Transactions of the Materials Research Society of Japan. Vol. 20

DEVELOPMENT AND APPLICATION OF NEW TYPE JOINTS COMPOSED BY METAL CONNECTOR AND ADHESIVE IN TIMBER STRUCTURES

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This paper has described tests on the steel connectors embedded into timber with adhesive. These connectors are threaded steel rods with a hole at center of each rod to transport the adhesive to the end/s of the rods. From this test result, the fundamental data for the structural design of timber structures was obtained. The application and construction example of this new type joint is described in this paper.

1. INTRODUCTION

In Japan, the shortage, advanced aging and declining ability of skillful carpenters are progressing rapidly at the building site of timber structures. It is necessary to develop the new type connection system by the easy and non-high technique. In the conventional assembly method, the metal plate and bolts system is adopted frequently. The problems in this system are the lower rigidity by the gap between a bolt and a hole and the obscurity of mechanical behavior.

We designed and tested the new type connection system composed by metal connector and adhesive to solve the problem mentioned above. The assembly at connection and reasonable structural design can be carried out easily by using this new connection system.

A severe earthquake attacked the south part of Hyogo prefecture in Japan on January 17, 1995. The earthquake caused severe damage to wooden houses constructed by conventional methods.

It was indicated that one cause of damage was the incomplete assembly method at the brace end and beam-column connections by the research report. The tests were carried out to grasp the earthquake-resistance, when the new type connection system was adopted to prevent the damage and to reinforce the wooden frames with braces.

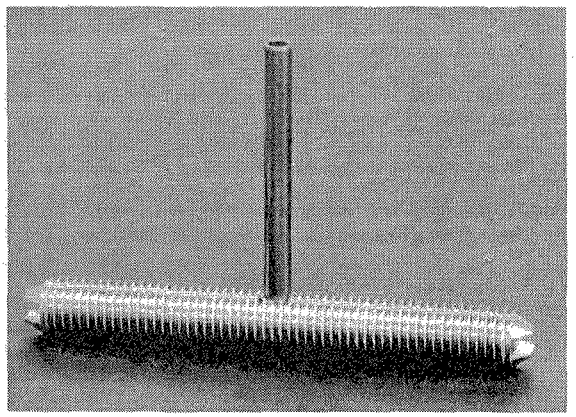

Photo-1 T-type rod

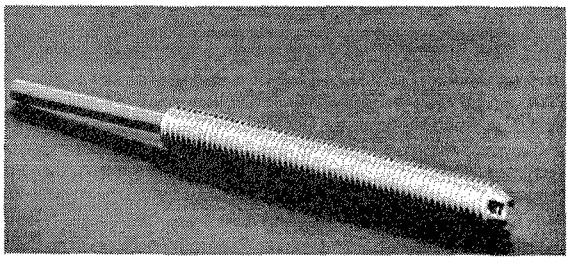

Photo-2 S-type rod

2. ASSEMBLY METHOD OF SPECIMENS

Samples of configurations of two kinds (T-type and S-type) of metal connectors are shown in Photo-1,2. T-type rods are used at splices loaded in tension or bending in this study. On the other hand, S-type rods are used at beam-column connections loaded in tension. These connectors are threaded steel rods with a hole at the center of each rod to transport the adhesive to the end/s of the rods and the screw for the branch pipe.

The assembly process of specimens for new type connections is described below and shown in Fig.1.

[1] Holes for T-type rods are drilled using an electric drill at both butted faces of the splice. Hole diameters are 3 mm larger than the rod diameter.
[2] A hole for a branch pipe is drilled using an electric drill for a hole mentioned above, respectively. This hole diameter is 3 mm larger than the branch pipe diameter.
[3] T-type or S-type rod with branch pipe is inserted into the hole.
[4] Both faces are butted and attached to each other temporarily using by nails and wood plates.
[5] Adhesive (urethane bond) is pumped into the cavities around the rods by using a conventional caulking gun. Pumped adhesive reaches the cavity through the branch pipe and the hole inside of the rod.
[6] Filling up of adhesive is confirmed by watching the adhesive which comes up through the space around the branch pipe.
[7] The branch pipe that is attached to the rod by screw is detached from the rod.
[8] A small wood piece is driven into the hole drilled for the branch pipe.
[9] After the curing period (two weeks in these tests), the wood plates are detached from the specimens.

Steel rods bonded into timber have excellent potential for making strong connections. There is no specimen with poor filling up of the adhesive at the gap between the timber hole and the steel rod.

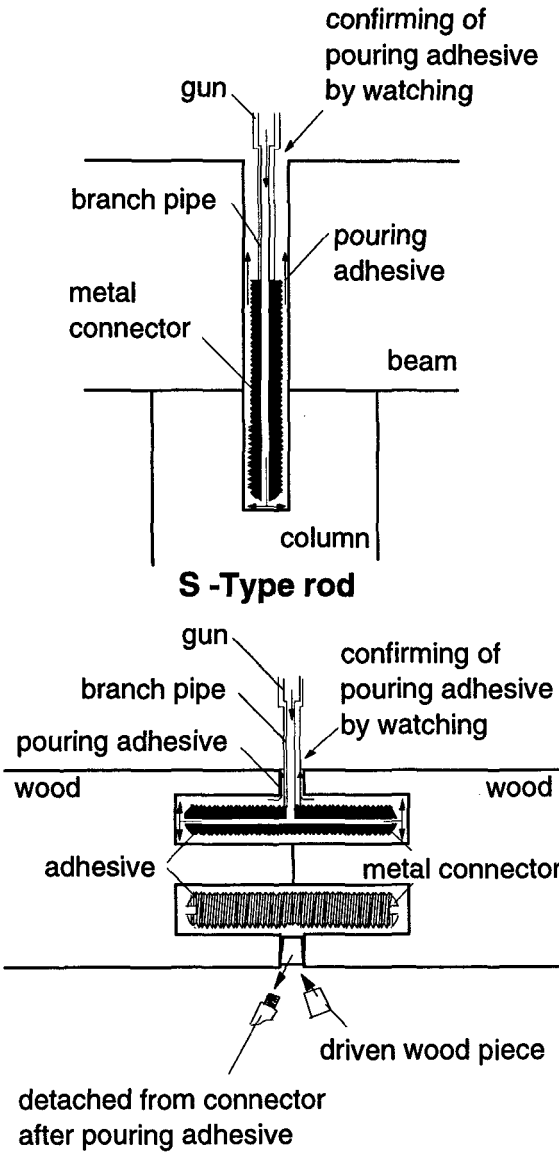

Fig.1 Filling Processes of adhesive

Advantages of this connection system include:

[1] Easy control of strength
[2] Ease of assembly
[3] Fire resistance
[4] Corrosion resistance
[5] Fine appearance
[6] Saving material
[7] Wide use for various kinds of materials which can be drilled

3. OUTLINE OF TEST[1)]

The main objective of this study is to investigate experimentally the mechanical behavior of new type joints by using metal connectors and adhesive and to propose a structural design method when this connection system is adopted.

Tension tests for splices, tension tests for beam-column connections, bending tests for mid-span splices, the relationship between the tension strength and the curing time of adhesive and horizontal loading test for wooden frames built by conventional system were carried out.

4. TEST RESULTS

It is possible to obtain the tension strength and bending strength larger than that of the conventional splices used in Japan. The value of strength per unit surface area of half part rod Tu (=294N) can be used in the practical structural design of timber structures.

The relationship between the tension strength and the curing time of adhesive was obtained. The specific tension strength used in the structural design was obtained in two weeks after filling up of adhesive. From these tests results, a bending formula was obtained for structural design purposes.

The calculated ultimate bending moment of new type splice can be obtained by a formula such as

$$Mucal = At \cdot Tu \cdot j$$

where

Mucal = calculated ultimate bending moment of new type splice

Tu =tension strength per unit surface area of half part steel rod (i.e. ultimate bond stress of rod)

j = distance between compressive and tensile resultants (assumed to be 7/8d)

d = distance between center of tensile rod and compressive edge of cross section

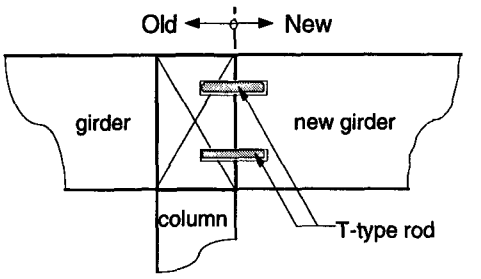

Fig.2 Connection detail with new type joint for additional building

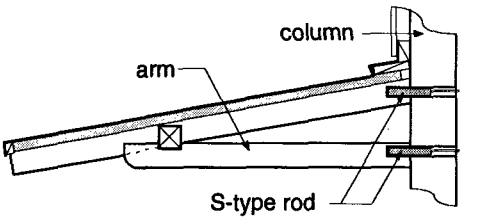

Fig.3 Eaves by new type joint

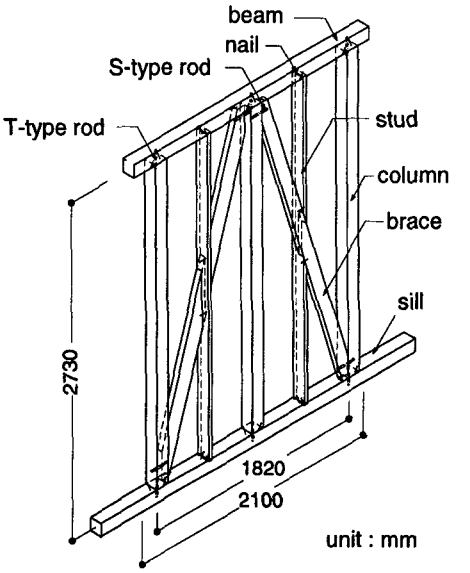

Fig.4 Frame with new type joint

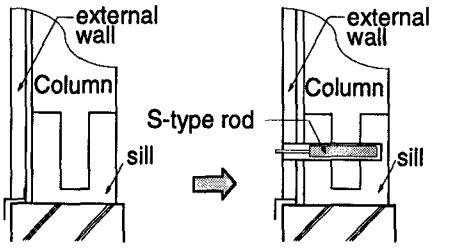

Fig.5 Reinforcing for earthquake by new type joint

5. APPLICATION OF NEW TYPE CONNECTION SYSTEM

Fig.2 shows the detail of connection when the extension work are carried out to add the room to the house already built. It is easy to connect the old and new girders by using new connecting system.

Fig.3 shows the new construction method at the eaves. The eaves reinforced by new connection system by using S-type rod has the high rigidity for the gravity load.

Fig.4 shows the conventional frame with braces assembled by new type connection system. This wooden frame has higher earthquake-resistance by using the new type connection system at beam-column and brace end connections. There are no complex works to assemble this frame. These types of frames were tested to investigate the effect of the new type connection system and earthquake-resistance.

From test results, higher strength and rigidity were confirmed than that of the frame assembled conventionally by metal plate, bolts and nails.

Fig.5 shows the reinforcing method for earthquake by the new type connection system by using an S-type rod at the connection of the column to the sill. The effect of this reinforcing method on earthquake-resistance were confirmed by loading tests. The frame reinforced by the S-type rod and adhesive is twice as strong as the non-reinforced frame at the column-sill joints. Pulling out of the column from the sill did not occur in any of the specimens reinforced at column-sill joints.

Many wooden houses with the non-reinforced column-sill joints exist in Japan. The new type connection system by using S-type rods and adhesive can be used to reinforce wooden houses, mentioned above, for earthquakes.

Photo.3 shows the detail of connection in the moment resisting frame where the new type system was adopted. Photo.4 and Photo.5 are truss frame. Photo.4 shows a part of the roof truss frame where the new type system

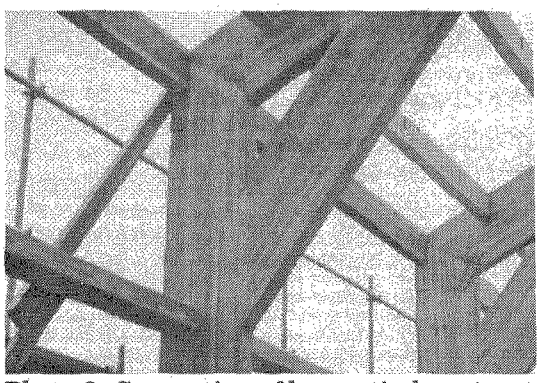

Photo.3 Connection of heavy timber struct

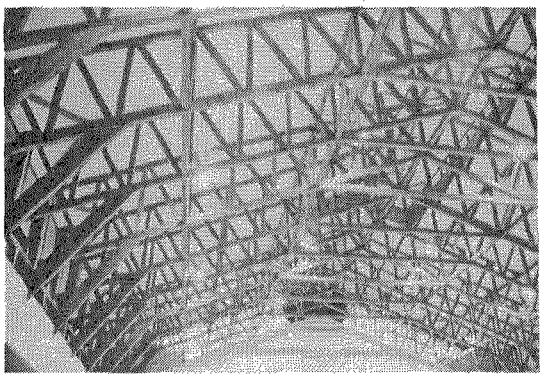

Photo.4 Structure of roof truss frame

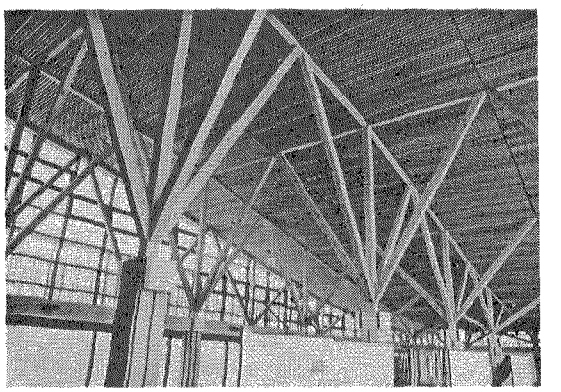

Photo.5 New type connection in truss structure

was adopted.

These timber structures have a fi appearance because the steel rods a embedded into the timbers at connections.

REFERENCE

1. Inoue, M. et al. " Experimental Study Rigidity and Strength of Joints Compos by Metal Connector and Adhesive in Timl Structures " Proc. of Pacific Timber En neering Conference, July 1994. Gold Coa