INFLUENCE OF USING LOW QUALITY MECHANICAL SPLICES AT THE SAME CROSS SECTION ON THE BEHAVIOR OF REINFORCED CONCRETE BEAMS

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I. INTRODUCTION

Nowadays, mechanical splices are very popular in construction of reinforced concrete structures. Japan Society of Civil Engineers (JSCE) Standard stipulates that mechanical splices shall be staggered in the longitudinal direction at least the sum of the splice length and 25 times the bar diameter (25d+l). This requirement is conservative and must be changed following the improvement of construction field in Japan. The staggering length is required due to safety reason of the structure even if low quality mechanical splices are used. The objective of this study is to clarify the influence of low quality mechanical splices arranged at the same cross section on the behavior of RC beams. A control RC beam without mechanical splices and four RC beams using mechanical splices with different quality were prepared and tested under cyclic loading. The test results included load-displacement curves and failure modes of the beams were used to compare the behavior of the beams using mechanical splices and the beam without mechanical splices.

II. OUTLINE OF EXPERIMENT

Low quality mechanical splices were created by controlling the insertion length of steel bars into the coupler (Fig.1). Tensile tests were carried out to identify the mechanical properties of these mechanical splices. The test results were shown in Fig.2 and Table 1.

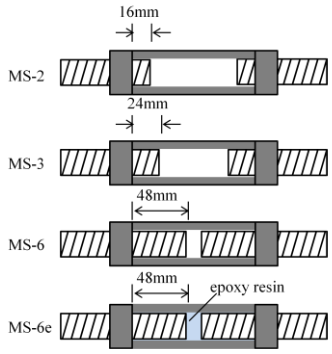

Fig.1. Quality control of mechanical splices

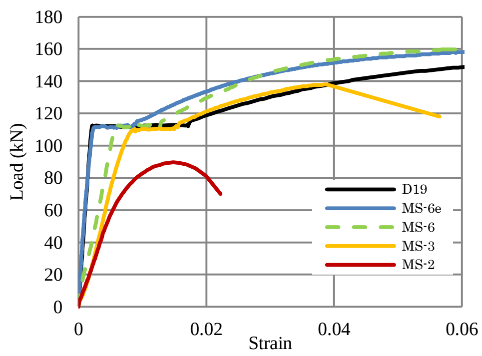

Fig.2. Load – strain curves of tensile test results

Table 1. Tensile test results

Type	P_y (kN)	P_u (kN)	$\frac{P_u}{P_{y-D19}}$	Failure mode
D19	112	159	142%	BB
MS-16	-	90	80%	SO
MS-24	112	138	123%	SO
MS-48	112	160	143%	BB
MS-48e	112	159	142%	BB

BB: bar break
SO: slip out

Five RC beams were designed and constructed (Fig.3 and Table 2). The beams were longitudinally reinforced by four D19 steel bars and transversely reinforced in shear span by D10 stirrups with 100 mm spacing. Mechanical splices were located at the mid span in the 800 mm uniform bending moment region which was obtained by applying two symmetric concentrate loads 400 mm far from mid span. No stirrup was used in this region in order not to disturb the crack patterns. The specimens were tested under cyclic loading with the pattern as shown in Fig.3 (Psy: yield load of D19 bar).

Table 2. Beam specimens

Beam	Mechanical splice	f'_c (N/mm^2)
B1	None	36.2
B2 – MS-2	MS-2	38.3
B3 – MS-3	MS-3	36.8
B4 – MS-6	MS-6	33.8
B5 – MS-6e	MS-6e	31.5

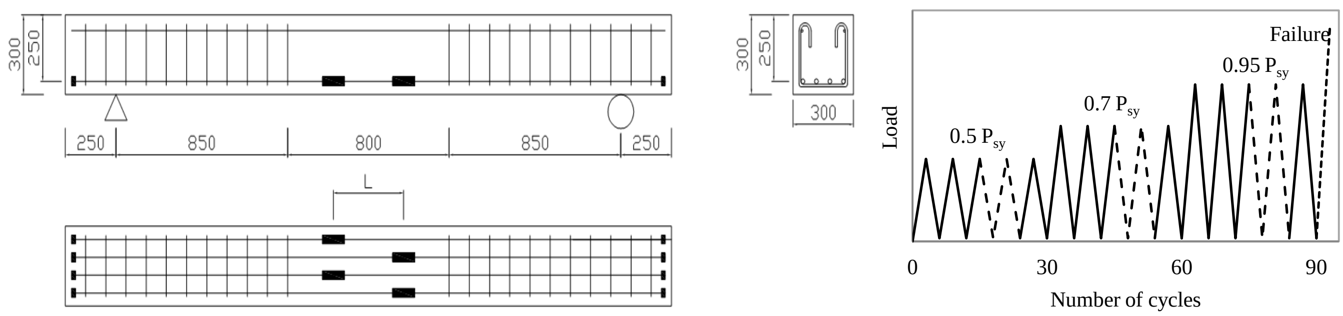

Fig.3. Specimen configuration and loading patterns

Keyword: mechanical splices, tensile test, four-point cyclic loading, load displacement curve
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III. RESULTS AND DISCUSSION

1. Load – displacement curves (Fig.4)

Before flexural cracking, the load–displacement curves of all specimens are closed to each other regardless of the using mechanical splices. It can be observed from Fig.4 that as the load increased, the rate of stiffness degradation after the initial flexural crack of the specimen using mechanical splices was increased higher than that of specimen B1. Although the different load-strain relationships of mechanical splices used in each specimen, the RC beams using them exhibited quite the same stiffness. The reason is that the quality of mechanical splices inside concrete is improved due to restrain effect of the concrete to the mechanical splices.

The beam using MS-2 which can develop 80% yield strength of the steel bar shows the lower strength than the beam without mechanical splice (about 75%) and almost behaved in brittle manner. The other beams using mechanical splices which can develop over yield strength of the steel bar (MS-3, MS-6 and MS-6e) could achieve peak loads the same as the beam without mechanical splices. The different between them is the ductility. The beam using MS-3 was less ductile than the beams using MS-6. The beam using epoxy injected mechanical splices (MS-6e) was more ductile than the beams using mechanical splices without epoxy (MS-6). This can be explained by the mechanical properties of each type of the mechanical splice. For MS-3, the failure mode of tensile test was slipped out of the bar from the coupler. Therefore the beam using MS-3 showed less ductile than the beam without mechanical splices. For MS-6 and MS-6e, they could achieve bar break failure mode so that the beams using them had almost the same ductility with the beam without mechanical splices. The epoxy injected in MS-6e made it stiffer than MS-6 and this affect a little to the ductility of the beam using MS-6e compare to the beam using MS-6.

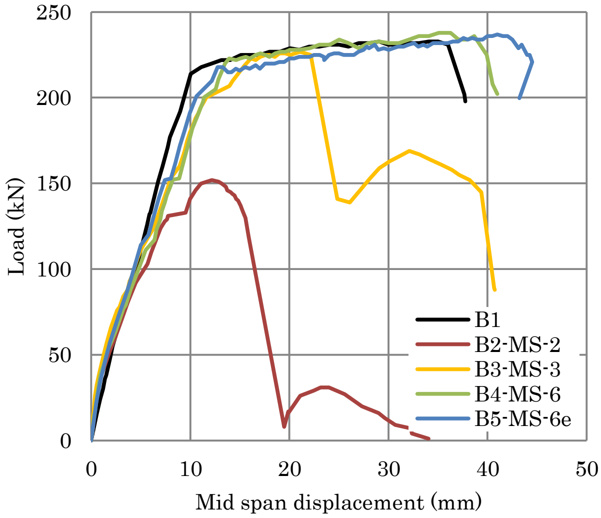

Fig.4. Envelope load – displacement curves

2. Failure modes

The beam B1 without mechanical splice failed after significant strain of tensile reinforcement with crushing of the compression concrete at the maximum moment zone. For the others beams using mechanical splices, the failure modes are so different. The beams using MS-6 and MS-6e failed in the same manner as the beam without mechanical splice. The beams using MS-2 failed because of slipping out of the rebar from the mechanical splices. For the beams using MS-3, it was observed that first the rebar slipped out from mechanical splices then the beams still had bearing capacity and finally the compression concrete crushing.

After testing, the specimens were broken in order to see what happen at the mechanical splices location. The steel bars were slipped out from the mechanical splices. As can be seen in Fig.5, all mechanical splices of beam B2-MS-2 were slipped out and the strength of B2-16-0 is the lowest. Beams B4-MS-6 and B5-MS-6e had no mechanical splice slipped out and they behaved like the beam without mechanical splices. Beam B3-MS-3 had three mechanical splices slipped out and it achieved yield strength of longitudinal bars but its ductility is about two third of the beams using MS-6 and MS-6e.

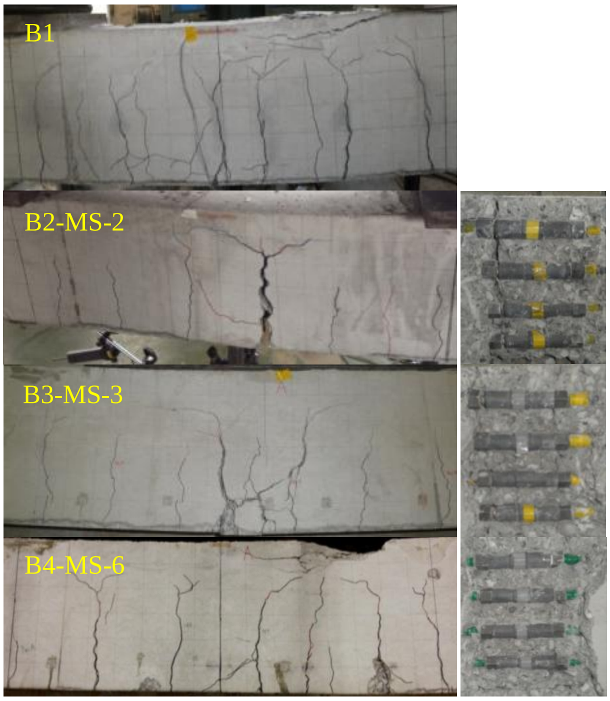

Fig. 5. Failure modes of beam test and mechanical splices after testing

IV. CONCLUSIONS

Five RC beams using low quality mechanical splices arranged at the same cross section were tested under cyclic lateral loading. The test results show that the beams using mechanical splices achieved bar break failure type (MS-6 and MS-6e) behaved almost the same as the one without mechanical splices. For the beams using mechanical splices which failed due to slipping out of the bar from the coupler (MS-2 and MS-3), they were more brittle even with the beam using mechanical splices obtained the yield strength of the bar (MS-3). The strength of RC beams was ensured if the mechanical splices obtained the yield strength of the bar (MS-3, MS-6 and MS-6e).