EXPERIMENTAL STUDY ON FLUSH END-PLATE CONNECTIONS

Tokyo Metropolitan University	Student Member	Mativo J.M.*
Tokyo Metropolitan University	Member	Yamasawa T.
Tokyo Metropolitan University	Member	Nogami K.
Tokyo Tekkotsu Kyoryo Corporation	Member	Suzuki T.
Tokyo Tekkotsu Kyoryo Corporation	Member	Irube T.

1. INTRODUCTION

Flush end plate connections have been shown to possess intermediate stiffness [1)] and are neither pinned nor rigid as might be commonly assumed. This behavior has significant influences on a steel frame's overall response to loading and therefore there is need to incorporate the actual connection behavior in structural engineering analysis and design. Various methods have been proposed to predict the flush end plate connection moment-rotation behaviour but their application is limited unless verified against the more reliable full scale experimental test results. The first primary objective of this research is to determine the influence of varying the end plate thickness t_p and the tension bolt gage p_t on the overall behaviour of the connection assembly, shown in figure 1. The secondary objective is to increase the world-wide experimental data bank for flush end plate connections. The nominal connection geometric parameter sizes in the experimental study were t_p – 12 and 15mm, and p_t – 50 and 65mm. All test assemblies did not have stiffeners (i.e. t_s = 0). The actual parameter sizes are tabulated in table 1.

2. DESCRIPTION OF EXPERIMENTAL TESTS

A total of four beam-to-column steel flush end plate connection experimental tests were carried out at the Tokyo Metropolitan University civil engineering laboratories. The test assemblies consisted of a cantilever beam section attached to a column section, as illustrated in figure 2 and 3. The connection elements comprised of an end plate welded onto the beam section and then bolted to the column flange. The end plates were connected to the beam-end by full strength 45° – continuous fillet welds. The shop fillet welding was performed in accordance with current Japanese welding specification. Steel type SM400 was used for the column, beam and end plate. All the fasteners were 22mm diameter FT10 high strength bolts and nuts. The four test specimens were fabricated by Tokyo Tekkotsu Kyoryo Corporation.

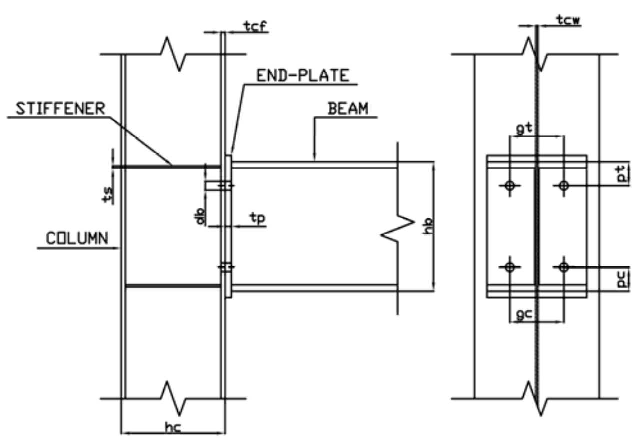

Fig. 1 Connection layout

The connection assemblies consisted of an 850mm long beam 350X175 I-section and a 2000mm long column 250X250mm I-section The columns were fixed at both ends onto restraining supports that had been anchored to the laboratory 1.5m thick floor. The connection assembly layout is in a T-shaped arrangement, rotated 180° for practical purposes.

Table 1 Connection test matrix

Specimen ID	Thickness of end plate t_p mm	Average tension bolt gage p_t mm	Average comp. bolt gage p_c mm	Horz distance btw bolts g_t, gc mm
Test 1	12	65.1	48.4	105
Test 2	15	63.7	50.4	105
Test 3	12	49.1	50.5	105
Test 4	15	50.3	50.2	105

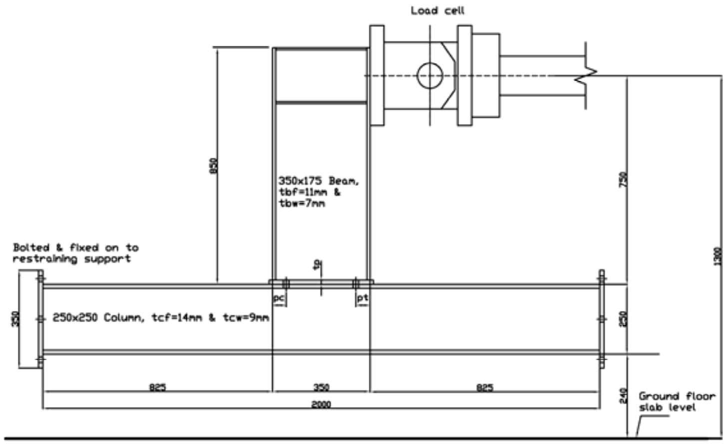

Fig. 2 Experimental tests layout

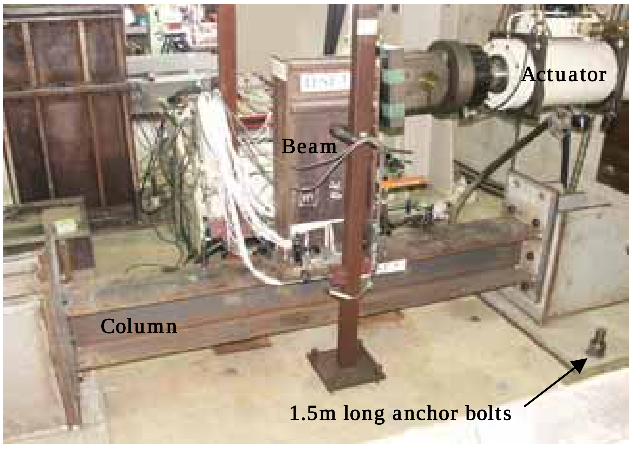

Fig. 3 Typical Test arrangement

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〒192-0397 Tokyo Metropolitan University, Civil Engineering Department, Minami Osawa 1-1, Hachioji-shi
Tel: 0426-77-1111 (Ext. 4562), Fax: 0426-77-2772

3. INSTRUMENTATION

In order to monitor and measure the applied load, horizontal and verticle displacement, and strains, the following instruments were used for each test; nine linear voltage displacement transducers (LVDTs), see figure 4, and 19 Three-direction 45° rosette strain gauges. The data acquisition system TDS 303 and switch box ISW 50 were used to record strain gauge and displacment transducers readings.

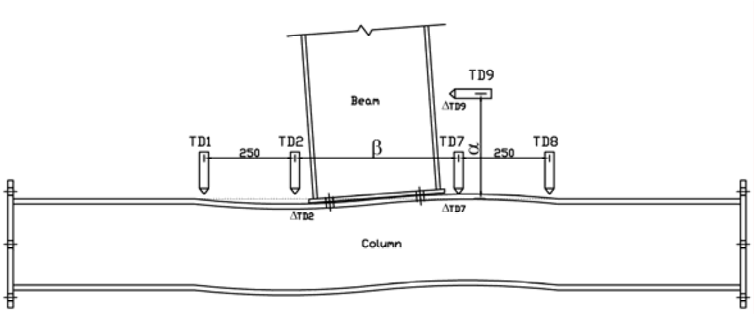

Fig. 4 Location of displacement transducers

4. TEST PROCEDURE

The specimens were subjected to monotonic loading. The actuator loading was by displacement control. The static loading rate between two loading-displacement reading/recording sessions was in steps of 0.2mm/s. The main loading sequence was in two phases. In the first phase the beam was loaded until a 'loading head' displacement of approximately 20mm was achieved then followed by complete unloading. In the second phase, loading was applied continuously until a 'loading head' displacement of approximately 40mm was achieved and it was similarly followed by complete unloading. The load steps were executed in regular 0.5mm steps and data points recorded.

5. TEST OBSERVATIONS AND RESULTS

The connection's overall deformation is primarily due to both the column flange in bending and the end plate in bending. The bending action of the two elements provided ductility to the connection. The test assemblies was loaded to a maximum load of Test 1 – 155.0kN, Test 2 – 174.34kN, Test 3 – 176.34kN and Test 4 – 181.45kN, prior to final and complete unloading phase. At the end of the experimental studies, there was profound noticeable permanent deformation on the column flange and the end plate as shown in figure 5. Bolts, bolt holes, nuts and washers had no sign of deformation/damage/elongation. Bolt holes remained round indicating that bearing was not a source of deformation. No evidence of cracks in welds noted. The moment-relative rotation curves for Test 1, test 2, Test 3 and Test 4 are plotted in figure 6. The connection relative rotation θ_r is defined as the difference between the beam rotation θ_b and the column rotation θ_c as illustrated in figure 4, where

Fig. 5 Test specimen after loading (Test 3)

$$\theta_r = \theta_b - \theta_c = Tan^{-1}\left[\frac{\Delta_{TD9}}{\alpha}\right] - Tan^{-1}\left[\frac{\Delta_{TD7} - \Delta_{TD2}}{\beta}\right]$$

Δ_{TD9} = displacement at transducer TD9, Δ_{TD7} = displacement at transducer TD7 and Δ_{TD2} = displacement at transducer TD2

6. CONCLUSIONS

(1) The end plate in bending and the column flange in bending are the primary source of deformation in the connection assembly. This is confirmed by physical observation of the test and by the strain gauge readings.

(2) An increase in the end plate thickness results in an increase in the connection resistant to rotation and deformation. A decrease in the tension gage also results in an increase in connection strength.

(3) The loading and unloading curves are not identical, but are both almost parallel to the initial connection stiffness.

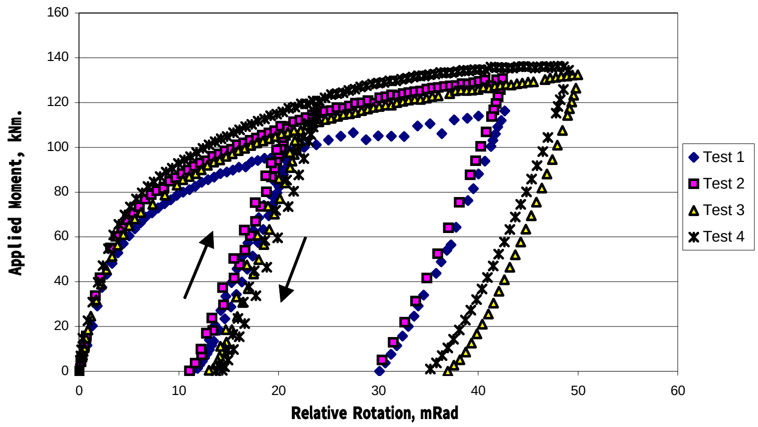

Fig. 6 Moment-rotation curves

REFERENCES

1) **J.M. Mativo, T. Yamasawa and K. Nogami (2006)**, "Developing flush end plate connection M-θ_r curves," Proceedings of International Colloquium on Stability and Ductility of Steel Structure, Lisbon, Portugal, Sep 2006 Vol.1, pp 485-492