PARAMETRIC STUDY OF FLUSH END-PLATE CONNECTIONS

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1. INTRODUCTION

Experimental observations have shown that most bolted connections in practice possess intermediate stiffness and are neither pinned nor rigid as commonly assumed. This behavior has significantly influences on the frame overall response. Although experimental tests are the most reliable method for predicting connection behavior[1], finite element models are proposed in this paper due to the cut down in cost and time need. The main objective of this paper is to carry out a parametric study of flush end-plate connections in order to identify the parameters that greatly influence the behavior of the connection.

2. EXPERIMENT TEST AND FINITE ELEMENT MODEL

24 flush end-plate connections were modeled and analyzed using a finite element software package MARC. Experimental data for the connections was based on studies carried out by J.R. Ostrander (1970)[2]. The cantilevered connection's general layout and the bilinear stress-strain curve are shown in Fig. 1 and 2 respectively. A set of experimental and F.E. model moment-rotation curves for one specimen is plotted in Fig. 3. In order to evaluate the reliability of using F.E. models in generating connection behavior data the following were chosen as points of comparison against experimental data, as illustrated in Fig 3, the: - a) initial rotational stiffness K_i, b) strain-hardening stiffness K_p, flexural resistance moment at 0.025rad rotation M_{25} and c) flexural resistance at 0.045Rad rotation M_{45}. The results are summarized in table 1.

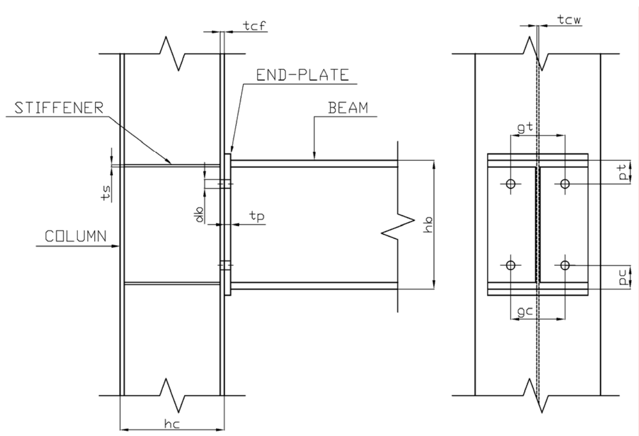

Fig. 1 Connection layout

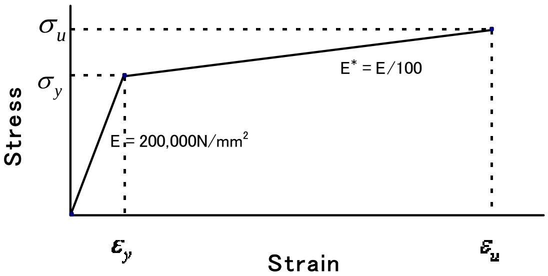

Fig. 2 Stress-strain curve

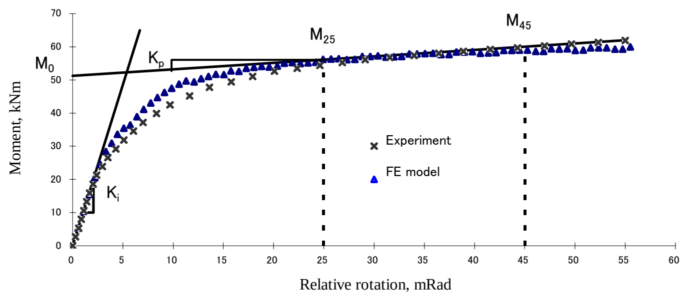

Fig. 3 Moment-rotation curve for specimen FEP1

Table 1 Connection details and results

Specimen ID	Beam	Column	t_p mm	g_t mm	p_t mm	p_c mm	Beam & Plate yield/ultimate stress N/mm2	Column yield/ultimate stress N/mm2	t_s mm	d_b mm	FEM RESULTS K_i kNm/rad	K_p kNm/rad	M_{25} kNm	M_{45} kNm	M_o kNm	EXP. RESULTS K_i kNm/rad	K_p kNm/rad	M_{25} kNm	M_{45} kNm	M_o kNm
FEP1	W10X21	W8X28	12.70	88.90	63.50	63.50	285 / 461	352 / 533		20	10,229	145	56.0	60.9	55.9	9,700	203	54.6	60.0	51.2
FEP2	W10X21	W8X28	9.53	88.90	63.50	63.50	285 / 461	352 / 533		20	8,613	165	47.0	51.8	45.5	10,089	189	48.4	53.4	45.8
FEP3	W10X21	W8X28	6.35	88.90	63.50	63.50	285 / 461	352 / 533		20	7,187	250	28.1	33.3	22.2	5,863	241	27.2	32.3	21.6
FEP4	W10X21	W8X28	19.05	88.90	63.50	63.50	295 / 332	316 / 516		20	12,571	175	56.4	61.5	54.9	21,446	215	60.0	65.3	56.5
FEP5	W12X27	W8X40	9.53	101.60	63.50	63.50	400 / 543	290 / 494		20	14,599	310	59.3	66.5	53.2	14,731	385	61.0	69.6	52.9
FEP6	W12X27	W8X40	12.70	101.60	63.50	63.50	400 / 544	290 / 494		20	19,312	245	78.5	84.9	74.9	21,415	318	81.0	88.7	75.3
FEP7	W12X27	W8X40	15.88	101.60	63.50	63.50	400 / 544	290 / 494		20	21,077	400	91.2	100.2	82.7	13,706	601	91.7	103.8	79.0
FEP8	W12X27	W8X24	9.53	101.60	63.50	63.50	400 / 543	435 / 543		20	11,829	95	54.6	59.7	58.3	14,162	77	54.9	61.2	59.9
FEP9	W12X27	W8X24	12.70	101.60	63.50	63.50	400 / 543	435 / 543		20	13,926	255	61.9	68.5	58.2	8,473	138	63.8	71.2	69.1
FEP10	W12X27	W8X24	15.88	101.60	63.50	63.50	400 / 543	435 / 543		20	15,018	285	62.4	69.6	58.0	13,062	300	64.1	71.8	59.6
FEP11	W12X27	W8X48	15.88	101.60	63.50	63.50	400 / 543	265 / 453		20	22,381	690	108.1	123.3	93.0	23,675	894	102.0		80.9
FEP12	W10X21	W8X28	12.70	88.90	63.50	63.50	285 / 533	352 / 533	9.53	20	13,251	160	64.3	69.1	65.0	11,364	248	62.3	70.0	61.4
FEP13	W10X21	W8X28	12.70	88.90	63.50	63.50	285 / 533	352 / 533	6.35	20	12,633	120	62.6	67.0	63.0	11,748	159	60.7	66.2	61.0
FEP14	W10X21	W8X28	9.53	88.90	63.50	63.50	285 / 533	352 / 533	6.35	20	11,555	150	47.6	52.1	46.7	17,431	114	50.3	56.5	51.8
FEP15	W10X21	W8X28	6.35	88.90	63.50	63.50	285 / 533	352 / 533	6.35	20	8,677	190	28.8	33.1	25.0	6,159	130	29.1	32.9	28.3
FEP16	W10X21	W8X28	6.35	88.90	63.50	63.50	285 / 533	352 / 533	9.53	20	9,085	245	29.3	34.8	24.4	9,325	226	28.9	34.1	24.6
FEP17	W10X21	W8X28	19.05	88.90	63.50	63.50	295 / 332	317 / 516	9.53	20	15,507	269	73.8	80.8	69.8	26,191	364	75.3	83.4	67.6
FEP18	W12X27	W8X40	9.53	101.60	63.50	63.50	400 / 543	290 / 494	6.35	20	18,641	320	68.4	75.8	62.0	12,844	251	67.8	75.6	66.7
FEP19	W12X27	W8X40	12.70	101.60	63.50	63.50	400 / 543	290 / 494	6.35	20	22,072	660	90.2	104.4	75.3	25,162	730	93.6		77.8
FEP20	W12X27	W8X40	15.88	101.60	63.50	63.50	400 / 543	290 / 494	6.35	20	25,984	455	105.3	116.4	97.4	35,407	565	110.5		98.0
FEP21	W12X27	W8X24	9.53	101.60	63.50	63.50	400 / 543	435 / 543	6.35	20	14,459	245	64.1	70.5	60.6	11,478	238	58.0	65.1	56.5
FEP22	W12X27	W8X24	12.70	101.60	63.50	63.50	400 / 543	435 / 543	6.35	20	18,850	290	76.6	84.6	72.9	11,382	254	73.9	83.5	76.5
FEP23	W12X27	W8X24	15.88	101.60	63.50	63.50	400 / 543	435 / 543	6.35	20	20,975	530	77.5	89.6	66.9	25,861	384	77.2	85.9	69.4
FEP24	W12X27	W8X48	15.88	101.60	63.50	63.50	400 / 543	265 / 453	6.35	20	27,696	700	117.8	134.8	105.8	42,452	816	116.0		98.3

Key Words: *Finite Element Model, Parametric study, Initial Stiffness, Flexural resistance moment*
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3. PARAMETRIC STUDY

The reliability of using finite element models to generate moment-rotation curves is confirmed upon studying the comparative results summarized in Table 1. The F.E. model and experimental values for K_i, M_{25} and M_{45} are found to be in relatively good agreement. In order to carry out a parametric study a further 170 connection assemblies, made up of various combinations of geometric and material properties, were analyzed. Connection parameters were varied and combined within the limits tabulated in Table 2. The connection parameters are defined in Figure 1.

Table 2 Range of connection geometric and material properties

Parameter	t_{cf} mm	t_p mm	t_s mm	t_{cw} mm	h_b mm	h_c mm	g_t mm	p_t mm	p_c mm	d_b mm	Yield stress N/mm2
Lowest value	10.1	6.35	2.5	6.22	214	201.4	68.9	38.1	38.1	9.8	220
Highest value	20.6	22.5	11.1	10.9	336.5	318.3	122	88.9	88.9	25	435

Figure 4 shows the predicted failure mode and deformation shapes for the non-stiffened specimen FEP 11 and stiffened specimen FEP22 on the left and right hand side respectively. It can be seen that there is pronounced deformation at the top of the end-plate and the column flange around the top bolt. This was accompanied by deformation on the column flange in the compression zone, and buckling of the column web.

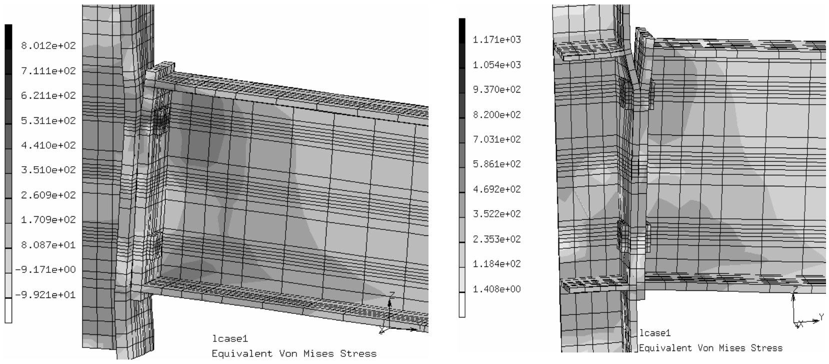

Fig. 4 Deformation shape for specimen FEP11 (L) and FEP22 (R)

Geometric properties of specimen FEP1 were used to non-dimension connection parameters of the other connections. The influence of the non-dimensional connection parameter on the initial stiffness K_i and the moment resistance at 0.025rad M_{25} are plotted in Figure 5 and 6 respectively.

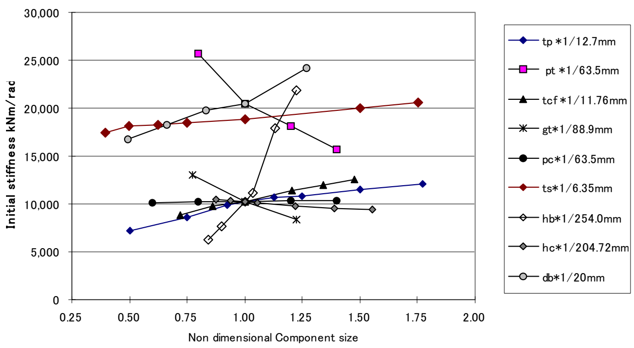

Fig. 5 Influence of varying the connection geometric properties on the initial stiffness.

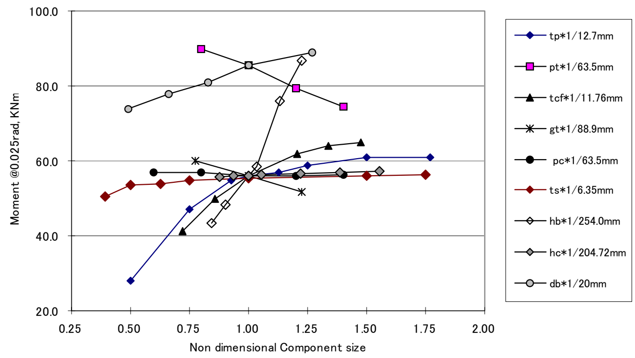

Fig. 6 Influence of varying the connection geometric properties on the moment resistance at 0.025rad.

From Fig. 5 and 6 we can conclude that both the initial rotational stiffness and the flexural resistance moment are primarily affected by variations in the following connection parameters; end plate thickness t_p, tension gage distance p_t, column flange thickness t_{cf}, horizontal spacing between bolts g_t, stiffener thickness, t_s, beam depth h_b and diameter of tension bolt d_b.

4. CONCLUSION

Finite element models can be used to generate reliable full moment-rotation curves which can further be used to perform a parametric study so as to investigate the influence of the connection components on the connection behavior.

REFERENCES

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2) **W. F. Chen, Y. Goto and J.R.R. Liew,** *Stability Design of Semi-rigid frames*, John Wiley & Sons, Inc, 1996