Experimental verification of actual behaviour of header plate connections

Dr Milan Pilgr[1]
[1]*Institute of Metal and Timber Structures, Faculty Of Civil Engineering, Brno University of Technology, Brno, Czech Republic*

ABSTRACT: The paper deals with problems of an actual behaviour of header plate connections in steel building frames. A traditional model of the joint under examination represents a nominally pinned joint. Such a model is regarded by the author as not quite accurate. That is why he examines the necessity of a general conception of idealization of strain mechanism of this joint type. In order to describe generally the joint behaviour in the loading process, he uses characteristics applied in the theory of semi-rigid connections, i.e. M–ϕ relationship, where M is bending moment and ϕ is rotation; besides that he defines another deformation component, so-called connection unfolding c, and analogically introduces M–c relationship.

1 INTRODUCTION

The paper deals with problems of an actual behaviour of header plate connections in steel building frames. A traditional model of the joint under examination represents a nominally pinned joint stemming from the following assumption. During the loaded bar system deformation, all the connected member end caps have the same deflections while the end cap cross-section rotation is not interdependent. Such a model is regarded by the author as not quite accurate. That is why he examines the necessity of a general conception of idealization of this joint type actual behaviour. In order to describe generally the joint behaviour in the loading process, he uses characteristics applied in the theory of semi-rigid connections, i.e. M–ϕ relationship, where M is bending moment and ϕ is rotation; besides that he defines another deformation component, so-called connection unfolding c, and analogically introduces M–c relationship. Connection unfolding c is the distance between end plate and column flange. The distance is due to deformation of header plate by prying. The unfolding c depends on the connection rotation ϕ, because the axis of rotation and the beam axis are skew lines. We size the unfolding c along beam axis, see figure 1.

2 EXPERIMENTS

The experimental method has been selected as the key method for data collection. Henceforth, 33 test specimens have been constructed and tested. They represent a portion of the real bar system including altogether 11 different arrangement variations of the header plate connection. The joint configuration is shown in figure 2. It's single sided joint between beam from IPE and column from HEB. The table 1 is included connection geometry. The variable were bolt diameter d, end plate geometry b_p, h_p, t_p, horizontal spacing e_y, w, vertical spacing e_z, p, height of beam h_b and distance between lower edge of end plate and centroid of beam d_p. Views of experiments are shown in figures 3 and 4.

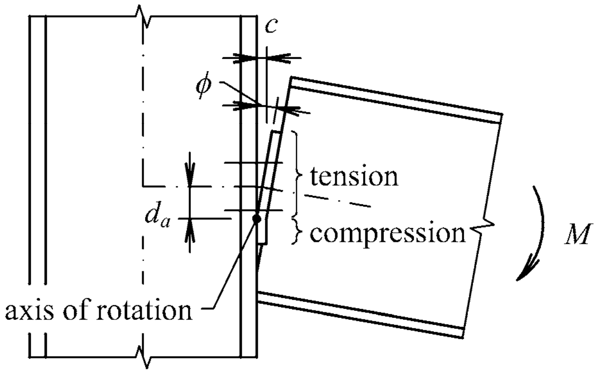


Figure 1. Schema of strain mechanism of connection.

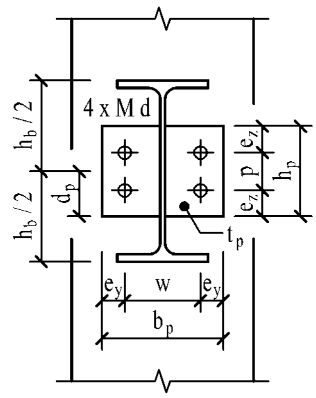
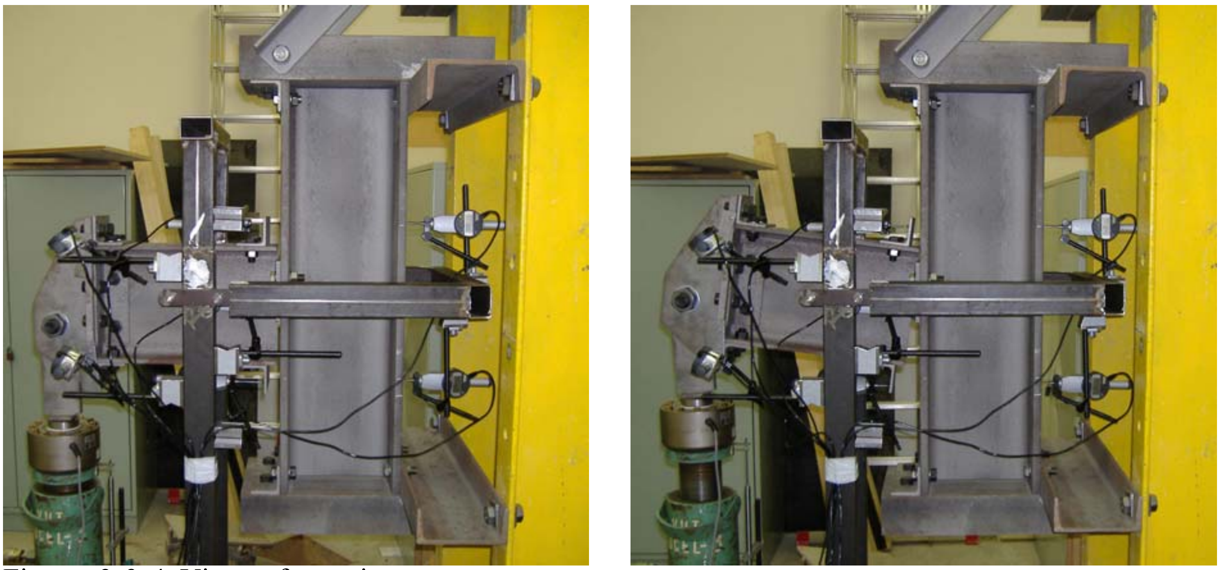


Figure 2. Symbols for connection geometry.

Table 1. Values of connection geometry in mm

	d	b_p	w	e_y	h_p	p	e_z	t_p	h_b	t_{wb}	d_p
T-1	16	160	100	30	120	50	35	10	240	6,2	60
T-2	20	180	100	40	150	70	40	10	240	6,2	75
T-3	24	200	100	50	180	80	50	10	240	6,2	90
T-4	16	160	100	30	120	50	35	8	240	6,2	60
T-5	16	160	100	30	120	50	35	12	240	6,2	60
T-6	16	160	100	30	120	50	35	10	240	6,2	25
T-7	16	160	100	30	120	50	35	10	240	6,2	95
T-8	16	160	100	30	120	50	35	10	270	6,6	60
T-9	16	160	100	30	120	50	35	10	270	6,6	10
T-10	16	160	100	30	120	50	35	10	270	6,6	110
T-11	16	160	100	30	120	50	35	10	300	7,1	60



Figures 3 & 4. Views of experiments.

3 RESULTS

An immediate result of experiments represents a piece of knowledge of strain mechanism of connection. The connection consists of two parts – tension part and compression part, see figure 1. The axis of connection rotation is based on the boundary between tension and compression parts – d_a is the distance between axis of rotation and centroid of beam. The actual behaviour of connection is illustrated in figures 5 and 6 – they are relationships *M*–ϕ and *M*–*c*, where *M* is bending moment, ϕ rotation and *c* unfolding. Research focuses above all on the determination of relationships *M*–ϕ and *M*–*c* of header plate connections of the selected geometrical configuration and on the relation between these relationships. An immediate application of relationships *M*–ϕ and *M*–*c* rests in the rotation stiffness determination $S = M / \phi$ (transferred from the theory of semi-rigid joints) and in the newly introduced, so-called translational characteristic $T = M / c$.

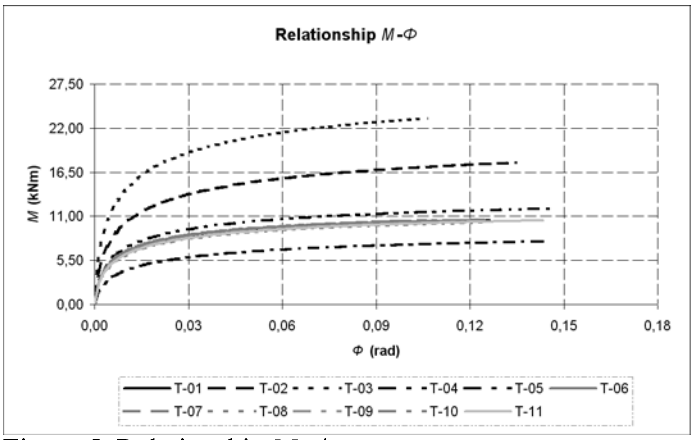


Figure 5. Relationship *M*–ϕ.

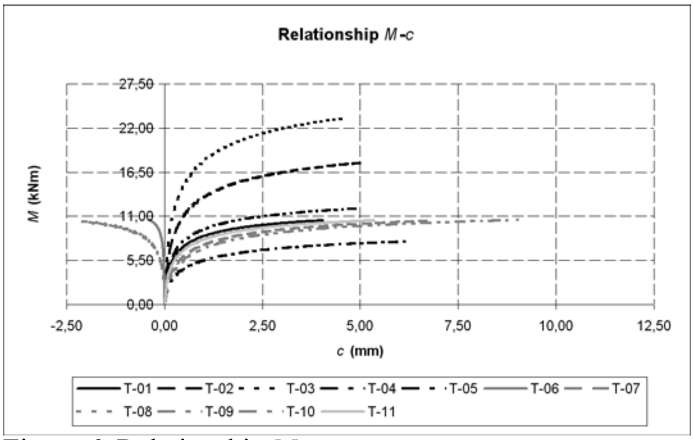


Figure 6. Relationship *M*–*c*.

The relationship *M*–ϕ should be setted using the following equation

$$M = \frac{S_0\,\phi}{\left[1+\left(\frac{S_0\,\phi}{M_u}\right)^n\right]^{1/n}}, \qquad (1)$$

where M_u is maximal moment,
S_0 initial stiffness,
n parameter of curve shape.

The relationship *M*–*c* should be setted using the following equation

$$M = \frac{T_0\,c}{\left[1+\left(\frac{T_0\,c}{M_u}\right)^n\right]^{1/n}}, \qquad (2)$$

where M_u is maximal moment,
T_0 initial translational characteristic,
n parameter of curve shape.

The table 2 is included values of parameters M_u, S_0, T_0, n of functions (1) and (2).

Relation between quantities S and T is based on the following equation (setted according an analysis of experimental data)

$$T = \frac{S}{d_p - q\, e_z}, \tag{3}$$

where

$$q = \frac{\Delta d_a}{e_z}, \tag{4}$$

$$\Delta d_a = d_p - d_a, \tag{5}$$

where e_z is the distance between bolt and edge of end plate,
d_p the distance between lower edge of end plate and centroid of beam,
d_a the distance between axis of rotation and centroid of beam.

The table 1 is included values of parameters e_z, d_p, the table 2 is included values of parameter d_a.

Table 2. Values of joint quantities

Test specimens	M_u (kNm)	S_0 (kNm)	T_0 (kNm/mm)	n (–)	d_a (mm)	Δd_a (mm)	q (–)
T-1	12,884	5 777,1	181,00	0,53338	31,922	28,078	0,8022
T-2	23,169	10 539,9	279,04	0,47995	37,772	37,228	0,9307
T-3	30,309	15 964,2	367,64	0,48958	43,424	46,576	0,9315
T-4	10,610	3 779,4	87,16	0,47555	43,362	16,638	0,4754
T-5	15,043	7 497,0	221,41	0,49417	33,861	26,139	0,7468
T-6	12,797	5 764,0	– 1879,36	0,54694	– 3,067	28,067	0,8019
T-7	12,928	5 790,2	86,48	0,54643	66,953	28,047	0,8013
T-8	12,906	5 821,2	175,91	0,51182	33,091	26,909	0,7688
T-9	12,862	5 808,0	– 336,23	0,52652	– 17,274	27,274	0,7796
T-10	12,993	5 834,4	71,38	0,54090	81,735	28,265	0,8076
T-11	12,932	5 865,3	157,23	0,51892	37,303	22,697	0,6485

4 CONCLUSION

The goal of the paper is to present some conclusions of experimental research of actual behaviour of header plate connections. The research was done in the laboratory of Institute of Metal and Timber Structures, Faculty of Civil Engineering, Brno University of Technology – Brno, Czech Republic. The actual behaviour of header plate connection may be expressed by the connection rotation ϕ and the connection unfolding c. The relationships M–ϕ and M–c are based on the rotation stiffness S and the translational characteristic T. Relation between quantities S and T is based on parameter q. Variation in the parameter q is 0,5–0,9. An explanation of how the results should be used in design was published in [Pilgr, 2008].

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