EFFECT OF JOINT HOOPS ON DEFORMATION AND STRENGTH OF INTERIOR BEAM-COLUMN JOINTS

Saitama University Student Member O Abeygunawardana Navoda Tharunduni
Saitama University Regular Member Takeshi MAKI

1. INTRODUCTION

The strength and deformation of the beam-column joint should be maintained in earthquake resistant design of reinforced concrete moment resisting frame because joint should have sufficient stiffness and strength to resist the load coming from the adjacent beams and columns. The main objective of this study was to widen the current knowledge and understanding of the effect of joint hoops on deformation and strength of interior beam-column joints. The main test parameters were the amount of joint hoops and the column-to-beam strength ratio, and the effect of joint hoops was investigated on deformation and strength of interior beam-column joints subjected to reversed cyclic loading.

2. EXPERIMENTAL METHOD

The half scaled eight interior beam-column joint specimens with same geometry and with different reinforcement details were prepared for the experimental program. The detailed information of the specimens is tabulated in Table 1. The main test parameters were amount of joint hoops and column-to-beam flexural strength ratio. The cross-sectional dimensions of the column and beam were 250mm x 250mm and 200mm x 250mm, respectively. The distance between the column top loading point and the bottom pin support was 1500mm and the length between the beam supports was 2500mm. A maximum axial load of 130kN (equivalent to column axial stress of 2.08MPa) was exerted at the top of the column with a hydraulic jack and the horizontal reversed cyclic load was given to the column top using the horizontal actuator. Then each specimen was subjected to reversed cyclic loading with increasing story drift ratios up to the total failure. The given first story drift ratios were 0.25%, 0.5%, 0.75% and 1.0% with three cycles and here after that increased the story drift by 0.5% until story drift reached to 3.5% or 4.0%. The reaction forces at the beam ends were measured to calculate the joint shear. Strain gauges attached on the joint hoops as shown in the Fig 1, account an important role in measuring stress and strain during the experiment process.

Table 1: Details of the Test Specimens and Test Results

Series ID	Column-to-beam flexural strength ratio	Longitudinal reinf.		Specimen ID	Joint hoops		Test results		
		Beam	Column		Ratio	Arrangement	Max. joint shear (kN)	Ductility factor (Ave.)	Failure mode
SRWB	1.34	Top: 3D16 Bot: 3D16	12D13	SRWB1	0.00%	No Joint Hoops	379	2.09	Mode 1
				SRWB2	0.36%	2D6 @ 40	409	2.43	Mode 1
				SRWB3	0.72%	4D6 @ 40	398	2.36	Mode 1
SR	1.21	Top: 5D13 Bot: 5D13	8D13	SR1	0.00%	No Joint Hoops	447	2.07	Mode 1
				SR2	0.36%	2D6 @ 40	478	2.42	Mode 1
				SR3	0.72%	4D6 @ 40	516	2.15	Mode 1
UR	1.51	Top: 5D13 Bot: 3D13	12D13	UR1	0.00%	No Joint Hoops	399	2.40	Mode 2
				UR2	0.72%	4D6 @ 40	416	2.48	Mode 2

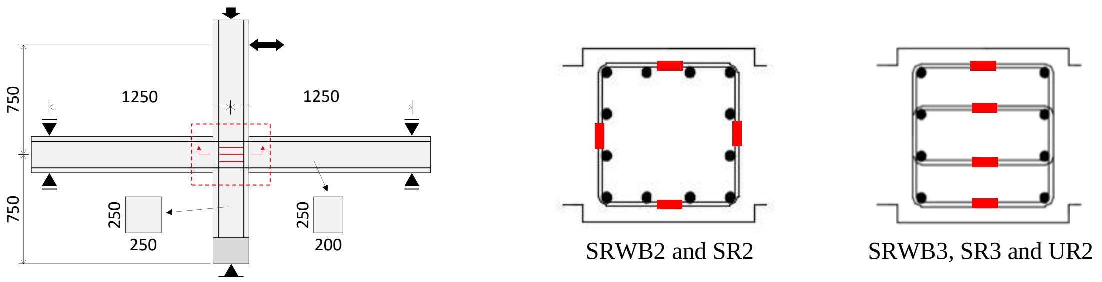

Fig. 1 Strain gauges attached location on the joint hoops

3. TEST RESULTS AND DISCUSSIONS

The applied cyclic load versus displacement at column top was used to develop the hysteresis curves and using those curves ductility factors were calculated. The displacement ductility factor is defined as the ultimate displacement to the

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Contact address: Nakamura Heights, Rm. 203, 338-0824, Saitama-Shi, Sakura-ku, Kami-Okubo 721-4 Tel: 08079672003

displacement at yielding. The ductility factors and joint shear forces obtained from the test results are shown in Table 1. With the comparison of all specimens, the UR series which is having highest column to beam flexural strength ratio shows the highest ductility factors compared to SRWB and SR series. It means that compared to the SRWB and SR series the UR series having the high ability to absorb energy without critical failures, and it can undergo large plastic deformations with small decrease in strength. The specimen SRWB2 is having the highest ductility factor in SRWB series while SRWB3 is showing the less ductility. And also, Specimen SR2 is having the highest ductility factor in SR series while SR3 showing the less ductility. It means that, by adding the joint hoops we can increase the ductility capacity and further increasing the number of joint hoops leads to decrease the ductility capacity.

The Failure mode 1 and 2 mentioned in the Table 1, are explained as follows:
Failure mode 1: Specimen failed due to the joint failure, diagonal cracks appeared at the joint core and then the core zone was split into several small zones. Meanwhile some flexural cracks at the beam end near to joint also appeared. When the specimen was subjected to the failure, concrete in the joint zone was crushed and stirrups in the joint core yielded or very close to yielding and concrete spalling occurred.
Failure mode 2: Huge flexural cracks developed at the beam end near to the joint while diagonal cracks appeared at the joint core. Therefore, these specimens failed in a hybrid mode that combined different failure characteristics. Meanwhile the propagated cracks in the joint region were spread to the column top and bottom.

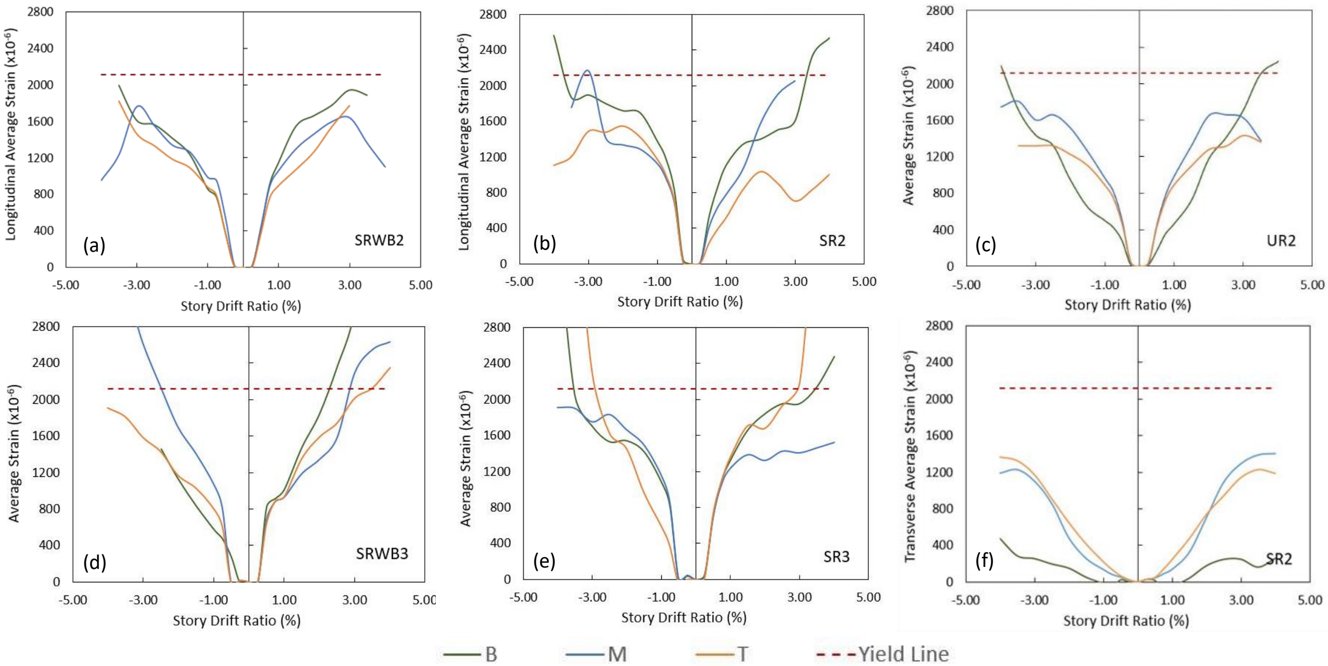

Fig. 2(a,b,c,d,e,f) Experimental Strain in joint hoops

The B, M and T notations stands for the bottom, middle and top layers respectively, the Fig 2(a,b,c,d,e) for the Longitudinal strain and Fig 2(f) for the Transverse strain in joint hoop for the specimen SR2, as an example. It is clearly showing that the transverse joint hoop rebars were not yielded and longitudinal joint hoop rebars were yielded or very close to yielding due to the load application direction. The other specimens with same joint hoop arrangement also have showed the same behaviour. Almost all the longitudinal joint hoops in SR series, which having lowest column-to-beam flexural strength ratio, were yielded as shown in Fig. 2(b,e). It means that there is a significant contribution from the joint hoops to the beam-column joint behavior when the column-to-beam flexural strength ratio is close to unity. The average strain in joint hoop started to decrease when the drift ratio reached to around 3.0%. This is because of the large cracks appeared after story drift ratio of 3.0% and occurred concrete spalling at the joint region. Even though it showed strain decrease after 3.0% of story drift, it was contributed to the confinement of the joint core until the failure.

4. CONCLUSIONS

The one of the major role of the joint hoop is contribution to the confinement of joint core concrete at the post peak region. The joints with low column-to-beam flexural strength ratio which close to unity can have the highest joint shear force and it tends to fail under the joint failure. The ductility factor values indicate that the joint hoops have a significant influence for the deformation capacity for the specimens with low column-to-beam flexural strength ratio while highest ductility factors for the UR series which is having the highest column-to-beam flexural strength ratio. Even though adding joint hoops have an influence on the deformation in post peak region but increasing the joint hoops from 0.36% to 0.72% had given less increase in ductility.