Proceedings of The Fourth East Asia-Pacific Conference on

Structural Engineering and Construction :

Progress in Harmony

Edited by

Y. K. Shin S. P. Chang H. M. Koh

Volume II

20-22 September 1993

Seoul, Korea

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East Asia-Pacific Conference on Structural Engineering and Construction
(4th : 1993 : Seoul, Korea)
Structural engineering and construction : progress in harmony :
Proceedings of the Fourth East Asia-Pacific Conference on Structural
Engineering and Construction, Seoul, 20-22 September 1993 / Edited by
Y. K. Shin, S. P. Chang, H. M. Koh, Korea, Seoul National University,
1993.
3 v.

Includes index.

1. Structural Engineering - Congresses. I. Shin, Y. K. II. Chang, S. P.
III. Koh, H. M. IV. Title

Printed and bound by The Dongam Printing Co.
Printed in Korea.

ISBN : (set) 89-950002-0-1
v.1 89-950002-1-X
v.2 89-950002-2-8
v.3 89-950002-3-6

Distributed by EASEC-4 Secretariat, Department of Civil Engineering,
Seoul National University, Seoul 151-742, Korea

The Fourth East Asia-Pacific Conference on Structural Engineering & Construction
Seoul, Korea, September 20-22, 1993

Effects of Contact Surface Conditions on Mechanical Behavior of Beam-to-Column Connections with T-stubs

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ABSTRACT

Investigated is the mechanical behavior of beam-to-column connections with bolted T-stubs. The aim of this study is to establish the design guide to beam-to-column connections with split-tee joints. Experiments of beam-to-column connections with various joint surface conditions are carried out, in order to obtain qualitative and quantitative effects of the joint surface conditions on mechanical behavior of the beam-to-column connections. On the basis of the experimental results obtained here, it is revealed that the mechanical behavior is greatly influenced by joint surface conditions, and that angular welding distortion and longitudinal welding distortion advantageously work in the mechanical view point when the distortions are convex-wise.

INTRODUCTION

Tension-type connections have been recently paid attention in the field of civil engineering because of some advantages. One of the most attractive advantages is that this sort of connection has relatively high stiffness compared with other types of connections.

One of us has recently investigated the mechanical behavior of tension-type connections, which have been used in the field of building construction for a long while, subjected to tensile loads, and then he concluded that effects of contact surface conditions should not be neglected when we investigate the mechanical behavior of the connections[1,2]. From his experimental results, we presumed that contact surface conditions might affect the mechanical behavior, which we investigate here, of beam-to-column connections with bolted T-stubs.

In this study, Beam-to-column connections with various types of contact surfaces are subjected to quasi-static cyclic loads, to obtain qualitative and/or quantitative effects of the conditions on mechanical behavior of the connections.

TEST SPECIMENS

Figure 1 shows configuration and dimensions of test specimens used. The test specimens are composed of two beam members and a column member , all of which are connected by using four T-stubs. Figure 2 shows configuration and dimensions of the T-stubs. All the members are fabricated from SM490 structural steel plates.

"Angular distortion" and "longitudinal distortion" generally remain in T-stubs fabricated by welding as shown in Figure 3. In this study, we consider these types of welding distortion as influential factors affecting the mechanical behavior of the connections. Then four types of contact surface conditions, as listed below, are used for the purpose mentioned above.

a)M-type specimens with machined contact surfaces.

b)S-type specimens with surfaces having angular distortion and longitudinal distortion both of which are caused by welding.

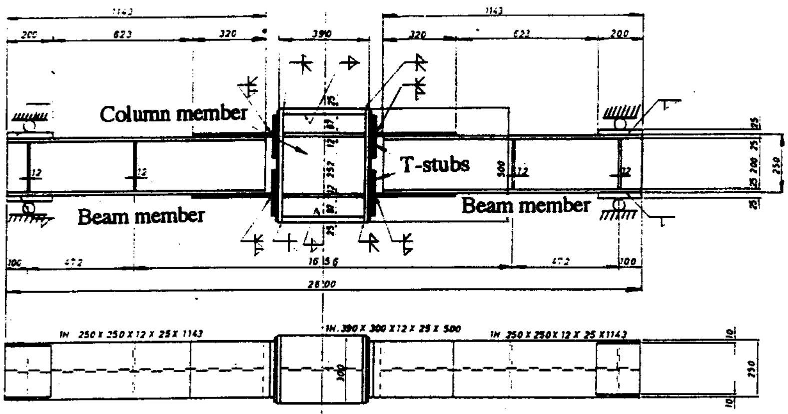

Figure 1. Configuration and dimensions of test specimens

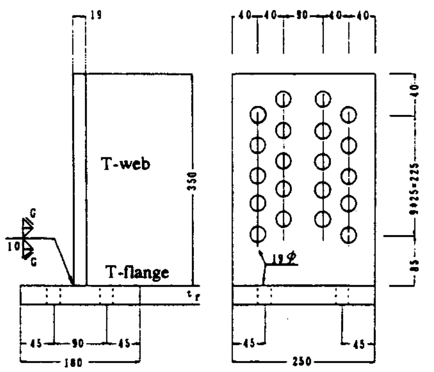

Figure 2. Configuration and dimensions of T-stubs

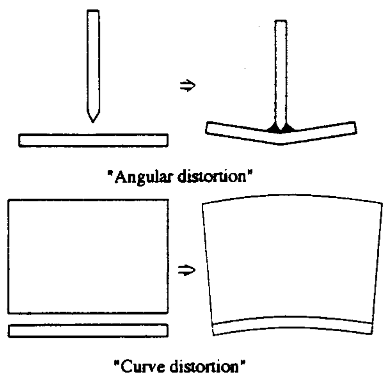

Figure 3. Welding distortion remained in T-stubs

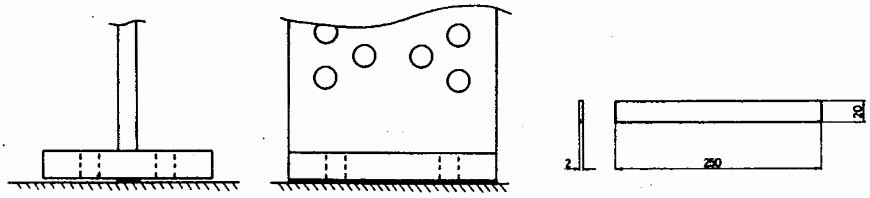

Figure 4. Fillers used for F-type specimens

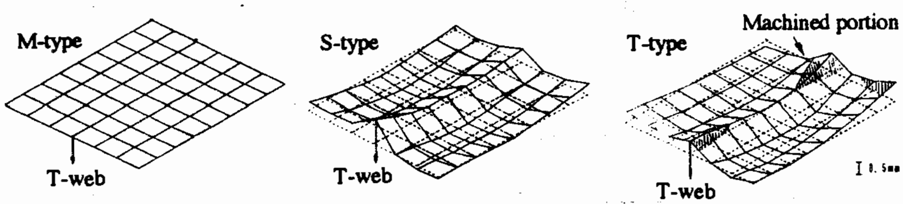

Figure 5. Three dimensional configuration of contact surfaces of T-stubs.

c)F-type specimens with fillers between pairs of machined surfaces, as shown in Figure 4.
d)T-type specimens with surfaces having angular distortion caused by welding. This type of specimen is made by eliminating longitudinal distortion of the S-type specimens.

Thickness of flange plates is 14mm or 19mm. High strength bolts of F10T.M16 are used and the initial bolt axial force of 114.2KN(11660kgf), which corresponds to 82.5% of the yield strength of the plates used here, is introduced to all the bolts.

Figure 5 shows three-dimensional configuration of contact surfaces of the T-stubs.

TESTING APPARATUS

A testing machine with a 30tf capacity actuator was employed and quasi-static cyclic loading tests were carried out. Displacement amplitude at the center of span length was controlled as shown in Figure 6.

First, we measured bending moment-rotational displacement relationships of the connected portions. Bending moments and rotational displacements were defined as follows, respectively.

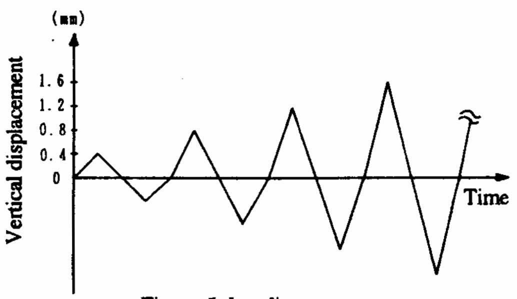

Figure 6. Loading pattern

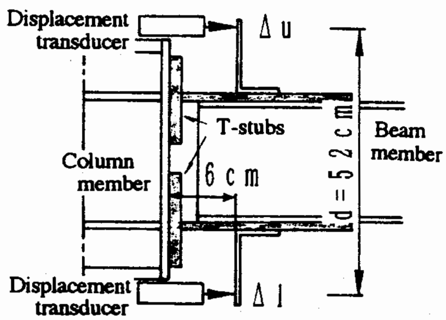

Figure 7. The way of measuring rotational displacement

$$M = \frac{P L_{fs}}{2} \quad (1)$$

$$\theta = \tan\theta = \frac{\Delta u - \Delta d}{d} \quad (2)$$

where P and L_{fs} denote the external load and the distance between one of the supports and a contact surface, respectively. Δu and Δd are horizontal displacements measured in the way shown in Figure 7, and d denotes the distance between two points where the horizontal displacements of the contact surfaces are measured.

Rotational stiffness is evaluated by numerically differentiating the bending moment with respect to the rotational displacement. Using the values of the bending moments, we calculated equivalent external forces by the following equation.

$$F = \frac{M}{d_b} \quad (3)$$

where d_b denotes the distance between upper and lower T-webs.

Second, the axial deformation of the bolts was detected by using strain gauges put into the bolt shafts and the values of the axial deformation were transformed to the bolt axial forces.

ROTATIONAL STIFFNESS

Figure 8 shows bending moment-rotation relationships in the case of M-type, S-type and T-type specimens with T-flanges of 14mm thickness, and Figure 9 shows relationships between rotational stiffness and rotational displacement obtained from the results shown in Figure 8 by means of a numerical differentiation technique. From these results, we can conclude that (1)the M-type specimen having contact surfaces that were machined accurately has higher stiffness compared with the S-type specimen having welding distortion except for relatively small displacement region, and (2) eliminating longitudinal distortion makes the stiffness high to some extent.

Figure 10 shows bending moment-rotational displacement relationships in the case of M-type, S-type and F-type specimens with T-flanges of 19mm thickness, and Figure 11 shows relationships between rotational stiffness and rotational displacement obtained from the results shown in Figure 10. Although initial stiffness of the M-type specimen is higher than that of the S-type specimen, displacement range having the same stiffness as initial stiffness of the M-type specimen is relatively narrow. In the case of the F-type specimen, stiffness is almost the same as that of the M-type specimen.

BOLT AXIAL FORCE

Figure 12 shows relationships between the bolt axial forces divided by the initial bolt axial force and the equivalent external forces divided by the initial bolt axial force in the case of M-type, S-type and T-type specimens with T-flanges of 14mm thickness.

In the case of the M-type specimen, the bolt axial force non-linearly increases as the equivalent external force increases. On the other hand, the bolt axial force of the S-type specimen linearly increases . Change in the bolt axial force is much more drastic in the case of the S-type specimen compared with the M-type specimen. Although the bolt axial force of the T-type specimen tends to change in the same way as the S-type specimen, the degree of the change is apparently small.

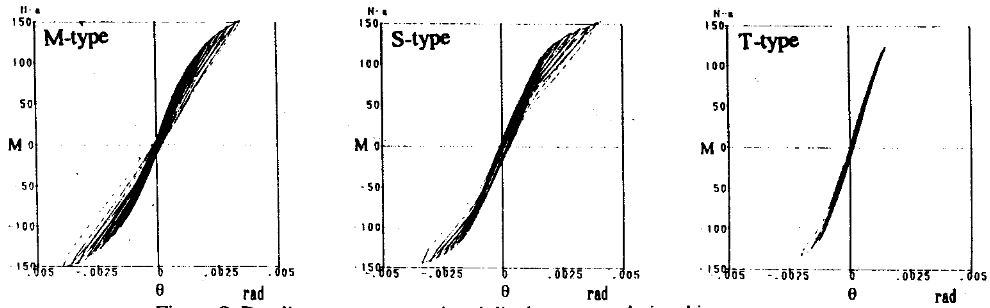

Figure 8. Bending moment-rotational displacement relationships
(in the case of specimens with T-flanges of 14mm thickness)

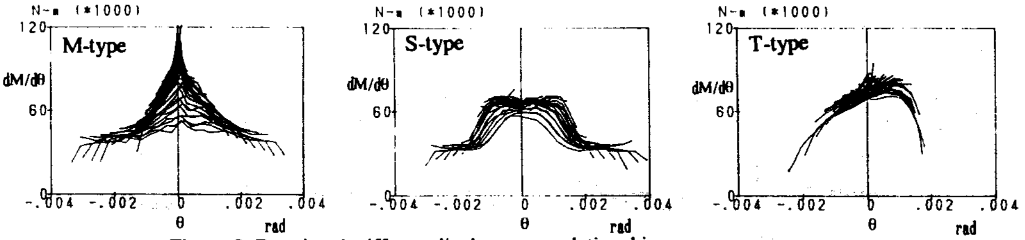

Figure 9. Rotational stiffness-displacement relationships
(in the case of specimens with T-flanges of 14mm thickness)

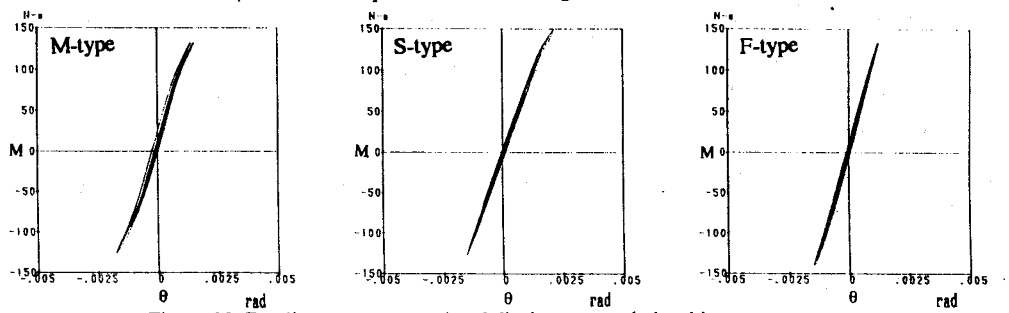

Figure 10. Bending moment-rotational displacement relationships
(in the case of specimens with T-flanges of 19mm thickness)

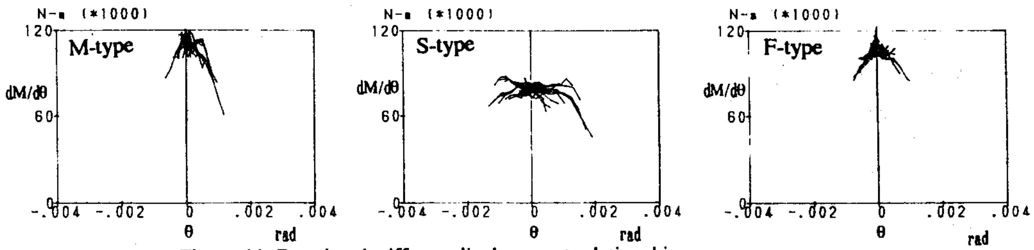

Figure 11. Rotational stiffness-displacement relationships
(in the case of specimens with T-flanges of 19mm thickness)

Figure 13 is the same kind of figure as Figure 12 in the case of F-type, M-type and S-type specimens with T-flanges of 19mm thickness. From these figures, the F-type specimen evidently behaves much more similarly as the S-type specimen than the M-type specimen.

One of the main reasons why the F-type and the T-type specimens are relatively stiff and de

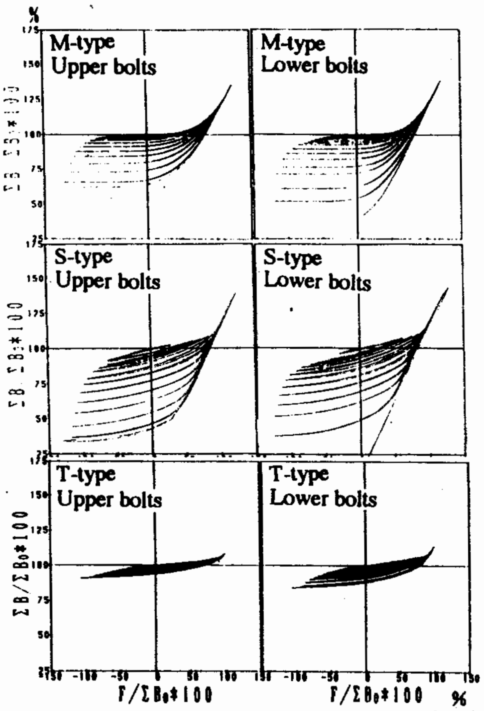

Figure 12. Relationships between nondimensional bolt axial force and nondimensional equivalent external force (in the case of specimens with T-flanges of 14mm thickness)

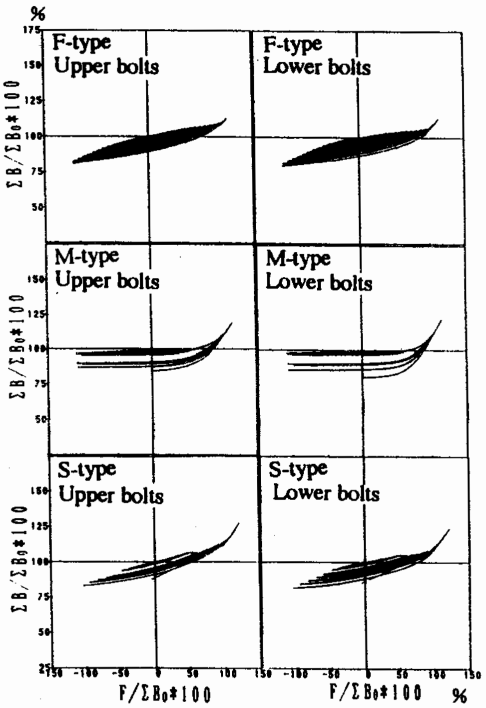

Figure 13. Relationships between nondimensional bolt axial force and nondimensional equivalent external force (in the case of specimens with T-flanges of 19mm thickness)

sirable in the mechanical view point is that compression forces can be concentrated on the portions where T-web plates are welded to T-flange plates.

CONCLUSIONS

Conclusions obtained in this study are as follows.

(1) The mechanical behavior is remarkably affected by the type of the contact surface used.

(2) Welding distortions having convex patterns do not affect the rotational stiffness of beam-to-column connections disadvantageously.

(3) Longitudinal distortions caused by welding should be deleted.

(4)Compression forces should be generally concentrated on the portions where T-web plates are welded to T-flange plates.

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