An Analytical Investigation of Influence of Bending Radius of Reinforcement on Failure Mechanism in L Beam-Column Joint by FEM

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1. Background

Nowadays in Japan, seismic design code is becoming more stringent. To satisfy the stringent requirements, lager amounts of reinforcement must be placed, resulting in increased reinforcement congestion. This problem particularly occurs at beam-column joints, where reinforcements meet from many different directions. As a result, it becomes difficult to ensure proper concrete compaction and then poorer concrete quality may result. Moreover structural performance in L beam-column joints is thought to change according to reinforcement arrangement. However, it is difficult to clarify the structural performance on complicated reinforcement arrangement like beam-column joints, so only little analysis have been done for the beam-column joints. From the previous experiment by Horita, different failure pattern occurs in L beam-column joints according to different bending radius and local failure occurs with small bending radius. In this study, numerical simulations were carried out to simulate the local failure and investigate the influence of the bending radius in the L beam-column joints by FEM (Finite Element Method).

2. Analysis Model

To investigate the influence of bending radius of reinforcement on failure mechanism in L beam-column joints, numerical simulations were carried out by COM3, FEM software, based on the experiment by Horita[1)]. The parameter is bending radius of reinforcement (20mm, 80mm) and how to reproduce the reinforcement (RC element (Fig.2 (a)), steel element (Fig.2 (b))). With RC element, difference of bending radius cannot be reproduced due to meshing, so totally 3 cases, 1 for RC and 2 for steel, were carried out (Table1). The property of the element is same as experiment. The shape of steel element is square which has same area as experiment because of meshing problem. At the end of the beam and column, rigid steel plates with enough high elastic modulus were set same as the experiment. 0.2mm/step displacement were introduced to the center point of the beam end and the center point of the column end was fixed (Fig.2). In ST2 and ST8, reinforcement was arranged same as experiment but the detail reinforcement was not set due to calculation cost.

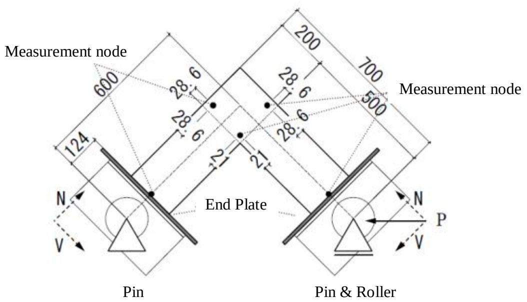
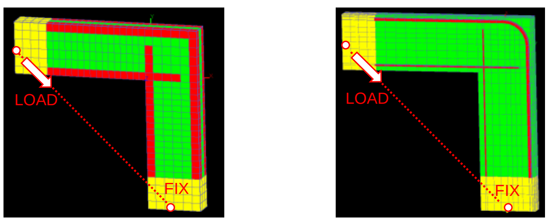


Fig.1 Experimental Setup(Horita, 2012) (Unit:mm)



(a) RC(Red : RC element) (b) ST8(Red : Steel element)

Fig.2 Analysis Overview

(Green : Concrete, Yellow : Rigid Steel)

Table.1 Analysis Cases

Case	Bending Radius (mm)	Concrete			Steel		Number of Element
		f_t (MPa)	f'_c (MPa)	Elastic Modulus (kN/mm²)	Elastic Modulus (kN/mm²)	Yielding Value (MPa)	
RC	-	2.97	39.3	29,900	190,000	457	1,316
ST2	20						8,019
ST8	80						6,696

Keywords L Beam-Column Joint, Bending Radius, Local Failure, Finite Element Method

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3. Result of Analysis

3.1 Load-Displacement Relationship

In 80mm case of the experiment, failure occurred out of bending reinforcement area, as a result of that, the load did not decrease after maximum load (Fig.3). In ST8 of analysis, failure and load shows same tendency as experimental result (Fig.4). In 20mm case of the experiment, local failure occurred in bending area of reinforcement, so the load decreased after maximum load. In ST2 of analysis, failure and load shows same tendency. In RC of analysis, the load did not decrease after maximum load. In all 3 cases, maximum load capacity and initial stiffness are higher than the experiments, that are issues to be solved next.

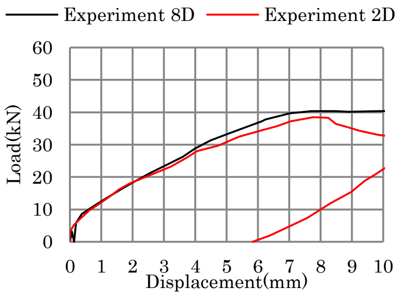


Fig.3 Load-Displacement Relationship

(Experiment by Horita, 2012)

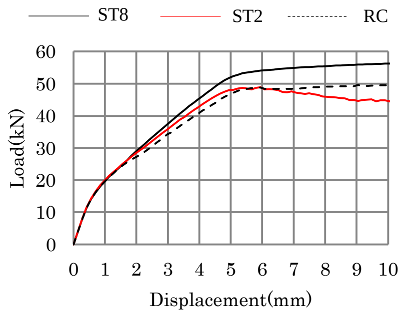
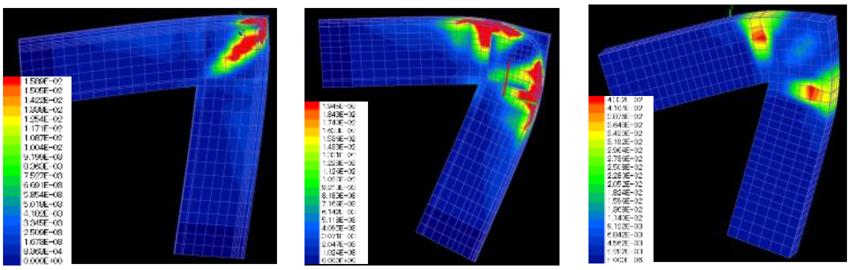


Fig.4 Load-Displacement Relationship

(Analysis)

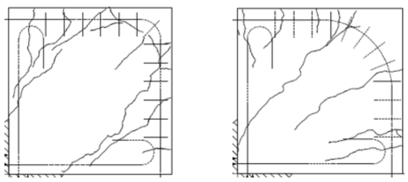
3.2 Crack Pattern

Fig.5 shows stress distributions. In ST2, crack occurs from bending reinforcement area to inside of joint, on the other hand, in ST8, bending crack occurs at the bending start and end area which is out of bending area. This analysis could simulate different crack pattern according to different bending radius. About the failure mechanism, in ST2, the compression stress concentrated from bending reinforcement area to inside of joint and then failure occurs in joint, on the other hand, in ST8, compression stress did not concentrate in joint and then bending failure occurs out of bending reinforcement area, that are same as the experimental result (Fig.6). In RC of analysis, cracks occurred not in joint but out of joint, and stress did not transfer well into joint. From the result above, this analysis with steel element (ST2, ST8) could simulate the different load capacity and failure mechanism according to different bending radius.



(1)ST2 (2)ST8 (3)RC

Fig.5 Stress distribution at the maximum loading(magnification:10 times)



(a)20mm (b)80mm

Fig.6 Cracks in joint（Horita, 2012）

4. Conclusions

From the result of FEM simulations investigating the influence of bending radius of reinforcement on failure mechanism in L beam-column joints, the following conclusions are made.

(1) The analysis with steel element could simulate the local failure and the different failure mechanism according to the different bending radius, however, the analysis with RC element is not applicable to the failure in joint.

(2) In analysis with steel element, when bending radius is enough small, local failure occurs from bending reinforcement area in joint due to compression concentration and as a result, the load capacity is less than that of large bending radius.

References

1) Horita, Nishizawa : An Experimental Investigation of Influence of Reinforcement Arrangement on Shear Strength Capacity in L Beam-Column Joint, Proceedings of the Japan Concrete Institute, Vol.34, No.2, pp.283-288, 2012(in Japanese)