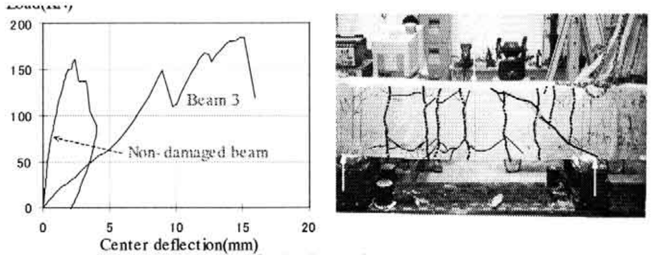


Fig. 4c: Beam 3

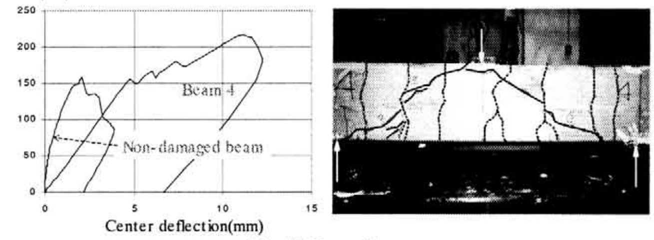


Fig. 4d: Beam 4

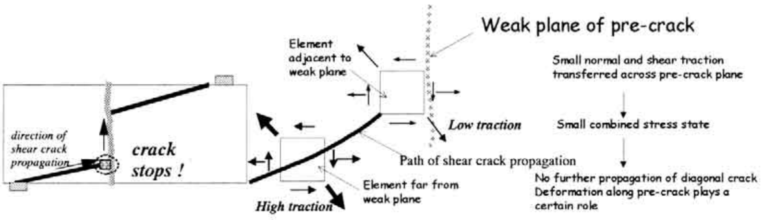
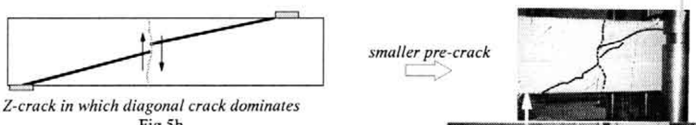
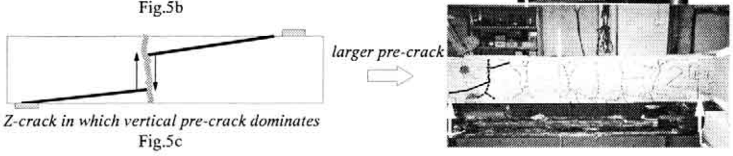


Fig.5a: Mechanism of crack stoppage and diversion



Z-crack in which diagonal crack dominates
Fig.5b



Z-crack in which vertical pre-crack dominates
Fig.5c

Instead, large slip along vertical pre-cracks resulted. Through the stoppage and resulting diversion of diagonal crack propagation, sudden formation of one failure diagonal crack as observed in non-damaged beam was prevented. Consequently, shear capacity of damaged beams was increased. The formation of diagonal cracks, when combined with the vertical pre-crack, resulted in a crack having the shape similar to the alphabet Z. Hereupon, this crack configuration will be referred to as Z-crack. Failure characteristics as well as ultimate capacity of damaged beams were significantly affected by the behavior of Z-crack, which depended upon its geometry.

Initial condition of pre-crack played great role on the geometry of Z-crack. If the width of pre-crack was adequately large, as in the case of beam 2, initially formed Z-crack attained the shape somewhat like in **Fig. 5c** reflecting dominant contribution of pre-crack. This geometry was difficult to fail the beam. The beam was failed by the formation of new diagonal cracks after yielding of main bars as shown in **Fig. 4b**. Here, cracks *a* and *b* formed first at load around 128 KN but could not fail the beam. Beam attained significantly higher loading until it yielded at load 233 KN. Crack *c* and *d* were then suddenly formed and upon merging with cracks *a* and *b*, could lead to failure of the beam. Beam 4 offered different story. Due to smaller width of pre-cracks, Z-crack followed the shape as shown in **Fig.5b**. The behavior was dominantly governed by diagonal crack and therefore could fail the beam soon after its formation (see **Fig.4d**). In beam 3 with clearly unequal damage extent between the left and right side (**Fig.3**), Z-cracks similar to those of beam 2 were observed in the side of more damages while Z-crack similar to that of beam 4 was observed in the side of less damage (**Fig.4c**). The failure behavior of this beam was thus governed by Z-crack in the side of less damage. Load-deflection relationship of damaged beams showed nonlinearity from the beginning of loading due to the deformation of pre-cracks. Later stage of nonlinearity reflects the interaction of pre-cracks and diagonal cracks forming the Z-crack.

5. CONCLUSIONS

This paper reports the effects of pre-cracks on the shear behavior of the reinforced concrete beam. Significant difference exists between beams with pre-cracks and non-damaged beam in terms of loading capacity, failure characteristics and the load-displacement relationship. The phenomena of crack stoppage and diversion as well as the formation of Z-crack demonstrated the strong influence of non-orthogonal crack interaction, which dramatically affects the behavior of damaged beams.

REFERENCES

1. ASCE-ACI Committee 445 on Shear and Torsion, “Recent Approach to Shear Design of Structural Concrete” J. of Struct. Eng.,124, Dec. 1998, pp.1375-1417