method for RC beam especially T shaped cross section which has comparatively smaller width. The method is that steel rod is inserted in the direction perpendicular to the axis of beam and tensile force is applied on these rods. This generates compressive force on the reinforcing member helping to increase resistance to the shear force. The reinforcement effect will increase for the RC beam as both steel rods is inserted and compressive force is used.

The experiment for this reinforcing technique of RC beam is carried out to verify the reinforcing effect. Based on the experimental method, elastic-plastic analysis of RC beam is performed by using finite element analysis program ANSYS. The analysis is done by changing the reinforcement conditions to find the effective reinforcement pattern.

2. LOADING TEST OF RC BEAM

2.1 Specimen and reinforcement method

Fig. 1 and Fig. 2 show specimen, reinforcement method and overview of the loading test (Endoh 2013). The shear strength of the specimen is smaller than the bending strength (JSCE 2007). When the loading test is performed, RC beam is calculated so that shear fracture occurs first.

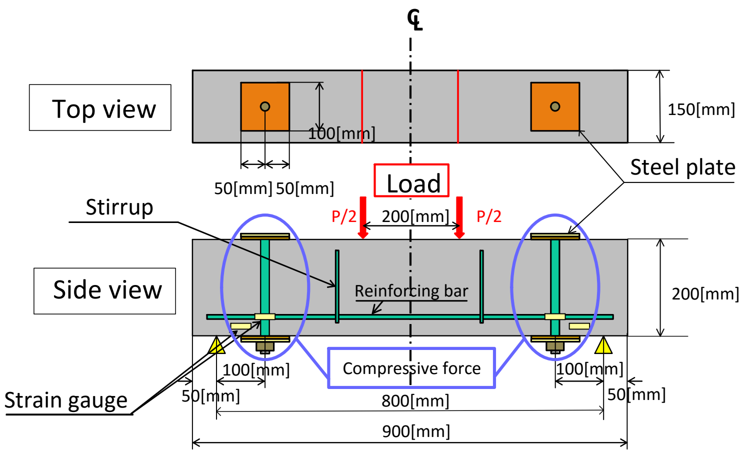

Fig. 1 Experiment outline (specimen)

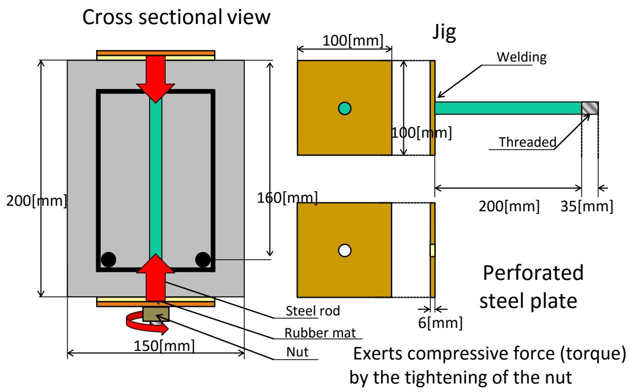

Fig. 2 Experiment outline (cross section and reinforcement method)

The construction process of the reinforcement is described below. First, at the distance of 100 (mm) from support point where the occurrence of shear cracks of RC beam is expected, hole of φ23 (mm) is created in the direction perpendicular to the axis. Jig used for reinforcing has the steel plate of geometry 100 (mm) × 100 (mm) × 6 (mm). Hole of φ23 [mm] is made at center part and steel rod of φ19 (mm), length of 240 (mm) is inserted (material SR235). Next, after inserting a steel rod to the hole, grout material is injected into the void (as a grout, mortar which water-cement ratio is 0.37 and fine aggregate cement ratio 2.0 is used). The bottom part of beam, steel plate of with hole of φ23 (mm) was placed and after inserting a steel rod into the hole given torque is applied to the nut. In order to make the contact between tool and the steel sheet uniform, rubber of same size as the steel sheet of 100 (mm) × 100 (mm) × 3 (mm) is placed between the upper and lower surfaces of RC and steel sheet. Flat washer is also placed between steel plate and the nut.

When the shear crack is generated in the RC beam, change in volume occurs in inner part of concrete. Further, when the shear fracture occurred, since fracture is a brittle in nature, strength will be significantly reduced. With respect to above, the reinforcement technique proposed here is insertion of steel rod in the perpendicular direction to the axis, fix them by steel plate and application of tensile force. Therefore, when carrying out the reinforcement, the following two effects are expected. At first, by insertion of the steel rod in the perpendicular direction to the axis, increase in amount of shear reinforcement rods occurs. Furthermore by setting a steel rod and steel plate and applying tensile force on concrete near the reinforcement, shear deformation is restricted and cross section restraining effect occurs. By the application of tensile force in the concrete of reinforcement portion in the vertical direction to the axis, transition of principal stress to horizontal direction occurs. Therefore the horizontal component of principal stress is burden by tensile reinforcement arranged in same direction. In general, shear cracks are generated from bottom of RC beam of tension side. The bending stress is small in the portion near support point. When the horizontal component of the principal stress is very high, it can bear a sufficient tensile stress and the control of shear cracks is expected.

2.2 Loading test

Loading test is performed in the following five RC beams with the properties shown in Fig. 1.

BEAM1: Before loading tests, the round steel of *φ*19 (mm) is inserted in RC beams
BEAM2: Before loading tests, 100(N･m) torque is applied in jig
BEAM3: Before loading tests, 50 (N･m) torque is applied in jig
BEAM4: No reinforcement
BEAM5: After conducting a load test on BEAM4, unload after shear failure and reinforcement is done by applying 100 (Nm) torque on jig.

Fig. 3 shows the relationship between the load and vertical displacement of central part of span. Load carrying capacity of BEAM1 reinforced by inserting a steel rod is a 91.0 (kN) whereas load carrying capacity of BEAM4 with no reinforcement is 79.6 (kN). When steel bar is inserted in same position as proposed reinforcement technique, the fracture pattern is shear and load after reaching the maximum load is significantly reduced. In contrast, load carrying capacity of BEAM2 and BEAM3 is about 160 (kN). The load carrying capacity is improved up to 75 (%) by applying a compressive force. Comparing BEAM2 and BEAM3, the former has been applied twice the compression force of the latter, the maximum value of the applied load is 3 (%) larger in the former. In addition, immediately after the maximum load loading of BEAM3, load is reduced. This is caused because the amount of the torque introduced to BEAM3 is half the torque introduced to BEAM2. In the unloading process of BEAM2, the significant decrease in vertical displacement can be confirmed. Further, the residual displacement of BEAM2 is significant decrease nearly 0. By the application of compressive force in the vertical direction to the axis, the cross section restraint effect is formed. This effect is same as increased of restoring force in prestressed concrete structure.

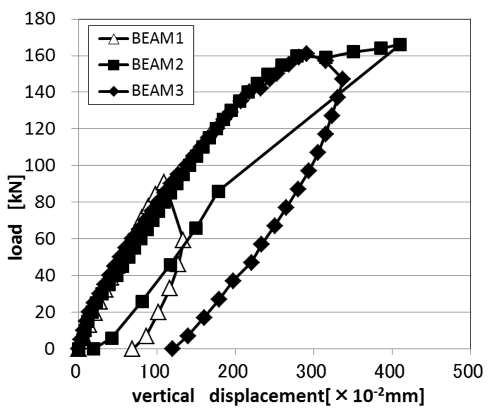

Fig. 3 Load-deflection curve (BEAM1, BEAM2 and BEAM3)