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STEEL BEAM TO COLUMN CONNECTIONS - A REVIEW
OF TEST DATA AND THEIR APPLICABILITY TO
THE EVALUATION OF THE JOINT BEHAVIOUR OF THE
PERFORMANCE OF STEEL FRAMES

BY

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TABLES & FIGURES

Table 2

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Type of connection	Reference for experimental data	Date	Country of origin	No of tests	Type of fastener	Column axis restrained	Comments on M- ϕ curves
1. Single web cleat	Lipson (17) Lipson (18) Lipson & Antonio (19)	1968 1977 1980	Canada Canada Canada	138 43 33	3/4 in bolts 3/4 in A325 bolts 3/4 in A325 bolts	Major Major Major	- Provided for 17 bolt/bolt tests and 4 weld/bolt tests - Provided as bolt M vs ϕ for 13 weld/bolt tests - Provided as bolt M vs ϕ for 11 weld/bolt tests
2. Double web cleats	Batho & Rowan (1) Rathbun (6) Hechtman & Johnston (31) Munse et al (24) Lewitt et al (25) Sommer (39) Bergquist (26) Bennetts et al (27) Mansell & Pham (28) Bose (29) Birkemoe & Gilmour (20) Ricles & Yura (21/22) Wing & Harris (23) Bjorhovde (30)	1934 1936 1947 1959 1969 1969 1977 1978 1981 1981 1978 1982 1983 1984	U.K. U.S.A. U.S.A. U.S.A. U.S.A. Canada U.S.A. Australia Australia U.K. Canada U.S.A. Canada U.S.A.	3 7 4 4 7 4 3 2 8 1 2 8 12 10	3/4 in rivets 7/8 in rivets 3/4 in rivets 3/4 rivets/bolts 3/4 bolts/rivets 3/4 in A325 bolts bolts M20 8.8 bolts M20 8.8 & 4.6 bolts M20 8.8 bolts 3/4 in A325 bolts 3/4 in A325 bolts 3/4 in A325 bolts 3/4 in A325 bolts & welds	Major Major Major Major Major Major Major Major Major Major Major Major Major Major	Provided for each test Provided for each test Provided for each test Also provides unloading stiffness Provided for each test Some indication from shear and rotation results Provided Not provided Not provided Not provided Provided for each test
3. Web side plate	Pham & Mansell (28,34)	1982	Australia	5	M20 8.8 bolts	Major	Some indication from shear rotation results
4. Flange cleats	Batho & Rowan (1) Maxwell et al (35) Bose (29) van Dalen & Godoy (36) Hotz (37.) Rathbun (16) Hechtman & Johnston (31)	1936 1981 1981 1982 1983 1936 1947	U.K. U.K. U.K. Canada W. Germany U.S.A. U.S.A.	10 12 1 1 37 3 19	1/4 in. rivets/bolts M20 8.8 & HSFG bolts bolts M20 8.8 & HSFG bolts 1/4 in A325 bolts M12, M16 & M24 bolts rivets rivets	Major Major Major Major Major Minor 14 Major 7 Minor	Provision of full curves Provision of full curve Full curve for this test and for 2 similar composite specimens Provision of full curves
5. Bottom flange cleat & web cleat	-						

Table 2 (continued)

Type of connection	Reference for experimental data	Date	Country of origin	No of tests	Type of fastener	Column axis restrained	Comments on M-φ curves
6. Header plate	Sommer (39)	1969	Canada	20*	3/4 in A325 bolts	Major	- 8 M-10 curves given in ref. 40 - Provision of full curves - Provision of full curves including unloading and, in one case, reloading - Some indication from shear-rotation results
	Kennedy & Hafez (41)	1984	Canada	8	3/4 in A325 bolts	Major	
	Bennetts et al (27)	1978	Australia	2	M20 8.8 bolts	Major	
	Pham & Mansell (28,34)	1982	Australia	7	M20 8.8 bolts	Major	
7. Flush end plate	Zoetemeijer & Kolstein (47)	1975	Netherlands	12	M24Gr 8.8 bolts	Major	Provided for each test Provided Provided for each test M versus deflection curves provided Provided for 16 tests only in ref. 43, other 7 supplied privately Provided for each test Provided for each test Provided for all tests four of which were for joints in frames
	Bose (29)	1981	U.K.	1	M20Gr 8.8 bolts	Major	
	Morris & Newsome (48)	1981	U.K.	4	7/8 in preloaded bolts	Major	
	Mann & Morris (44,45)	1981	U.K.	6	M22 HSFG bolts	Major	
	Zoetemeijer (43)	1981	Netherlands	23	M24Gr 8.8 bolts	Major	
	Phillips & Packer (46)	1981	Canada	5	M22 A325 bolts	Major	
	Jenkins et al (49)	1984	U.K.	3	M20Gr 8.8 bolts	Major	
	Zoetemeijer (50)	1974	Netherlands	6	M20 10.9 bolts	Major	
8. Extended end plate	Sherbourne (51)	1961	U.K.	5	3/4 & 7/8 in HT bolts	Major	Provided for 4 joints in frame test only in ref. 46 Load-deflection curves only provided Provided for 3 tests only Provided for 2 tests only in ref. 53 Provided for 1 test in ref. 54, available for all tests in ref.55 Provided for each test Provided for 2 tests only Provided for each test Provided for each test Provided for each test
	Johnson et al (52)	1960	U.K.	1	3/4 in HT bolts		
	Bailey (53)	1970	U.K.	13	HSFG bolts	Major	
	Surtees & Mann (54)	1970	U.K.	6	3/4, 1 & 1 1/4 in HSFG bolts	Major	
	Zoetemeijer (50)	1974	Netherlands	8	M20 & M22 Gr 10.9 bolts	Major	
	Grundy et al (55)	1980	Australia	2	7/8 in HSFG bolts	Major	
	Packer & Morris (56)	1977	U.K.	5	M16 HSFG bolts	Major	
	Tarpy & Cardinal (57)	1981	U.S.A.	16	3/4, 7/8 & 1 in A325 bolts	Major	
	Bahia et al (58,59)	1981	U.K.	20	M16 HSFG bolts	Major	
	Jenkins et al (49)	1984	U.K.	3	M20 Gr 8.8 bolts	Major	
	Moore & Sims (60)	1983	U.K.	4	M16 Gr 8.8 bolts	Major	
	Zoetemeijer & Munter (61)	1984	Netherlands	4	M20 Gr 8.8 bolts	Major	
	Zoetemeijer (62)	1981	Netherlands	10	M20 & M24 Gr 8.8 bolts	Major	
	Zoetemeijer (63)	1981	Netherlands	5	M20 & M24 Gr 8.8 bolts	Major	

TABLE 4 (continued)

Type of connection	Reference for experimental data	Date	Country of origin	No of tests	Type of fastener	Column axis restrained	Comments on M-φ curves
9. Combined web and flange cleats	Batho and Rowan (1)	1934	U.K.	2	Rivets	Major	Provided for each test
	Young and Jackson (15)	1934	Canada	4	Welded	2-Major 2-Minor	
	Rathbun (16)	1936	U.S.A.	2	Rivets	Minor	
	Hechtmann & Johnston (31)	1947	U.S.A.	2	1/2 in rivets	Major	
	Zoetemeijer (50)	1974	Netherlands	4	Bolts	Major	
10. Tee stubs	Batho and Rowan (1)	1934	U.K.	2	Rivets	Major	Provided for each test Provided for 2 tests only
	Rathbun (16)	1936	U.S.A.	6	Rivets	5-Min/1 Maj	
	Hechtmann & Johnston (31)	1947	U.S.A.	1	1/2 rivets	Major	
	Douty (64)	1964	U.S.A.	3	Bolted	Major	
	Bannister (65)	1966	U.K.	8	Bolted	Major	
	Zoetemeijer (50)	1974	Netherlands	8	Bolted	Major	
11. Top plate and seat angle	Young and Jackson (15)	1934	Canada	10	Welded	Minor	Provided for each test
	Johnston and Deits (66)	1942	U.S.A.	2	Welded	Major	
	Brandes and Mains (67)	1944	U.S.A.	17	Welded	5-Major 12-Minor	
	Pray and Jensen (68)	1956	U.S.A.	1	Welded	Major	
	Johnston (69)	1959	U.K.	1	Welded	Major	
	Johnston (52)	1960	U.K.	1	Welded	Major	
	Van Dalen and Godoy (36)	1982	Canada	3	Welded	Major	
12. Tee-stub and web cleats	Batho and Rowan (1)	1934	U.K.	1	3/4 in rivets	Major	Provided for 1 test only in ref. 46
	Young and Jackson (5)	1934	Canada	4	7/8 in rivets	2 Major 2 Minor	
	Young and Jackson (5)	1934	Canada	4	Welds	2-Maj/2 Min	
	Hechtmann & Johnson (31)	1947	U.S.A.	1	1/2 in rivets	Major	
	Zoetemeijer (50)	1974	Holland	13	M20 & M22 bolts	Major	
13. I-beam to RHS column	Picard & Giroux (71)	1976	Canada	21	Welds	Major	Provided for each test Provided for each test Provided for both beams of a cruciform arrangement
	Giroux & Picard (72)	1977	Canada	13	Welds	Major	
	Echeta & Owens (73)	1981	U.K.	1	Welds + 8.8 bolts	Major	

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
25	FK-3	12WF27	10WF49	6 x 4 x 1/4 - 8 1/2 in. long	6 rivets	6 x 1/2 in. A352 bolts	13/16 in.	snug + 1/2 turn	cruciform load in column	Almost identical M-φ for both sides.
	FK-4AB	18WF50	12WF65	6 x 4 x 1/4 - 11 1/2 in. long	8 x 1/2 in. A325 bolts	8 x 1/2 in. A325 bolts	13/16 in.	snug + 1/2 turn	cruciform load in column	M-φ for side with washers approx. 10% stiffer than for side without washers
	FK-4AB	18WF50	12WF65	6 x 4 x 1/4 - 11 1/2 in. long	8 x 1/2 in. A325 bolts	8 x 1/2 in. A325 bolts	13/16 in.	snug + 1/2 turn	cruciform load in column	No washers under nuts on column flange, almost identical M-φ for both sides.
	FK-4P	18WF50	12WF65	6 x 4 x 1/4 - 11 1/2 in. long	8 x 1/2 in. A325 bolts	8 rivets	13/16 in.	snug + 1/2 turn	cruciform load in column	No washers under nuts, almost identical M-φ for both sides.
	WF-4	18WF50	12WF65	6 x 4 x 1/4 - 11 1/2 in. long	8 x 1/2 in. A325 bolts	8 rivets	13/16 in.	snug + 1/2 turn	cruciform load in column	No washers under bolts heads or nuts, identical M-φ for both sides similar to FK-4P, cleats on column web.
	FB-4	18WF50	12WF65	4 x 3 x 1/4 - 11 1/2 in. long	8 x 1/2 in. A325 bolts	4 rivets	13/16 in.	snug + 1/2 turn	cruciform load in column	No washers under bolt heads or nuts, identical M-φ for both sides.
	FB-4A	18WF50	12WF65	4 x 3 1/2 x 1/4 - 11 1/2 in. long	4 rivets + 4 x 1/2 in. A325 bolts	4 x 1/2 in. A325 bolts	13/16 in.	snug + 1/2 turn	cruciform load in column	1 angle riveted to column flange, the other bolted, some difference in M-φ curves for both sides.
	FK-5	21WF62	12WF65	6 x 4 x 7/16 - 14 1/2 in long	10 x 1/2 in. A325 bolts	8 rivets	13/16 in.	snug + 1/2 turn	cruciform load in column	No washers under bolt heads or nuts, identical M-φ for both sides.
24	FK-4A	18WF50	12WF65	6 x 4 x 1/4 - 11 1/2 in. long	8 x 1/2 in. A235 bolts	8 rivets	13/16 in. punched	tightened to bolt force of 25,600 lb.	cruciform load in column	M-φ curve for 1 side only, 40 in. beam span.
	FK-43	18WF50	12WF50	6 x 4 x 1/4 - 11 1/2 in. long	8 x 1/2 in. A325 bolts	8 rivets	13/16 in. punched	tightened to bolt force of 25,600 lb.	cruciform load in column	Similar M-φ for both sides, 20 in. beam span.
	FK-4C	18WF50	12WF65	6 x 4 x 1/4 - 11 1/2 in. long	8 x 1/2 in. A325 bolts	8 rivets	13/16 in. punched	tightened to bolt force of 25,600 lb.	cruciform load in column	Similar M-φ for both sides, 10 in. beam span, stiffeners on beam web at load points.
	FK-4R	18WF50	12WF65	6 x 4 x 1/4 - 11 1/2 in. long	8 rivets	8 rivets	-	-	cruciform load in column	Similar M-φ for both sides close to that for FK-4A, 40 in. span
29	A	457 x 191 x 17 UB	305 x 305 x 97 UC	150 x 90 x 15-400mm long	10 x M20 8.8 bolts	9 x M20 8.8 bolts	-	podger spanner used	cruciform	Mean M-φ curve given, hardened washers under nuts.
30	1A	W18x45	W12x161	2 1/2 x 3 x 5/16 6 in. long	weld	2 x 1/2 in. A325 bolts	punched	turn of nut	cantilever	36 in. beam with 3 1/2 x 1 1/2 cope on tension side.

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
	1B	W18x45	W12x161	2½ x 3 x $\frac{5}{16}$ - 6 in. long	weld	2 x ¼ in. A325	punched	turn of nut	cantilever	84 in. beam with 3½ x 1½ cope on tension side.
	2A	W18x45	W12x161	2. x 3 x $\frac{5}{16}$ - 9 in. long	weld	3 x ¼ in. A325 bolts	punched	turn of nut	cantilever	36 in. beam with 3½ x 1½ cope on tension side.
	2B	W18x45	W12x161	2½ x 3 x $\frac{5}{16}$ - 9 in. long	weld	3 x ¼ in. A325 bolts	punched	turn of nut	cantilever	84 in. beam with 3½ x 1½ cope on tension side.
	2C	W18x45	W12x161	2½ x 3 x $\frac{5}{16}$ - 9 in. long	weld	3 x ¼ in. A325 bolts	punched	turn of nut	cantilever	36 in. beam with diagonal cope.
	3A	W24x76	W12x161	2½ x 3 x $\frac{5}{16}$ - 12 in. long	weld	4 x ¼ in. A325 bolts	punched	turn of nut	cantilever	36 in. beam with 3½ x 1½ cope on tension side.
	3B	W24x76	W12x161	2½ x 3 x $\frac{5}{16}$ - 12 in. long	weld	4 x ¼ in. A325 bolts	punched	turn of nut	cantilever	84 in. beam with 3½ x 1½ cope on tension side.
	3C	W24x76	W12x161	2½ x 3 x $\frac{5}{16}$ - 12 in. long	weld	4 x ¼ in. A325 bolts	punched	turn of nut	cantilever	84 in. beam with diagonal cope.
	4A	W18x45	W12x161	2½ x 3 x $\frac{5}{16}$ - 9 in. long	6 x ¼ in. A325 bolts	weld	punched	turn of nut	cantilever	36 in. beam with 3½ x 1½ cope on tension side.
	4B	W18x45	W12x161	2½ x 3 x $\frac{5}{16}$ - 9 in. long	6 x ¼ in. A325 bolts	weld	punched	turn of nut	cantilever	84 in. beam with 3½ x 1½ cope on tension side.
27	2	61OUB113	25OUC105	102 x 102 x 6.5 - 350mm long	6 x M20 8.8 bolts	3 x M20 8.8 bolts	22mm drilled	snug tight	propped cantilever	M-φ curve fell as ultimate shear was reached.
	4	41OUB54	25OUC105	102 x 102 x 6.5 - 210mm long	4 x M20 8.8 bolts	2 x M20 8.8 bolts	22mm drilled	snug tight	propped cantilever	M-φ curve fell as ultimate shear was reached.
26	A	W10x21	heavy	4 x 2½ x ¼ - 8½ in. long	6 x ¼ in. A325 bolts	3 x ¼ in. A325 bolts	-	turn of nut	cantilever	Unloading M-φ also provided.
	B	W10x21	heavy	3½ x 2½ x ¼ - 8½ in. long	$\frac{3}{16}$ in weld	3 x ¼ in. A325 bolts	-	turn of nut	cantilever	Unloading M-φ also provided.
	C	W10x21	heavy	4 x 2½ x ¼ - 8½ in. long	6 x ¼ A325 bolts	$\frac{3}{16}$ in weld	-	turn of nut	cantilever	Unloading M-φ also provided.
28	A1	36OUB45	-	102x102x6.5	4 x M20 4.6 bolts	2 x M20 4.6 bolts	22mm	snug tight	propped cantilever	Shear-rotation curve provided.
	A2	36OUB45	-	102x102x6.5	4 x M20 4.6 bolts	2 x M20 4.6 bolts	22mm	snug tight	propped cantilever	Shear-rotation curve provided.
	A3	36OUB45	-	102x102x6.5	6 x M20 4.6 bolts	3 x M20 4.6 bolts	22mm	snug tight	propped cantilever	Shear-rotation curve provided.
	A4	36OUB45	-	102x102x6.5	6 x M20	3 x M20	22mm	snug tight	propped	Shear-rotation curve provided.

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
35	A1	457 x 191 UB 67	305 x 305 UC 97	150 x 90 x 10 150mm long Gr. 43	2 x M20 8.8 bolts	4 x M20 HSFG bolts	22mm drilled	-	cruciform beam load	Average M-φ curve for both sides given.
	A2	457 x 191 UB 67	305 x 305 UC 97	150 x 90 x 10 200mm long Gr. 43	2 x M20 8.8 bolts	4 x M20 HSFG bolts	22mm drilled	-	cruciform beam load	Average M-φ curve for both sides given.
	A3	456 x 191 UB 67	305 x 305 UC 87	150 x 90 x 10 150mm long Gr. 50	2 x M20 8.8 bolts	4 x M20 HSFG bolts	22mm drilled	-	cruciform beam load	Average M-φ curve for both sides given.
	A4	456 x 191 UB 67	305 x 305 UC 97	150 x 90 x 10 200mm long Gr. 50	2 x M20 8.8 bolts	4 x M20 HSFG bolts	22mm drilled	-	cruciform beam load	Average M-φ curve for both sides given.
	B1	456 x 191 UB 67	305 x 305 UC 97	150 x 90 x 12 150mm long Gr. 43	2 x M20 8.8 bolts	4 x M20 HSFG bolts	22mm drilled	-	cruciform beam load	Average M-φ curve for both sides given.
	B2	456 x 191 UB 67	305 x 305 UC 97	150 x 90 x 12 200mm long Gr. 43	2 x M20 8.8 bolts	4 x M20 HSFG bolts	22mm drilled	-	cruciform beam load	Average M-φ curve for both sides given.
	B3	456 x 191 UB 67	305 x 305 UC 97	150 x 90 x 12 150mm long Gr. 50	2 x M20 8.8 bolts	4 x M20 HSFG bolts	22mm drilled	-	cruciform beam load	Average M-φ curve for both sides given.
	B4	456 x 191 UB 67	305 x 305 UC 97	150 x 90 x 12 200mm long Gr. 50	2 x M20 8.8 bolts	4 x M20 HSFG bolts	22mm drilled	-	cruciform beam load	Average M-φ curve for both sides given.
	C1	456 x 191 UB 67	305 x 305 UC 97	150 x 90 x 15 150mm long Gr. 43	2 x M20 8.8 bolts	4 x M20 HSFG bolts	22mm drilled	-	cruciform beam load	Average M-φ curve for both sides given.
	C2	456 x 191 UB 67	305 x 305 UC 97	150 x 90 x 15 150mm long Gr. 43	2 x M20 8.8 bolts	4 x M20 HSFG bolts	22mm drilled	-	cruciform beam load	Average M-φ curve for both sides given.
	C3	456 x 191 UB 67	305 x 305 UC 97	150 x 90 x 15 200mm long Gr. 50	2 x M20 8.8 bolts	4 x M20 HSFG bolts	22mm drilled	-	cruciform beam load	Average M-φ curve for both sides given.
	C4	456 x 191 UB 67	305 x 305 UC 97	150 x 90 x 15 200mm long Gr. 50	2 x M20 8.8 bolts	4 x M20 HSFG bolts	22mm drilled	-	cruciform beam load	Average M-φ curve for both sides given.
29	2	457 x 191 UB 67	305 x 305 UC 97	130 x 90 x 12 200mm long	2 x M20 8.8 bolts	4 x M20 HSFG bolts	22mm drilled	HSFG bolts at proof load	cruciform beam load	Average M-φ curve for both sides given.
36	SB1	W8x20	W8x20	2½x2½x¼ top 4x3x¼ bottom	2x¼in. A325 bolts + 4 x ¼in. A325 bolts	2 x ¼in. A325 bolts + 2 x ¼in. A325 bolts	-	-	cruciform load in column	One M-φ curve given.

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
	CB1	W8x20	W8x20	2½x2½x½ top 4x3x½ bottom	2x½in. A325 bolts + 4 x ½in. A325 bolts	2 x ½in. A325 bolts + 2 x ½in. A325 bolts	-	-	cruciform load in column	Composite version of SB1 with minimum slab reinforcement, one M-φ curve given.
	CB2	W8x20	W8x20	2½x2½x½ top 4x3x½ bottom	2x½in. A325 bolts + 4 x ½in. A325 bolts	2 x ½in. A325 bolts + 2 x ½in. A325 bolts			cruciform load in column	Composite version of SB1 with maximum slab reinforcement, one M-φ curve given.
37	A1	IPE180	IPB1 120	180 x 90 x 10	2 x M20 bolts	4 x M12 bolts	13mm	120 Nm torque	cantilever	Full M-φ curve provided.
	A2	IPE300	IPB1 120	180 x 90 x 10	2 x M20 bolts	4 x M12 bolts	13mm	120 Nm torque	cantilever	Full M-φ curve provided.
	A3	IPE180	IPB1 120	180 x 90 x 10	2 x M20 bolts	4 x M12 bolts	13mm	120 Nm torque	cantilever	Full M-φ curve provided.
	A4	IPE180	IPB1 120	180 x 90 x 10	2 x M20 bolts	4 x M12 bolts	13mm	120 Nm torque	cantilever	Full M-φ curve provided.
	B1	IPE180	IPB1 160	200 x 100 x 12	2 x M16 bolts	4 x M16 bolts	17mm	350 Nm torque	cantilever	Full M-φ curve provided.
	B2	IPE180	IPB1 160	200 x 100 x 12	2 x M16 bolts	4 x M16 bolts	17mm	350 Nm torque	cantilever	Full M-φ curve provided.
	B3	IPE180	IPB1 160	200 x 100 x 12	2 x M16 bolts	4 x M16 bolts	17mm	350 Nm torque	cantilever	Full M-φ curve provided.
	B4	IPE180	IPB1 160	200 x 100 x 12	2 x M16 bolts	4 x M16 bolts	17mm	350 Nm torque	cantilever	Full M-φ curve provided.
	C1	IPE360	IPB1 240	200 x 100 x 14	2 x M24 bolts	4 x M24 bolts	25mm	1100 Nm torque	cantilever	Full M-φ curve provided.
	C2	IPE360	IPB1 240	200 x 100 x 14	2 x M24 bolts	4 x M24 bolts	25mm	1100 Nm torque	cantilever	Full M-φ curve provided.
	C3	IPE360	IPB1 240	200 x 100 x 14	2 x M24 bolts	4 x M24 bolts	25mm	1100 Nm torque	cantilever	Full M-φ curve provided.
	D1	IPE180	IPB120	180 x 40 x 10	2 x M12 bolts	4 x M12 bolts	13mm	120 Nm torque	cantilever	Full M-φ curve provided.
	D2	IPE180	IPB120	180 x 40 x 10	2 x M12 bolts	4 x M12 bolts	13mm	120 Nm torque	cantilever	Full M-φ curve provided.
	D3	IPE180	IPB120	180 x 40 x 10	2 x M12 bolts	4 x M12 bolts	13mm	120 Nm torque	cantilever	Full M-φ curve provided.
	E1	IPE180	IPB120	180 x 40 x 10	2 x M12 bolts	4 x M12 bolts	13mm	120 Nm torque	cantilever	Top cleats on both beam faces, full M-φ curve provided.

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
E2	IPE180	IPB120	180 x 40 x 10	2 x M12 bolts	4 x M12 bolts	13mm	120 Nm torque	cantilever	Top cleats on both beam faces, full M-φ curve provided.	
E3	IPE180	IPB120	180 x 40 x 10	2 x M12 bolts	4 x M12 bolts	13mm	120 Nm torque	cantilever	Top cleats on both beam faces, full M-φ curve provided.	
F1	IPE240	IPB160	200 x 100 x 12	2 x M16 bolts	4 x M16 bolts	17mm	350 Nm torque	cantilever	Full M-φ curve provided.	
F2	IPE240	IPB160	200 x 100 x 12	2 x M16 bolts	4 x M16 bolts	17mm	350 Nm torque	cantilever	Full M-φ curve provided.	
F3	IPE240	IPB160	200 x 100 x 12	2 x M16 bolts	4 x M16 bolts	17mm	350 Nm torque	cantilever	Full M-φ curve provided.	
F4	IPE240	IPB160	200 x 100 x 12	2 x M16 bolts	4 x M16 bolts	17mm	350 Nm torque	cantilever	Full M-φ curve provided.	
G1	IPE360	IPB240	200 x 100 x 14	2 x M24 bolts	4 x M24 bolts	25mm	1100 Nm torque	cantilever	Full M-φ curve provided.	
G2	IPE360	IPB240	200 x 100 x 14	2 x M24 bolts	4 x M24 bolts	25mm	1100 Nm torque	cantilever	Full M-φ curve provided.	
G3	IPE360	IPB240	200 x 100 x 14	2 x M24 bolts	4 x M24 bolts	25mm	1100 Nm torque	cantilever	Full M-φ curve provided.	
G4	IPE360	IPB240	200 x 100 x 14	2 x M24 bolts	4 x M24 bolts	25mm	1100 Nm torque	cantilever	Full M-φ curve provided.	
I1	IPE180	IPBv120	180 x 90 x 10	2 x M12 bolts	4 x M12 bolts	13mm	120 Nm torque	cantilever	Full M-φ curve provided.	
I2	IPE180	IPBv120	180 x 90 x 10	2 x M12 bolts	4 x M12 bolts	13mm	120 Nm torque	cantilever	Full M-φ curve provided.	
I3	IPE180	IPBv120	180 x 90 x 10	2 x M12 bolts	4 x M12 bolts	13mm	120 Nm torque	cantilever	Full M-φ curve provided.	
I4	IPE180	IPBv120	180 x 90 x 10	2 x M12 bolts	4 x M12 bolts	13mm	120 Nm torque	cantilever	Full M-φ curve provided.	
J1	IPE240	IPBv160	200 x 100 x 12	2 x M16 bolts	4 x M16 bolts	17mm	350 Nm torque	cantilever	Full M-φ curve provided.	
J2	IPE240	IPBv160	200 x 100 x 12	2 x M16 bolts	4 x M16 bolts	17mm	350 Nm torque	cantilever	Full M-φ curve provided.	
J3	IPE240	IPBv160	200 x 100 x 12	2 x M16 bolts	4 x M16 bolts	17mm	350 Nm torque	cantilever	Full M-φ curve provided.	
J4	IPE240	IPBv160	200 x 100 x 12	2 x M16 bolts	4 x M16 bolts	17mm	350 Nm torque	cantilever	Full M-φ curve provided.	

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
39	5	18WF45	14WF38	15 x 6 x 1/4 in.	10 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	6	24WF76	14WF38	9 x 6 x 1/4 in.	6 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	7	24WF76	14WF38	12 x 6 x 1/4 in.	8 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	8	24WF76	14WF38	15 x 6 x 1/4 in.	10 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	9	24WF76	14WF38	18 x 6 x 1/4 in.	12 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	10	18WF45	14WF38	9 x 6 x 1/4 in.	6 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	11	18WF45	14WF38	12 x 6 x 1/4 in.	8 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	12	24WF76	14WF38	15 x 6 x 1/4 in.	10 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	13	24WF76	14WF28	9 x 6 x 1/4 in.	6 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	14	24WF76	14WF28	12 x 6 x 1/4 in.	8 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	15	24WF76	14WF28	15 x 7 x 1/4 in.	10 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	16	24WF76	14WF28	18 x 7 1/2 x 1/4 in.	12 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	17	24WF76	14WF28	12 x 7 1/2 x 1/4 in.	8 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	18	24WF76	14WF28	15 x 7 1/2 x 1/4 in.	10 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	19	24WF76	14WF28	12 x 7 1/2 x 1/4 in.	8 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	20	24WF76	14WF28	15 x 7 1/2 x 1/4 in.	10 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39,40
	25	18WF45	14WF28	12 x 6 x 1/4 in.	8 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39
	26	18WF45	14WF28	9 x 6 x 1/4 in.	6 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39
	27	12WF27	14WF28	9 x 6 x 1/4 in.	6 x 1/2 in. A325 bolts	weld	13/16 in. punched	snug + 1/2 turn	cantilever	M-φ curve in ref. 39

Table 6 (continued)

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Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
41	1	WWF27x106	heavy	457 x 162 x 9.5mm	12 x 1/4 in. A325 bolts	weld	13/16 in. drilled	torque to 370 ft. lbs.	cantilever	Full M-φ curve provided.
	2	WW 27x106	heavy	457 x 162 x 6.3mm	12 x 1/4 in. A325 bolts	weld	13/16 in. drilled	torque to 370 ft. lbs.	cantilever	Full M-φ curve provided.
	3	WWF27x106	heavy	457 x 200 x 9.5mm	12 x 1/4 in. A325 bolts	weld	13/16 in. drilled	torque to 370 ft. lbs.	cantilever	Full M-φ curve provided.
	4	WWF27x106	heavy	305 x 202 x 6.3mm	8 x 1/4 in. A325 bolts	weld	13/16 in. drilled	torque to 370 ft. lbs.	cantilever	Full M-φ curve provided.
	5	WWF27x106	heavy	305 x 200 x 9.5mm	8 x 1/4 in. A325 bolts	weld	13/16 in. drilled	torque to 370 ft. lbs.	cantilever	Full M-φ curve provided.
	6	WWF27x106	heavy	305 x 200 x 12.7mm	8 x 1/4 in. A325 bolts	weld	13/16 in. drilled	torque to 370 ft. lbs.	cantilever	Full M-φ curve provided.
	7	WWF27x106	heavy	36Q x 200 x 9.5mm	16 x 1/4 in. A325 bolts	weld	13/16 in. drilled	torque to 370 ft. lbs.	cantilever	Full M-φ curve provided.
	8	WWF27x106	heavy	360 x 200 x 6.3mm	16 x 1/4 in. A325 bolts	weld	13/16 in. drilled	torque to 370 ft. lbs.	cantilever	Full M-φ curve provided.
27	1	610UB113	250UC105	350 x 210 x 10mm	6 x M20 8.8 bolts	weld	22mm drilled	snug tight	propped cantilever	M-φ fell as ultimate shear was reached.
	3	410UB354	250UC105	210 x 210 x 10mm	4 x M20 8.8 bolts	weld	22mm drilled	snug tight	propped cantilever	M-φ fell as ultimate shear was reached, reloading M-φ curve was lower.
28, 34	F1	250UB31	310UC198	140 x 150 x 8mm	4 x M20 8.8 bolts	280mm of 6mm weld	22mm	snug tight	propped cantilever	Shear-rotation curve provided.
	F2	360UB45	310UC198	210 x 150 x 8mm	6 x M20 8.8 bolts	420mm of 6mm weld	22mm	snug tight	propped cantilever	Shear-rotation curve provided.
	F3	360UB45	310UC198	140 x 150 x 8mm	4 x M20 8.8 bolts	280mm of 6mm weld	22mm	snug tight	propped cantilever	Shear-rotation curve provided.
	F4	460UB67	310UC198	350 x 150 x 8mm	10 x M20 8.8 bolts	704mm of 6mm weld	22mm	snug tight	propped cantilever	Shear-rotation curve provided.
	F5	460UB67	310UC198	350 x 150 x 8mm	10 x M20 8.8 bolts	704mm of 6mm weld	22mm	snug tight	propped cantilever	Shear-rotation curve provided.
	F6	460UB67	310UC198	141 x 150 x 8mm	4 x M20 8.8 bolts	300mm of 6mm weld	22mm	snug tight	propped cantilever	Shear-rotation curve provided.
	F7	460UB67	310UC198	141 x 150 x 8mm	4 x M20 8.8 bolts	300mm f 6mm weld	22mm	snug tight	propped cantilever	Shear-rotation curve provided.

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
47	7	IPE400	HEA240A	25mm	6 x M24 8.8 bolts	weld	-	-	cruciform load in column	End plate depth = distance between flange centres, 214mm deep x 15mm backing plate on top 4 bolts.
	8	IPE400	HEA240A	25mm	6 x M24 8.8 bolts	weld			cruciform load in column	End plate extends below beam bottom flange, 214mm x 15mm backing plate on top 4 bolts
	9	IPE400	HEA240A	25mm	6 x M24 8.8 bolts	weld			cruciform load in column	End plate depth = distance between flange centres, 15mm compression stiffeners on column web.
	10	IPE400	HEA240A	25mm	6 x M24 8.8 bolts	weld			cruciform load in column	End plate depth = distance between flange centres, 214 x 15mm backing plates + 15mm compression stiffeners.
	11	IPE400	HEA240A	25mm	6 x M24 8.8 bolts	weld			cruciform load in column	End plate extends below beam bottom flange.
	12	IPE400	HEA240A	25mm	6 x M24 8.8 bolts	weld			cruciform load in column	End plate depth = distance between flange centres.
	13	IPE300	HEA240A	25mm	6 x M24 8.8 bolts	weld			cruciform load in column	End plate depth = distance between flange centres, 214mm x 15mm backing plates.
	14	IPE300	HEA240A	25mm	6 x M24 8.8 bolts	weld			cruciform load in column	End plate extends below beam bottom flange, 214mm x 15mm backing plates.
	15	IPE300	HEA240A	25mm	6 x M24 8.8 bolts	weld			cruciform load in column	End plate depth = distance between flange centres, 10mm compression stiffeners.
	16	IPE300	HEA240A	25mm	6 x M24 8.8 bolts	weld			cruciform load in column	End plate depth = distance between flange centres, 214mm x 15mm backing plates + 10mm compression stiffeners.
	17	IPE300	HEA240A	25mm	6 x M24 8.8 bolts	weld			cruciform load in column	End plate extends below beam bottom flange.
	18	IPE300	HEA250A	25mm	6 x M24 8.8 bolts	weld			cruciform load in column	End plate depth = distance between flange centres.
29	C	457 x 191 x 67 UB	305 x 305 x 97 UC	400 x 200 x 25mm	10 x M20 8.8 bolts	weld		podger spanner	cruciform	M-φ curve provided.

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
48	1	457 x 191 UB 67	305 x 165 UB 40	25mm	8 x 1/4 in. bolts	weld	-	preloaded	cruciform	End plates protrude above and below beam flanges, compression stiffeners on column web.
	2	457 x 191 UB 67	305 x 165 UB 40	25mm	8 x 1/4 in. bolts	weld		preloaded	cruciform	End plates protrude above and below beam flanges, small 12mm glut stiffeners on column web.
	3	457 x 191 UB 67	305 x 165 UB 40	25mm	8 x 1/4 in. bolts	weld		preloaded	cruciform	End plates protrude above and below beam flanges, 12mm k-stiffeners on column web.
	4	457 x 191 UB 67	305 x 165 UB 40	25mm	8 x 1/4 in. bolts	weld		preloaded	cruciform	End plates protrude above and below beam flanges, 10mm 'Morris' stiffeners on column web.
44, 45	1	406 x 140 UB 46	203 x 203 UC 71	440 x 200 x 12mm	8 x M22 HSFG bolts	8mm weld	24mm punched	-	cruciform, load in column	4 pairs of column web stiffeners.
	2	406 x 140 UB 46	203 x 203 UB 71	440 x 200 x 12mm	8 x M22 HSFG bolts	8mm weld	24mm punched		cruciform, load in column	4 pairs of column web stiffeners, distorted end plate.
	3	406 x 140 UB 46	203 x 203 UC 71	440 x 200 x 12mm	8 x M22 HSFG bolts	8mm weld	24mm punched		cruciform, load in column	4 pairs of column web stiffeners, shims under end plate.
	4	406 x 140 UB 46	203 x 203 UC 71	440 x 200 x 20mm	8 x M22 HSFG bolts	8mm weld	24mm punched		cruciform, load in column	4 pairs of column web stiffeners, load in column
	5	406 x 140 UB 46	203 x 203 UB 71	440 x 200 x 20mm	8 x M22 HSFG bolts	8mm weld	24mm punched		cruciform, load in column	4 pairs of column web stiffeners, distorted end plate.
	6	406 x 140 UB 46	203 x 203 UB 71	440 x 200 x 20mm	8 x M22 HSFG bolts	8mm weld	24mm punched		cruciform, load in column	4 pairs of column web stiffeners, shims under end plate.
43	16	HEA300	HE450M	290 x 230 x 12mm	4 x M24 8.8 bolts	10mm welds on inside and outside of end plate	-	-	cantilever	End plate depth = distance between flange centres.
	17	HEA300	HE450M	290 x 230 x 16mm	4 x M24 8.8 bolts	10mm welds on inside and outside of end plate			cantilever	End plate depth = distance between flange centres.
	18	HEA300	HE450M	290 x 230 x 12mm	4 x M24 8.8 bolts	10mm welds on inside and outside of end plate			cantilever	End plate depth = distance between flange centres.

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
19	HEA300	HEA300	HE450M	290 x 230 x 16mm	4 x M24 8.8 bolts	10mm welds on inside and outside of end plate	-	-	cantilever	End plate depth = distance between flange centres.
20	HEA300	HEA300	HE450M	290 x 230 x 12mm	4 x M24 8.8 bolts	10mm welds on inside and outside of end plate			cantilever	End plate depth = distance between flange centres.
21	HEA300	HEA300	HE450M	290 x 230 x 16mm	4 x M24 8.8 bolts	6mm welds on inside and outside of end plate			cantilever	End plate depth = distance between flange centres.
22	HEA300	HEA300	HE450M	290 x 230 x 12mm	4 x M24 8.8 bolts	6mm welds on inside and outside of end plate			cantilever	End plate depth = distance between flange centres.
23	HEA300	HEA300	HE450M	290 x 230 x 16mm	4 x M24 8.8 bolts	6mm welds on inside and outside of end plate			cantilever	End plate depth = distance between flange centres.
24	HEA300	HEA300	HE450M	290 x 230 x 12mm	6 x M24 8.8 bolts	6mm welds on inside and outside of end plate			cantilever	2 rows of top bolts. End plate depth = distance between flange centres.
25	HEA300	HEA300	HE450M	290 x 230 x 16mm	6 x M24 8.8 bolts	6mm welds on inside and outside of end plate			cantilever	2 rows of top bolts. End plate depth = distance between flange centres.
26	HEA300	HEA300	HE450M	290 x 230 x 12mm	6 x M24 8.8 bolts	6mm welds on inside and outside of end plate			cantilever	2 lines of top bolts. End plate depth = distance between flange centres.
27	HEA300	HEA300	HE450M	290 x 230 x 16mm	6 x M24 8.8 bolts	6mm welds on inside and outside of end plate			cantilever	2 lines of top bolts. End plate depth = distance between flange centres.
28	HEA300	HEA300	HE450M	290 x 230 x 12mm	6 x M24 8.8 bolts	6mm welds on inside and outside of end plate			cantilever	2 lines of top bolts. End plate depth = distance between flange centres.
29	HEA300	HEA300	HE450M	290 x 230 x 16mm	6 x M24 8.8 bolts	6mm welds on inside and outside of end plate			cantilever	2 lines of top bolts. End plate depth = distance between flange centres.

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
30		IPE400	HE450M	400 x 180 x 12mm	6 x M24 8.8 bolts	6mm welds on inside and outside of end plate	-	-	cantilever	2 rows of top bolt. End plate depth = distance between flange centres.
31		IPE400	HE450M	400 x 180 x 12mm	4 x M24 8.8 bolts	6mm welds on inside and outside of end plate			cantilever	
32		IPE400	HE450M	400 x 180 x 12mm	4 x M24 8.8 bolts	6mm welds on inside and outside of end plate			cantilever	
33		IPE400	HE450M	400 x 180 x 16mm	6 x M25 8.8 bolts	6mm welds on inside and outside of end plate			cantilever	2 rows of top bolts. End plate depth = distance between flange centres.
34		IPE400	HE450M	400 x 180 x 16mm	4 x M24 8.8 bolts	6mm weld on inside and outside of end plate			cantilever	
35		IPE400	HE450M	400 x 180 x 16mm	4 x M24 8.8 bolts	6mm welds on inside and outside of end plate			cantilever	
36		IPE400	HE450M	400 x 180 x 32mm	6 x M24 8.8 bolts	10mm welds on inside and outside of end plate			cantilever	2 rows of top bolts. End plate depth = distance between flange centres.
37		IPE400	HE450M	400 x 180 x 32mm	4 x M24 8.8 bolts	10mm welds on inside and outside of end plate			cantilever	
38		IPE400	HE450M	400 x 180 x 32mm	4 x M24 8.8 bolts	10mm welds on inside and outside of end plate			cantilever	
46	BM1	W250 x 33	W200 x 100	280 x 160 x 9.5mm	6 x A325 M22 bolts	weld	-	175 kN preload	cantilever	End plate protrudes above and below beam flanges, column web stiffeners opposite both beam flanges.
	BM2	W250 x 33	W200 x 100	280 x 160 x 15.9mm	6 x A325 M22 bolts	weld		175 kN preload	cantilever	End plate protrudes above and below beam flanges, column web stiffeners opposite both beam flanges.

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
	BM3	W250 x 33	W200 x 100	280 x 160 x 19.1mm	6 x A325 M22 bolts	weld	-	175 kN preload	cantilever	End plate protrudes above and below beam flanges, column web stiffeners opposite both beam flanges.
	BM4	W250 x 33	W200 x 100	280 x 160 x 22.2mm	6 x M325 M22 bolts	weld		175 kN preload	cantilever	End plate protrudes above and below beam flanges, column web stiffeners opposite both beam flanges.
	BM5	W250 x 33	W200 x 100	280 x 160 x 25.4mm	6 x M325 M22 bolts	weld		175 kN preload	cantilever	End plate protrudes above and below beam flanges, column web stiffeners opposite both beam flanges.
50	2	IPE300	HEA200A	325 x 200 x 32mm	6 x M20 10.9	weld	-	not preloaded	cantilever	End plate extends below bottom flange of beam
	22	IPE400	HEA200A	425 x 270 x 32mm	6 x M22 10.9	weld		not preloaded	cantilever	End plate extends below bottom flange of beam, 350 x 16mm backing plates.
	5A	IPE300	HE240A	320 x 180 x 25mm	6 x M22	weld	-	not preloaded	portal frame	End plate 20 mm below bottom flange + 260 x 95 x 15mm backing plates.
	5B	IPE300	HE240A	350 x 180 x 25mm	6 x M22	weld		not preloaded	portal frame	End plate 50mm below bottom flange + 260 x 95 x 15mm backing plates.
	5C	IPE300	HE240A	350 x 180 x 25mm	6 x M22	weld		not preloaded	portal frame	End plate 50mm below bottom flange + 260 x 95 x 15mm backing plates.
	5D	IPE300	HE240A	350 x 180 x 25mm	6 x M22	weld		not preloaded	portal frame	End plate 50mm below bottom flange + 260 x 95 x 15mm backing plates.
49	1	305 x 165 UB 40	254 x 254 UC 89	325 x 200 x 8mm	4 x M20 8.8 bolts	weld	22mm	-	-	column stiffening
	3	305 x 165 UB 40	254 x 254 UC 89	340 x 240 x 12mm	6 x M20 8.8 bolts	weld	22mm			column stiffening
	5	305 x 165 UB 54	254 x 254 UC 132	340 x 240 x 25mm	6 x M20 8.8 bolts	weld	22mm			column stiffening

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
50	9	IPE300	HE200A	400 x 200 x 32mm	6 x M20 10.9 bolts	weld	-	not preloaded	cantilever	300 x 80 x 13mm flange backing plates. 350 x 110 x 16mm flange backing plates.
	10	IPE300	HE200A	400 x 200 x 32mm	6 x M20 10.9 bolts	weld		not preloaded	cantilever	
	20	IPE400	HE300A	510 x 270 x 32mm	6 x M20 10.9 bolts	weld		not preloaded	cantilever	
	21	IPE400	HE200A	510 x 270 x 32mm	6 x M20 10.9 bolts	weld		not preloaded	cantilever	
	M3A	IPE300	HE240A	400 x 180 x 22mm	6 x M20 bolts	weld		not preloaded	portal frame	
	M3B	IPE300	HE240A	430 x 180 x 22mm	6 x M20 bolts	weld		not preloaded	portal frame	
	M3C	IPE300	HE240A	430 x 180 x 22mm	6 x M20 bolts	weld		not preloaded	portal frame	
	M3D	IPE300	HE240A	430 x 180 x 22mm	6 x M20 bolts	weld		not preloaded	portal frame	
55	T-1	610UB113	310UC240	30 x 12 x 1 in.	10 x 1/4 in. high strength bolts	weld		turn-of-nut	cruciform, load in column	
	T-2	610UB113	310UC240	30 x 12 x 1 1/4 in.	10 x 1/4 in. high strength bolts	weld		turn-of-nut	cruciform, load in column	
56	J1	245 x 102 UB 22	152 x 152 UC 37	368 x 15mm	6 x M16 HSFG bolts	weld	17.5 and 20.6mm clearance	-	cruciform, load in column	washers under bolt heads and nuts.
	J2	245 x 102 UB 22	152 x 152 UC 30	368 x 15mm	6 x M16 HSFG bolts	weld	17.5 and 20.6mm clearance		cruciform, load in column	washers under bolt heads and nuts.
	J3	245 x 102 UB 22	152 x 152 UC 23	368 x 15mm	6 x M16 HSFG bolts	weld	17.5 and 20.6 clearance		cruciform, load in column	washers under nuts only.
	J4	245 x 102 UB 22	152 x 152 UC 23	368 x 15mm	6 x M16 HSFG bolts	weld	17.5 and 20.6		cruciform, load in	washers under bolt heads and nuts, full depth web stiffeners in column.

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
	J5	245 x 102 UB 22	152 x 152 UC 23	368 x 15mm	6 x M16 HSFG bolts	weld	17.5 and 20.6 clearance	-	cruciform, load in column	washers under bolt heads and nuts, axial load in column of 35% of working load.
57	1A	W14 x 22	W8 x 35	1/4 in. thick	8 x 1/4 in. A325 bolts	weld	-	-	cruciform, load in column	$P_y/3$ in column, balanced loading M- ϕ curves provided.
	1B	W14 x 22	W8 x 35	1/4 in. thick	8 x 1/4 in. A325 bolts	weld			cruciform, load in column	$P_y/3$ in column, balanced loading. M- ϕ curves provided.
	1C	W14 x 22	W8 x 35	1 in. thick	8 x 1/4 in. A325 bolts	weld			cruciform, load in column	$P_y/3$ in column, balanced loading
	2A	W8 x 35	W10 x 49	1/4 in. thick	8 x 1/4 in. A325 bolts	weld			cruciform, load in column	$P_y/3$ in column, balanced loading M- ϕ curves provided.
	2B	W8 x 35	W10 x 49	1 1/4 in. thick	8 x 1/4 in. A325 bolts	weld			cruciform, load in column	$P_y/3$ in column, balanced loading M- ϕ curves provided.
	2C	W8 x 35	W10 x 49	1 1/4 in. thick	8 x 1/4 in. A325 bolts	weld			cruciform, load in column	$P_y/3$ in column, column web stiff- eners opposite both flanges.
	2D	W8 x 35	W10 x 49	1 1/4 in. thick	8 x 1/4 in. A325 bolts	weld			cruciform, load in column	$P_y/3$ in column, balanced loading
	3A	W24 x 55	W14 x 49	1/4 in. thick	8 x 1 in. A325 bolts	weld			cruciform, load in column	$P_y/3$ in column, balanced loading
	3B	W24 x 55	W10 x 49	1 1/4 in. thick	8 x 1 in. A325 bolts	weld			cruciform, load in column	$P_y/3$ in column, balanced loading
	3C	W24 x 55	W14 x 49	1 1/4 in. thick	8 x 1 in. A325 bolts	weld			cruciform load in column	$P_y/3$ in column, balanced loading, column web stiffness opposite both flanges.
	3D	W24 x 55	W14 x 48	1 1/4 in. thick	8 x 1 in. A325 bolts	weld			cruciform, load in column	$P_y/3$ in column, balanced loading
	4	W21 x 49	W14 x 74	1 1/4 in. thick	8 x 1 1/4 in. A325 bolts	weld			cruciform, load in column	$P_y/3$ in column, balanced loading

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
	5	W21 x 44	W8 x 40	1 1/2 in. thick	8 x 1 in. A325 bolts	weld			cruciform, load in column	P _y /3 in column, balanced loading
	6	W24 x 76	W10 x 49	1 1/2 in. thick	8 x 1 in. A325 bolts	weld			cruciform, load in column	P _y /3 in column, balanced loading
	7	W14 x 22	W8 x 31	1 in. thick	8 x 1/2 in. A325 bolts	weld			cruciform, load in column	P _y /3 in column, unbalanced loading
	8	W14 x 22	W10 x 33	1 1/2 in. thick	8 x 1 in. A325 bolts	weld			cruciform, load in column	P _y /2 in column, unbalanced loading
58, 59	P2	356 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 20mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	20mm column flange
	CS1-1	356 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 15mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	15mm column flange
	CS1-2	356 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 15mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	15mm column flange
	CS1-3	356 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 15mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	15mm column flange
	CS1-4	356 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 15mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	15mm column flange
	CS1-5	356 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 15mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	15mm column flange
	CS2-1	365 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 15mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	11.8mm column flange
	CS2-2	356 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 15mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	11.95mm column flange
	CS2-3	356 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 15mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	12.0mm column flange

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
	CS2-4	356 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 15mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	11.74mm column flange
	CS2-5	356 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 15mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	11.7mm column flange
	CS3-1	357 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 20mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	20mm column flange, $\sigma_y = 328$ N/mm ² for end plate and column flange
	CS3-2	357 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 20mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	20mm column flange, $\sigma_y = 328$ N/mm ² for end plate and column flange
	CS3-3	357 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 20mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	20mm column flange, $\sigma_y = 328$ N/mm ² for end plate and column flange
	CS3-4	357 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 20mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	20mm column flange, $\sigma_y = 328$ N/mm ² for end plate and column flange
	CS3-5	357 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 20mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	20mm column flange, $\sigma_y = 328$ N/mm ² for end plate and column flange
	CS4-1	357 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 15mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	20mm column flange, $\sigma_y = 328$ N/mm ² for end plate and column flange
	CS4-3	357 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 15mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	20mm column flange, $\sigma_y = 328$ N/mm ² for end plate and column flange
	CS5-1	357 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 20mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	17mm column flange, $\sigma_y = 328$ N/mm ² for end plate and column flange
	CS5-2	357 x 171 UB 45	200 x 200 x 12mm web UC shape	470 x 200 x 20mm	6 x M16 HSFG bolts	weld	18mm	75 kN shank tension	cruciform, load in column	17mm column flange, $\sigma_y = 328$ N/mm ² for end plate and column flange
49	2	305 x 165 UB 40	254 x 254 UB 89	400 x 200 x 12mm	6 x M20 Gr 8.8	weld	22mm	-	cruciform	column web stiffeners opposite both beam flanges.
	4	305 x 156 UB 54	254 x 254 UC 132	400 x 200 x 12mm	6 x M20 Gr 8.8	weld	22mm		cruciform	column web stiffeners opposite both beam flanges.
	6	305 x 156 UB 54	254 x 254 UC 73	200 x 200 x 25mm	6 x M20 Gr 8.8	weld	22mm		cruciform	-

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
56	J1	254 x 102 UB 22	152 x 152 UC 23	355 x 147 x 15mm	6 x M16 Gr 8.8 bolts	weld	18mm	-	cruciform	-
	J2	254 x 102 UB 22	152 x 152 UC 23	355 x 147 x 15mm	6 x M16 Gr 8.8 bolts	weld	18mm		cruciform	250 x 66 x 6mm flange backing plates.
	J3	254 x 102 UB 22	152 x 152 UC 23	355 x 147 x 15mm	6 x M16 Gr 8.8 bolts	weld	18mm		cruciform	M-φ curve provided.
	J4	254 x 102 UB 22	152 x 152 UC 23	355 x 147 x 15mm	6 x M16 Gr 8.8 bolts	weld	18mm		cruciform	250 x 66 x 6mm flange backing plates, M-φ curve provided.
61	1	IPE400	HE240A	500 x 240 x 20.5mm	6 x M20 8.8 bolts	weld	-	-	cruciform	No axial load in column.
	2	IPE400	HE240A	500 x 240 x 20.5mm	6 x M20 8.8 bolts	weld			cruciform	135 N/mm ² stress in column flanges.
	3	IPE400	HE240A	500 x 240 x 20.5mm	6 x M20 8.8 bolts	weld			cruciform	143 N/mm ² stress increasing to 235 N/mm ² in column flanges.
	4	IPE400	HE240A	500 x 240 x 20.5mm	6 x M20 8.8 bolts	weld			cruciform	73 N/mm ² stress increasing to 233 N/mm ² in column flanges
63	1	IPE400	HE300A	600 x 180 x 20mm	14 x M20 Gr 8.8 bolts	weld			cantilever	200mm flanged haunch on compression side of beam.
	2	IPE400	HE300A	600 x 180 x 20mm	14 x M20 Gr 8.8 bolts	weld			cantilever	200mm flanged haunch on compression side of beam, 600 x 185 x 10mm web doubler plate on column
	3	IPE400	HE300A	600 x 220 x 21mm	12 x M24Gr 8.8 bolts	weld			cantilever	400mm flanged haunch on compression side of beam
	4	IPE400	HE300A	600 x 220 x 21mm	12 x M24Gr 8.8 bolts	weld			cantilever	200mm flanged haunch on compression side of beam + 600 x 165 x 10mm web doubler plate on column
	5	IPE400	HE300A	700 x 220 x 20mm	12 x M24Gr 8.8 bolts	weld			cantilever	670mm flanged haunch on compression side of beam + 2 x 700 x 165 x 10mm web doubler plate on column
62	1-15	IPE400	HE300A	600 x 100 x 15.3mm	14 x M20Gr 8.8 bolts	weld	22mm drill	-	cruciform	Flanged haunch on compression side of beam.
	1-20	IPE400	HE300A	600 x 100 x 20mm	14 x M20Gr 8.8 bolts	weld	22mm drill		cruciform	Flanged haunch on compression side of beam.
	2-13	HE300A	HE300A	440 x 300 x 13mm.	12 x M20Gr 8.8 bolts	weld	22mm drill		cruciform	Flanged haunch on compression side of beam.
	2-20	HE300A	HE300A	440 x 300 x 13mm	12 x M20Gr 8.8 bolts	weld	22mm		cruciform	Flanged haunch on compression side

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
	3-18	IPE400	HE300A	590 x 220 x 18mm	12 x M24 Gr 8.8 bolts	weld	26mm drilled		cruciform	Flanged haunch on compression side of beam + doubler plate on column web and tension stiffeners on column web.
	3-21	IPE400	HE300A	590 x 220 x 21mm	12 x M24 Gr 8.8 bolts	weld	26mm drilled		cruciform	Flanged haunch on compression side of beam + doubler plate on column web and tension stiffeners on column web.
	4-18	IPE400	HE300A	600 x 220 x 18mm	12 x M24 Gr 8.8 bolts	weld	26mm drilled		cruciform	Flanged haunch on compression side of beam + doubler plate on column web and beam web 1/4 depth stiffeners at haunch toe.
	4-21	IPE400	HE300A	600 x 220 x 21mm	12 x M24 Gr 8.8 bolts	weld	26mm drilled		cruciform	Flanged haunch on compression side of beam + doubler plate on column web and beam web 1/4 depth stiffeners at haunch toe.
	4-18	IPE400	HE300A	700 x 220 x 18mm	16 x M24 Gr 8.8 bolts	weld	26mm drilled		cruciform	Plain haunch on compression side of beam, doubler plates on tension and compression side of column, backing plates behind column flanges.
	5-21	IPE400	HE300A	700 x 220 x 21mm	16 x M24 Gr 8.8 bolts	weld	26mm drilled		cruciform	Plain haunch on compression side of beam, doubler plates on tension and compression side of column, backing plates behind column flange.
53	1	320 x 127 UB 48	216 x 216 UC 71	203 x 114 x 25.4mm	4 x M22 & 4 x M25 HSFG bolts	weld	-	fully torqued using feeler gauges	cruciform	Grade 50 steel, high moment loading.
	2	254 x 102 UB 48	216 x 216 UC 59	165 x 111 x 19mm	4 x M16 & 4 x M22 HSFG bolts	weld		fully torqued using feeler gauges	cruciform	Grade 50 steel, high moment loading.
	3	254 x 102 UB 28	216 x 216 UC 59	171 x 111 x 19mm	4 x M20 & 4 x M22 HSFG bolts	weld		fully torqued using feeler gauges	cruciform	Grade 50 steel, high moment loading.
	4	320 x 127 UB 48	216 x 216 UC 59	178 x 114 x 32mm	4 x M22 & 4 x M20 HSFG bolts	weld		fully torqued using feeler gauges	cruciform	Grade 43 steel, high moment loading, column web stiffeners.
	5	360 x 127 UB 29	216 x 216 UC 59	178 x 108 x 25mm	8 x M20 & HSFG bolts	weld		fully torqued using feeler gauges	cruciform	Grade 43 steel, high moment loading, column web stiffeners.
	6	366 x 171 UB 67	216 x 216 UC 59	203 x 117 x 35mm	4 x M25 & 4 x M28 HSFG bolts	weld		fully torqued using feeler gauges	cruciform	Grade 43 steel, high moment loading, column web stiffeners.

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
	8	203 x 133 UB 30	216 x 216 UC 59	165 x 114 x 19mm	4 x M20 & 4 x M13 HSFG bolts	weld		fully torqued using feeler gauges	cruciform	Grade 43 steel, high moment loading column web stiffeners.
	9	203 x 133 UB 30	216 x 216 UC 59	165 x 114 x 19mm	4 x M16 & 4 x M20 HSFG bolts	weld		fully torqued using feeler gauges	cruciform	Grade 43 steel, high shear loading, column web stiffeners.
	10	320 x 127 UB 48	216 x 216 UC 59	178 x 114 x 21mm	4 x M20 & 4 x M25 HSFG bolts	weld		fully torqued using feeler gauges	cruciform	Grade 43 steel, high shear loading, column web stiffeners.
	11	366 x 127 UB 39	216 x 216 UC 59	165 x 108 x 22mm	4 x M16 & 4 x M20 HSFG bolts	weld		fully torqued using feeler gauges	cruciform	Grade 43 steel, high shear loading, column web stiffeners.
	12	320 x 165 UB 54	216 x 216 UC 59	191 x 111 x 27mm	4 x M22 & 4 x M25 HSFG bolts	weld		fully torqued using feeler gauges	cruciform	Grade 43 steel, high shear loading, column web stiffeners.
	13	366 x 171 UB 67	216 x 216 UC 59	191 x 117 x 32mm	4 x M25 & 4 x M28 HSFG bolts	weld		fully torqued using feeler gauges	cruciform	Grade 43 steel, high shear loading, column web stiffeners.
54	C1	12 x 5 UB 25	8x8 UC 48	¼ in. plate	6 x ¼ in. HSFG bolts	weld	-	-	cantilever	mild steel end plate, tension bolts preloaded, shear plate.
	C2	15 x 6 UB 40	10x10 UC 60	¼ in. plate	6 x 1 in. HSFG bolts	weld			cantilever	mild steel end plate, tension bolts preloaded, shear plate.
	C3	15 x 6 UB 40	10x10 UC 60	¼ in. plate	6 x 1 in. HSFG bolts	weld			cantilever	mild steel end plate, tension bolts preloaded, shear plate, compression stiffener on column.
	C4	15 x 6 UB 40	10x10 UC 60	1 in. plate	6 x 1 in. HSFG bolts	weld			cantilever	mild steel end plate, tension bolts preloaded, high strength end plate shear plate.
	C5	15 x 6 UB 40	10x10 UC 60	1 in. plate	6 x 1 in. HSFG bolts	weld			cantilever	high strength end plate, tension bolts preloaded, shear plate, high strength end plate shear plate.
	C6	15 x 6 UB 40	10x10 UC 60	1½ in. plate	6 x 1½ in. HSFG bolts	weld			cantilever	high strength end plate, tension bolts preloaded, shear plate, compression stiffener in column.
51	A1	15 x 5 UB 42	8 x 8 UC 35	18.5 x 7 x 1½ in.	8 x ¼ in. H.T. bolts + 4 x ¼ in. black bolts	weld	-	torque control	cruciform	-
	A2	15 x 5 UB 42	8 x 8 UC 35	19 x 7 x 1½ in.	8 x ¼ in. H.T. bolts	weld		torque control	cruciform	5/16 in. column web stiffeners.

Table 8 (continued)

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
	A3	15 x 5 UB 42	8 x 8 UC 35	19 x 7 x $\frac{3}{16}$ in.	8 x $\frac{1}{4}$ in. H.T.bolts + 4 x $\frac{1}{4}$ in. black bolts	weld		torque control	cruciform	$\frac{1}{4}$ in. column web stiffeners
	B1	15 x 5 UB 42	8 x 8 UC 35	19 x 7 x 1 in.	10 x $\frac{1}{4}$ in. H.T.bolts	weld		torque control	cruciform	$\frac{5}{16}$ in. column web stiffeners
	B2	15 x 5 UB 42	8 x 8 UC 35	18 x 7 x $\frac{1}{4}$ in.	10 x $\frac{1}{4}$ in. H.T.bolts	weld		torque control	cruciform	$\frac{1}{4}$ in. column web stiffeners

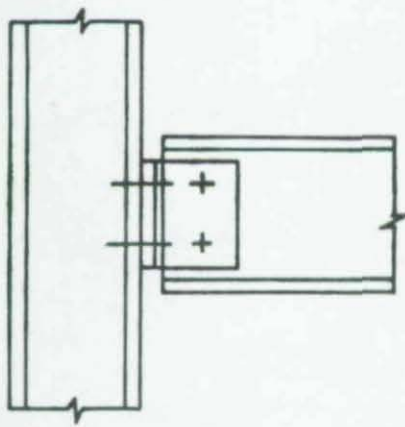
Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
50	M2A	IPE400	HE240A	100x100x12 angles, 180mm and 330mm long	10 x M20 bolts	7 x M20 bolts	-	-	Frame	Backing plates on outside of top angles
	M2B	IPE200	HE240A	160x100x12 angles on flanges, 100x100x12 angles 200mm long on web	10 x M20 bolts	11 x M20 bolts			Frame	Backing plates on outside of top angles
	M2C	IPE300	HE240A	100x100x12 angles 180 & 330mm long	10 x M22 bolts	7 x M22 bolts			Frame	-
	M2D	IPE400	HE240A	100x100x12 angles, 180 and 350mm long	10 x M22 bolts	7 x M22 bolts			Frame	Backing plates on outside of top angles

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
65	a	10 x 5in	12 x 8in	24 x 7 1/2 in split I	8 x 3/4 in H.T. bolts	8 x 3/4 in bolts	-	250ft-lb torque preload (turn of nut)	cruciform	
	b	10 x 5in	12 x 8in	24 x 7 1/2 in split I	8 x 3/4 in H.T. bolts	12 x 3/4 in bolts	-	250ft-lb torque preload (turn of nut)	cruciform	
	c	10 x 5in	12 x 8in	24 x 7 1/2 in split I	8 x 3/4 in H.T. bolts	16 x 3/4 in bolts	-	250 ft-lb torque preload (turn of nut)	cruciform	
	d	10 x 5in	12 x 8in	24 x 7 1/2 in split I	8 x 3/4 in H.T. bolts	20 x 3/4 in bolts	-	250 ft-lb torque preload (turn of nut)	cruciform	
	e		12 x 8in	24 x 7 1/2 in split I	8 x 3/4 in H.T. bolts	16 x 3/4 in bolts	-	250ft-lb torque preload (turn of nut)	cruciform	
	f	10 x 5in	12 x 8in	24 x 7 1/2 in	8 x 3/4 in	bolts & welds				
	-	10 x 5in	12 x 8in	24 x 7 1/2 in split I	8 x 3/4 in H.T. bolts	12 x 3/4 in bolts	-	250ft-lb torque preload (turn of nut)	cruciform	
	-	10 x 5in	12 x 8in	24 x 7 1/2 in split I	8 x 3/4 in H.T. bolts	12 x 3/4 in bolts	-	250ft-lb torque prelaod (turn of nut)	cruciform	column web stiffeners
50	8	IPE300	HE200A	250 x .156 x 32 x 16mm	4 x M20Gr 10.9 + 2 x M16Gr 10.9 bolts	6 x M20Gr 10.9 bolts	-	-	cantilever	backing plate behind column flange, short small I used as bottom seat
	12	IPE400	HE300A	335 x 180 32 x 16mm	4 x M22Gr 10.9 + 2 x M20 Gr 10.9 bolts	8 x M22Gr 10.9 bolts	-	-	cantilever	backing plate behind column flange short small I used as bottom seat
	19	IPE400	HE300A	335 x 180 32 x 16mm	4 x M22Gr 10.9 + 2 x M20 Gr 10.9 bolts	8 x M22Gr 10.9 bolts	-	-	cantilever	backing plate behind column flange, short small I used as bottom seat
	23	IPE400	HE300A	335 x 180 32 x 16mm	8 x M22 Gr 10.9 bolts	12 x M22 Gr 10.9 bolts	-	-	cantilever	tee-stubs top and bottom

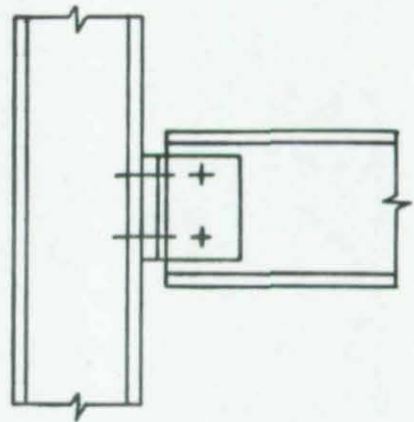
Table 12. Detailed results for tests on tee-stub and web cleat connections

Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
50	1	IPE 300	HE200A	250 x 150 x 32 x 12mm tee-stubs + 80 x 120 x 12mm angles	12 x M20 Gr 10.9 bolts	10 x M20 Gr 10.9 bolts	22mm	-	cantilever	-
	3	IPE 300	HE200A	250 x 150 x 32 x 12mm tee-stubs + 80 x 120 x 12mm angles	12 x M20 Gr 10.9 bolts	10 x M20 Gr 10.9 bolts	22mm	-	cantilever	-
	4	IPE 300	HE200A	250 x 150 x 32 x 12mm tee-stubs + 80 x 120 x 12mm angles	8 x M20 Gr 10.9 bolts + 4 x M16 Gr 10.9 bolts	10 x M20 Gr 10.9 bolts	22mm & 18mm	-	cantilever	M16 bolts in upper tee
	5	IPE 300	HE200A	250 x 150 x 32 x 12mm tee-stubs + 80 x 120 x 12mm angles	12 x M20 Gr 10.9 bolts + 4 x M16 Gr 10.9 bolts	14 x M20 Gr 10.9 bolts	22mm & 18mm	-	cantilever	slotted holes in web cleats + flange backing plates
	7	IPE 300	HE200A	250 x 150 x 32 x 12mm tee-stubs + 80 x 120 x 12mm angles	12 x M20 Gr 10.9 bolts + 4 x M16 Gr 10.9 bolts	14 x M20 Gr 10.9 bolts	22mm & 18mm	-	cantilever	slotted holes in web cleats + flange backing plates
	6	IPE 300	HE200A	250 x 150 x 32 x 12mm tee-stubs + 80 x 120 x 12mm angles	12 x M20 Gr 10.9 bolts + 4 x M16 Gr 10.9 bolts	14 x M20 Gr 10.9 bolts	22mm & 18mm	-	cantilever	column web stiffeners
	11	IPE 400	HE300A	335 x 180 x 32 x 16mm tee-stubs + 100A420 x 12mm angles	15 x M22 Gr 10.9 bolts	14 x M22 Gr 10.9 bolts	24mm	-	cantilever	-
	13	IPE 400	HE300A	335 x 180 x 32 x 16mm tee-stubs + 12mm angles	15 x M22 Gr 10.9 bolts	14 x M22 Gr 10.9 bolts	24mm	-	cantilever	-
	14	IPE 400	HE300A	335 x 180 x 32 x 16mm tee-stubs + 12mm angles	19 x M22 Gr 10.9 bolts	14 x M22 Gr 10.9 bolts	24mm	-	cantilever	2 slotted holes in web cleats + flange backing plates

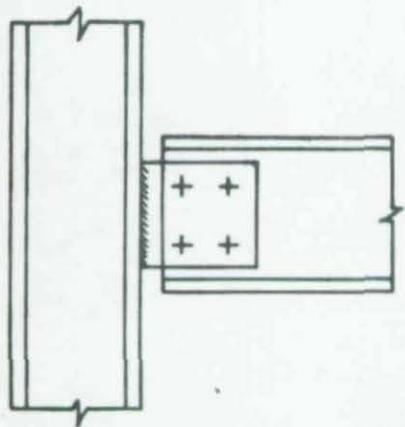
Ref.	Test	Beam size	Column size	Cleat size	Column fastening	Beam fastening	Hole type	Bolt tightening procedure	Test type	Comments
50	15	IPE 400	HE300A	335 x 180 x 32 x 16mm tee-stubs + 12mm angles	19 x M22 Gr 10.9 bolts	14 x M22 Gr 10.9 bolts	24mm	-	cantilever	2 slotted holes in web cleats + flange backing plates
	16	IPE 400	HE300A	335 x 180 x 32 x 16mm tee-stubs + 12mm angles	19 x M22 Gr 10.9 bolts	14 x M22 Gr 10.9 bolts	24mm	-	cantilever	2 slotted holes in web cleats + flange backing plates
	17	IPE 400	HE300A	335 x 180 x 32 x 16mm tee-stubs + 12mm angles	15 x M22 Gr 10.9 bolts	14 x M22 Gr 10.9 bolts	24mm	-	cantilever	column flange width reduced by 35mm
	18	IPE 400	HE300A	335 x 180 x 32 x 16mm tee-stubs + 12mm angles	15 x M22 Gr 10.9 bolts	14 x M22 Gr 10.9 bolts	24mm	-	cantilever	column flange thickness reduced to 10mm



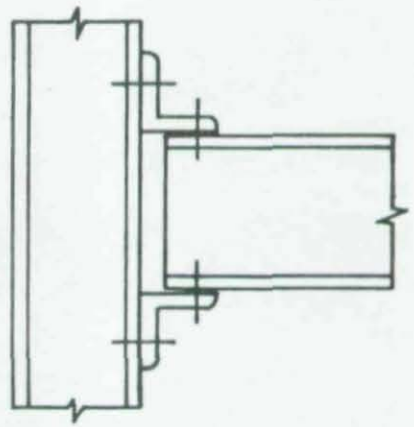
1. Single web cleat



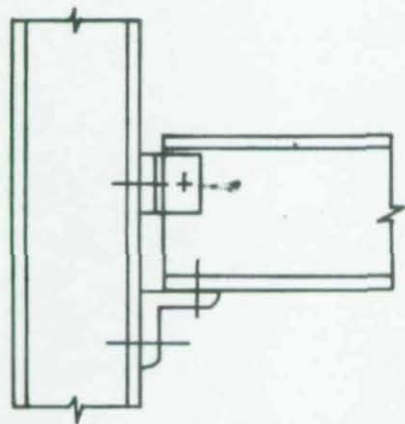
2. Double web cleat



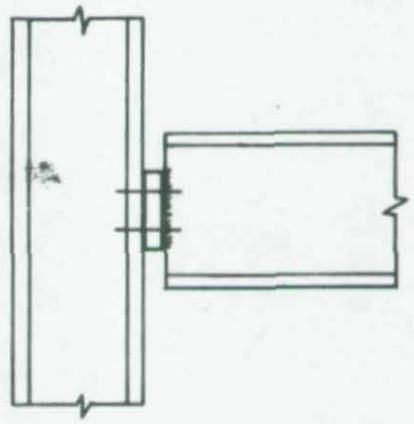
3. Web side plate



4. Flange cleats

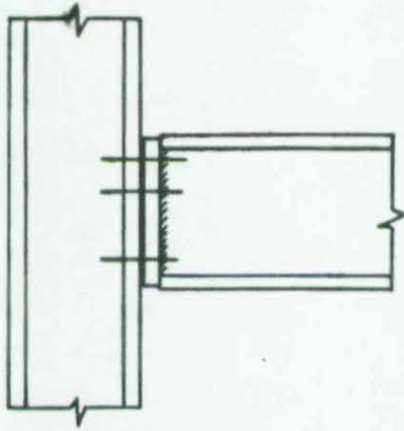


5. Bottom flange cleat
+ web cleat

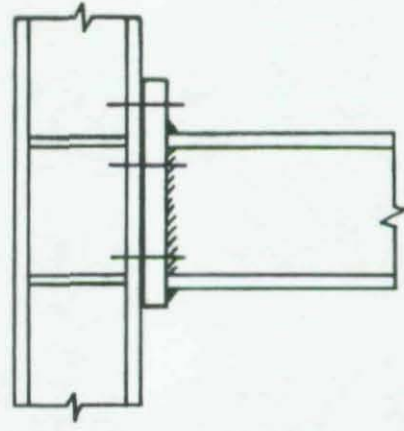


6. Flexible end plate
(header plate)

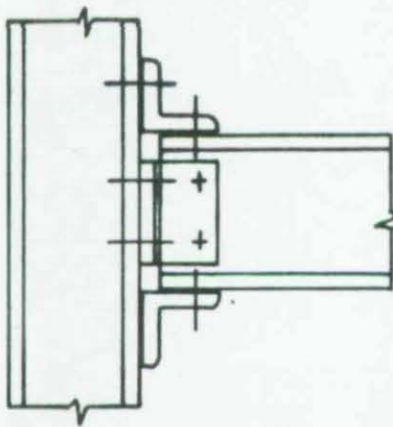
TABLE 1. COMMON FORMS OF BEAM TO COLUMN CONNECTION



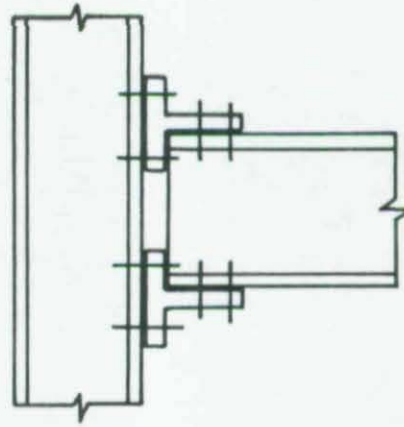
7. Flush end plate



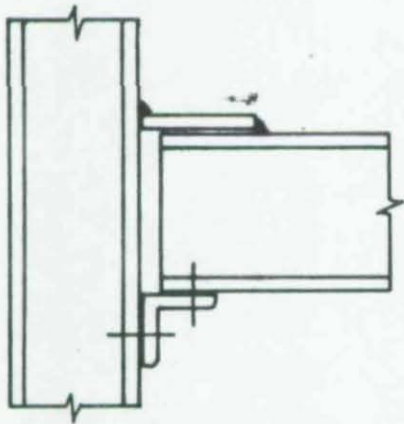
8. Extended end plate



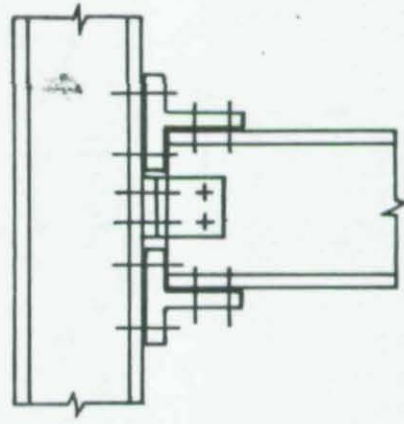
9. Web + flange cleats



10. Tee-stubs



11. Top plate + seat angle



12. Tee-stubs + web cleats

TABLE 1. (cont.)

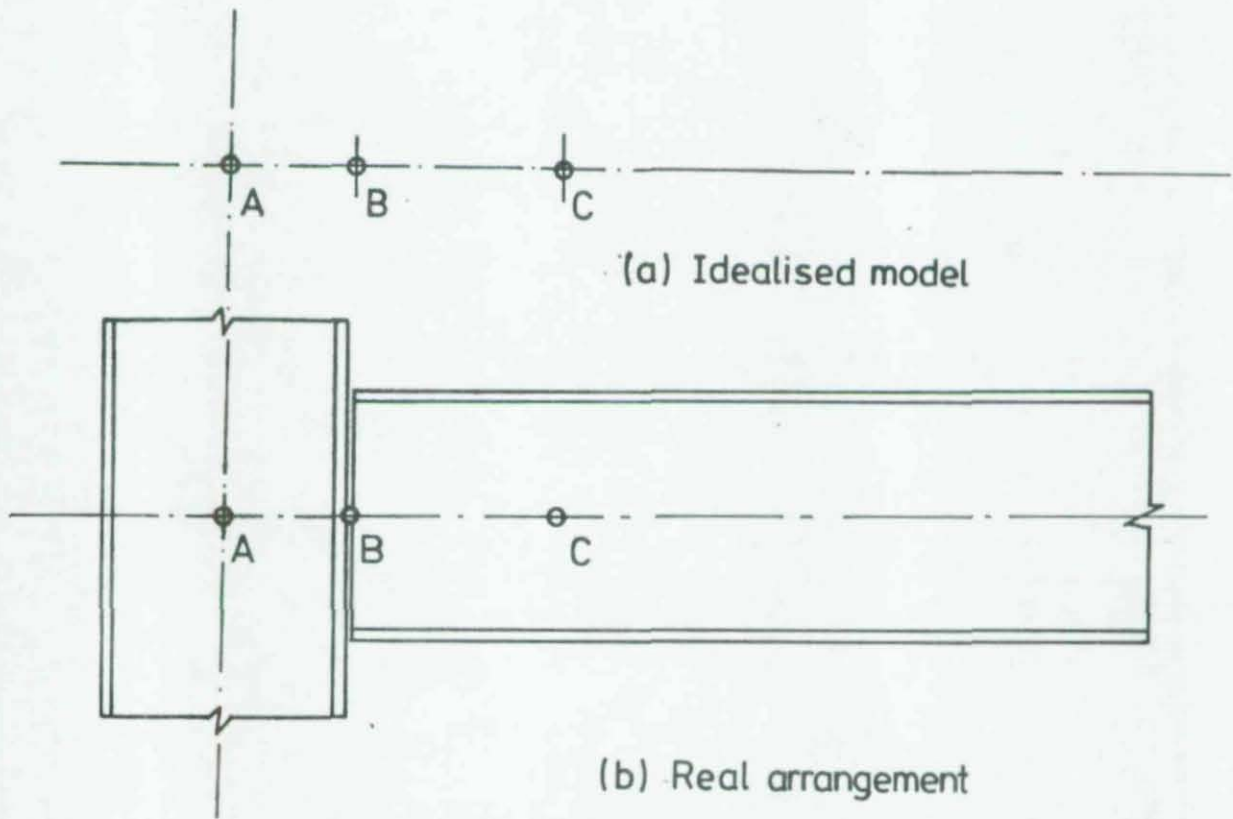


FIG 1. JOINT ROTATION MEASUREMENT

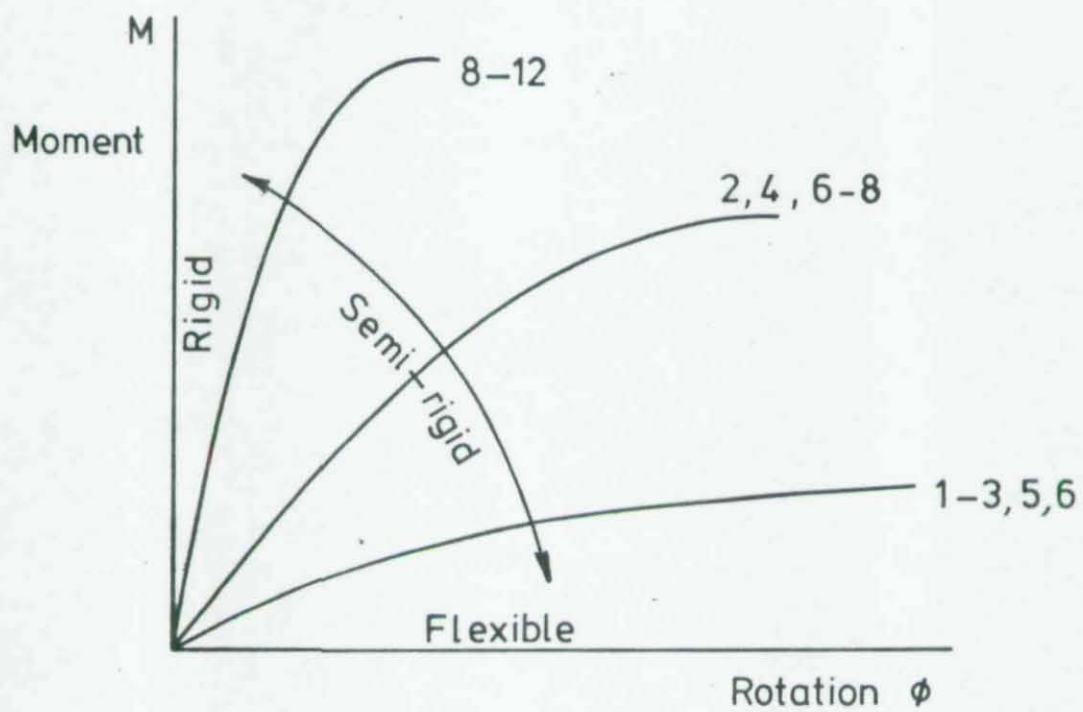
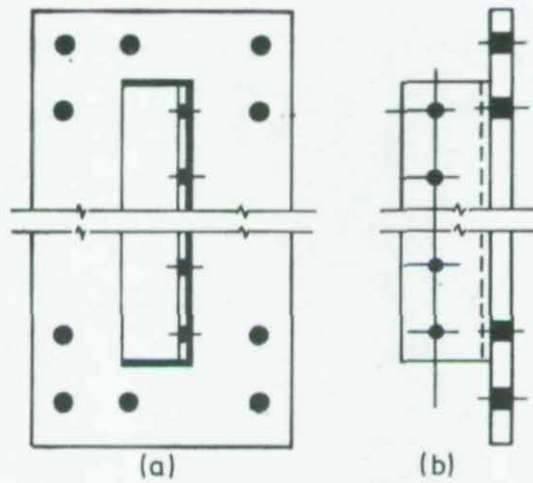
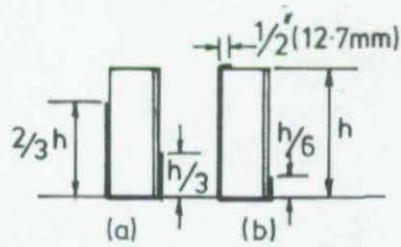


FIG.2 TYPICAL MOMENT—ROTATION CURVES



C series : (a) weld pattern in column leg
(b) beam leg



Details of welding for series D (a) and E (b) specimens

FIG.3 DETAILS OF FASTENING FOR SINGLE WEB ANGLES, REFS. 17-19

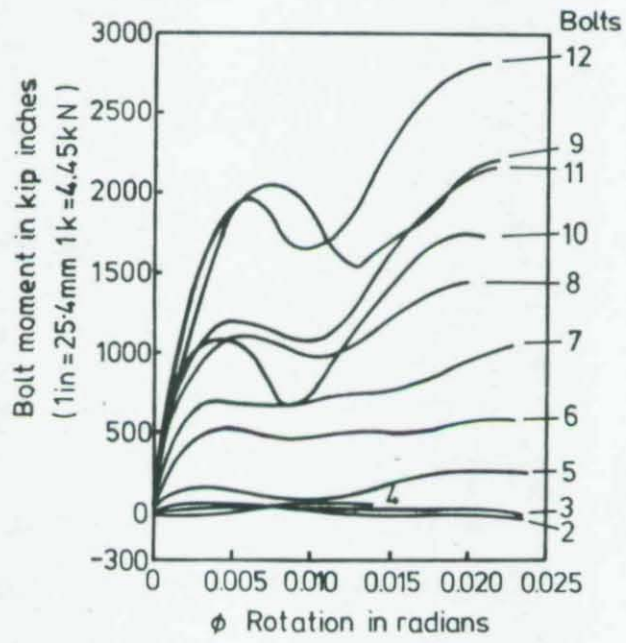


FIG.4 MOMENT-ROTATION CURVES:SERIES A1
OF REF. 17

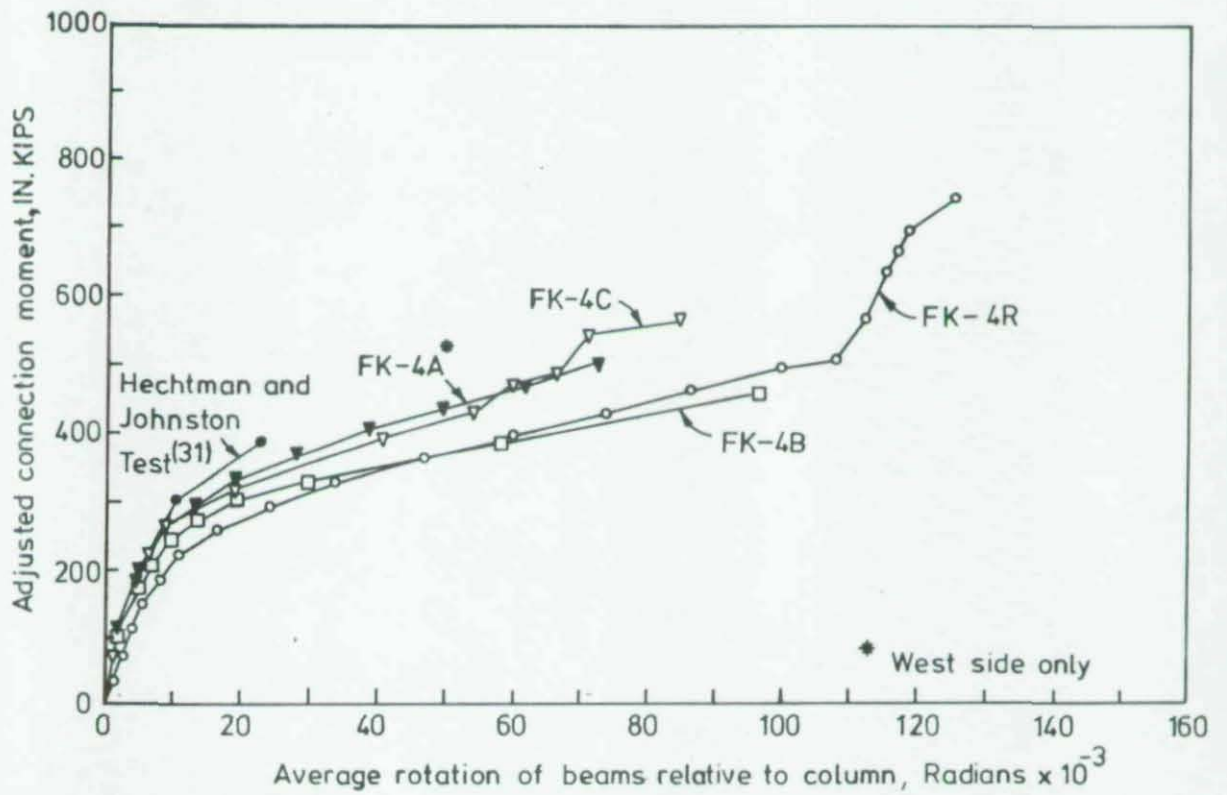


FIG. 5. COMPARISON OF MOMENT-ROTATION CURVES FOR RIVETED AND BOLTED CONNECTIONS FROM REFS. 24 AND 31

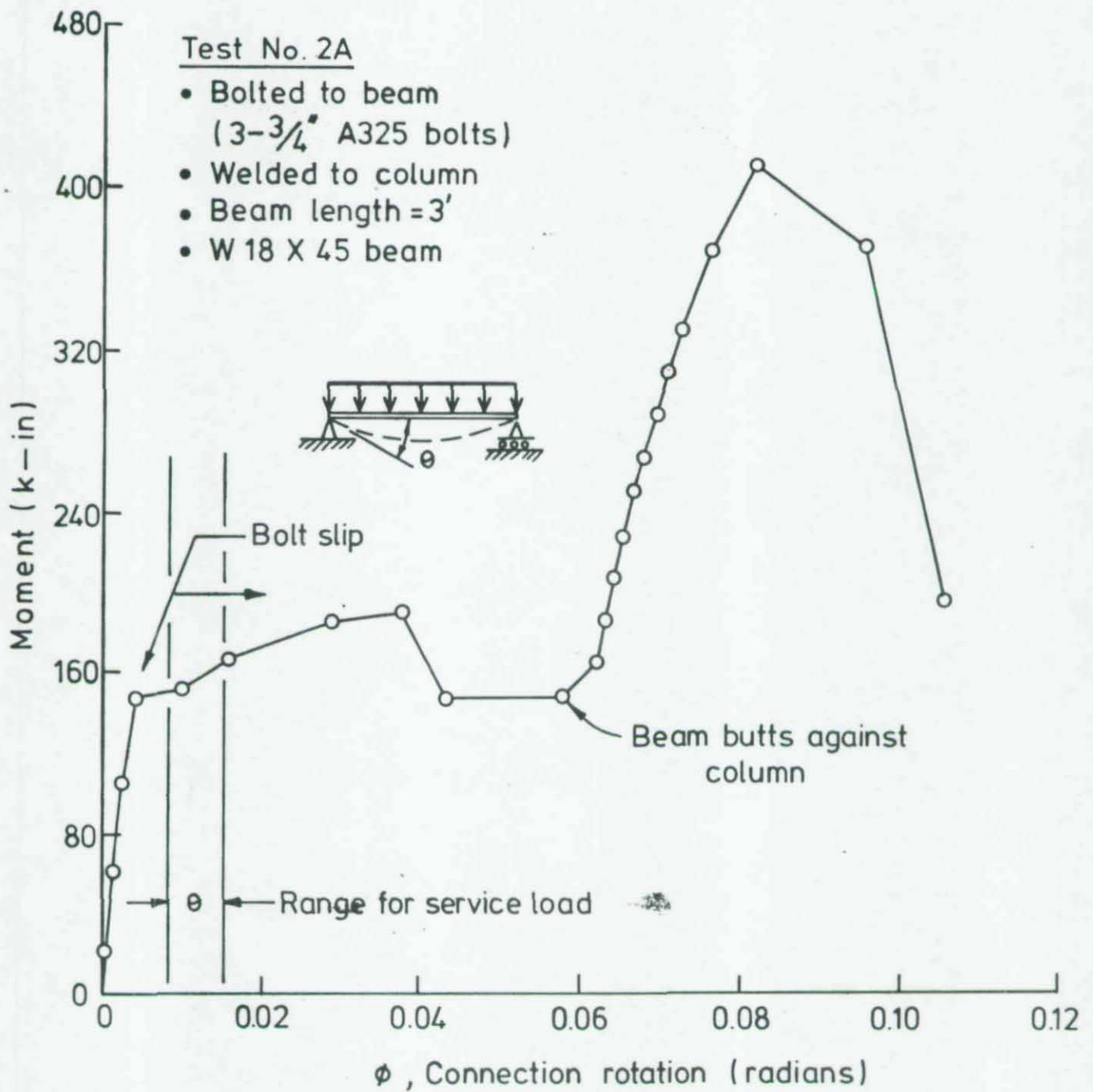


FIG.6. M- ϕ CURVE FOR DOUBLE WEB CLEAT CONNECTION OF REF. 30

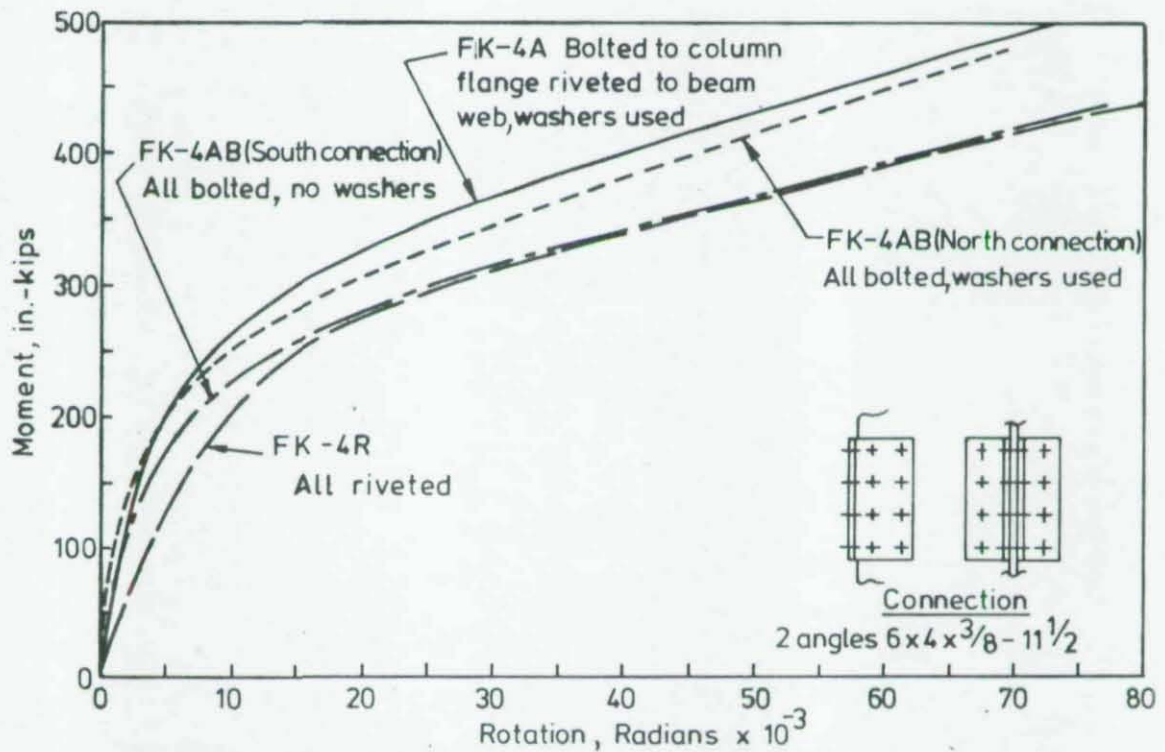


FIG. 7. COMPARISON OF MOMENT-ROTATION CURVES FOR SPECIMEN WITH DIFFERENT FASTENERS AND DIFFERENT FASTENER ASSEMBLIES REF. 25

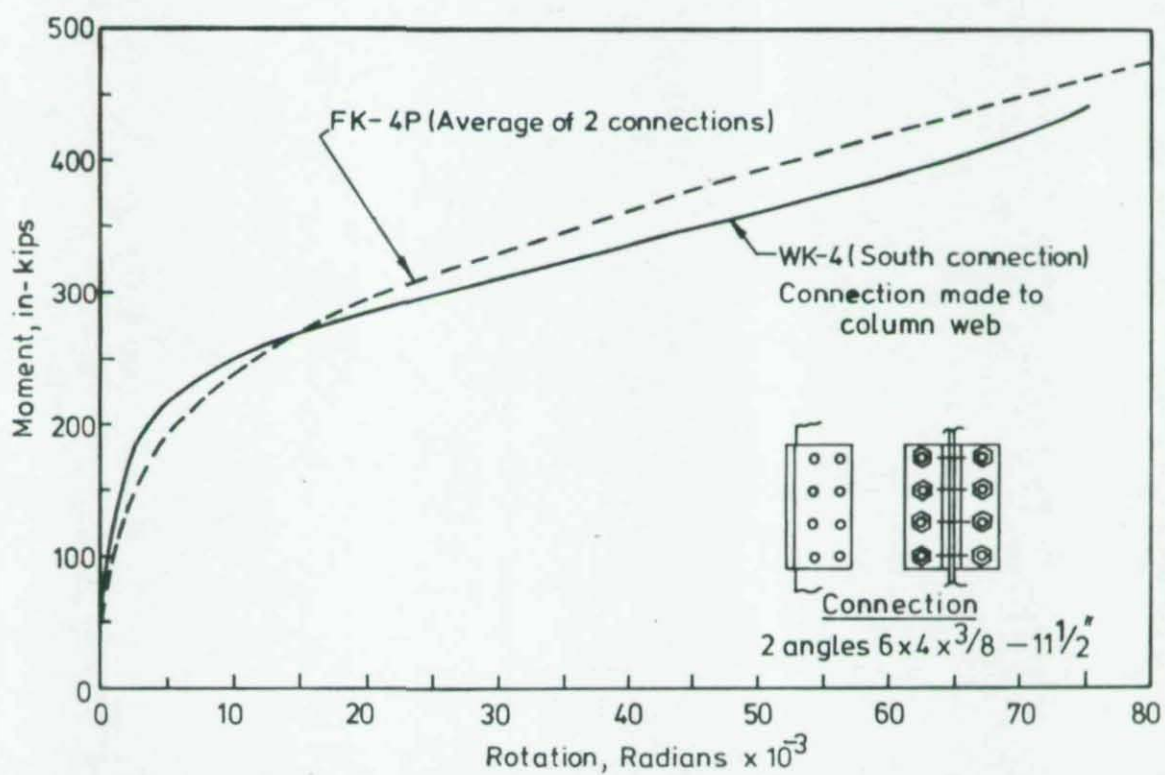


FIG.8 COMPARISON OF MOMENT-ROTATION CURVES FROM CONNECTIONS MADE TO COLUMN FLANGES AND WEB, REF. 25

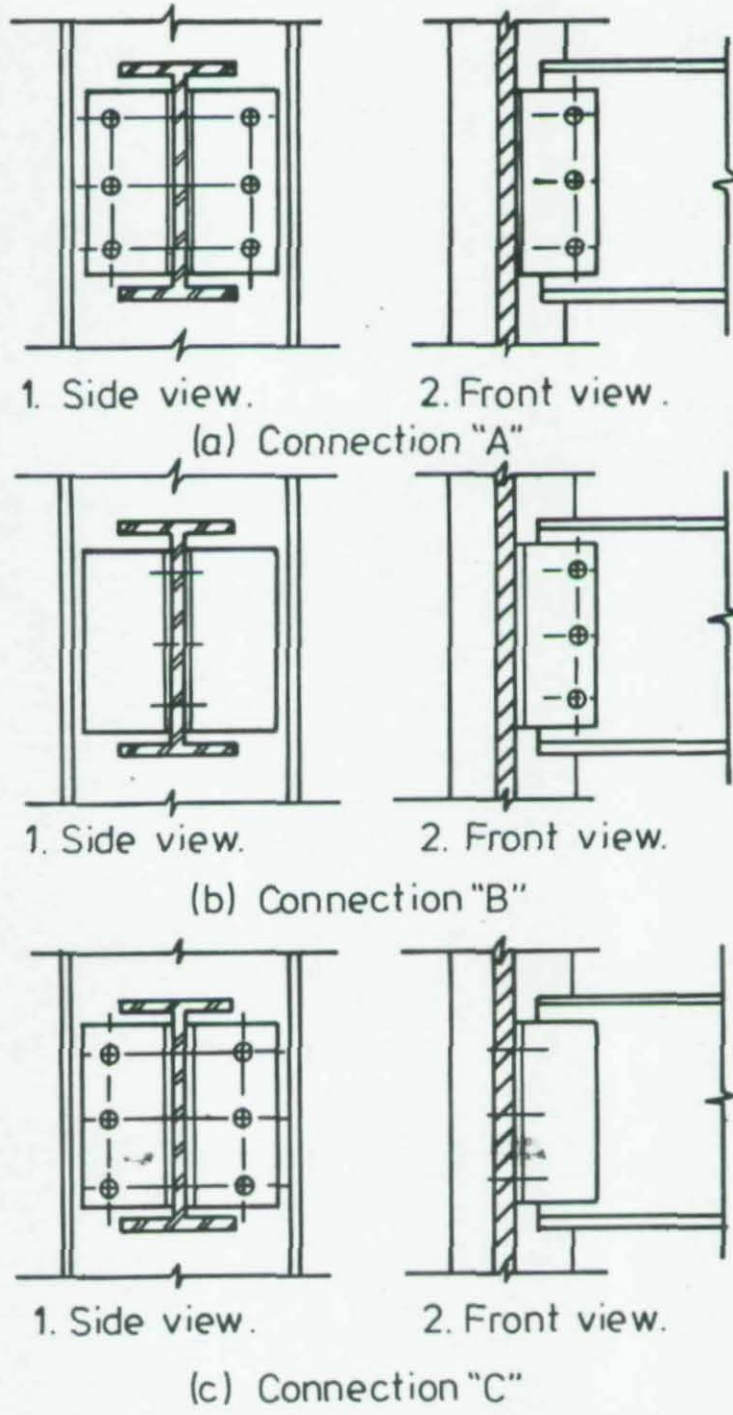


FIG. 9. "SIMPLE" CONNECTION DETAILS OF REF. 26.

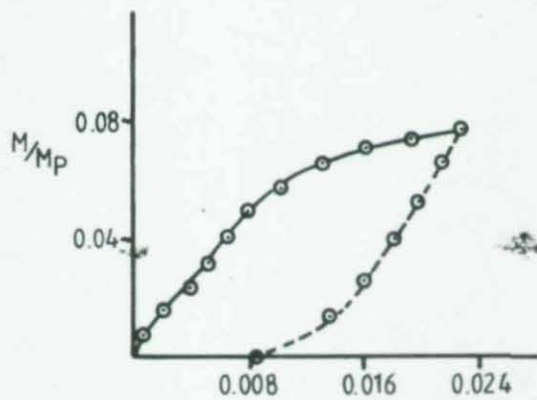
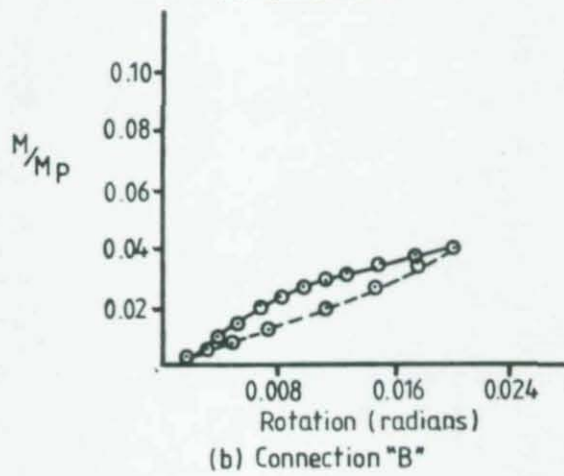
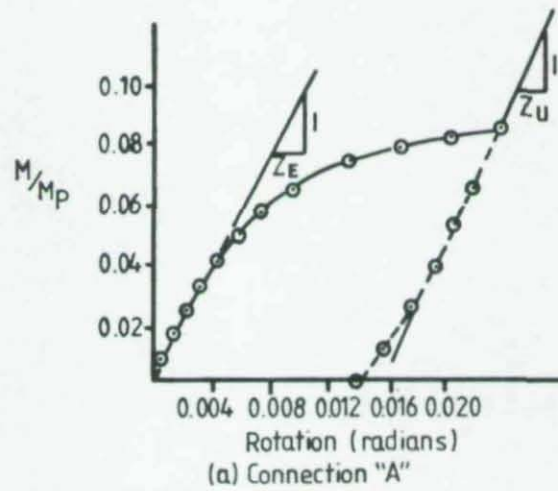


FIG. 10. MOMENT-ROTATION CHARACTERISTICS FOR CONNECTIONS OF FIG. 10, REF. 26.

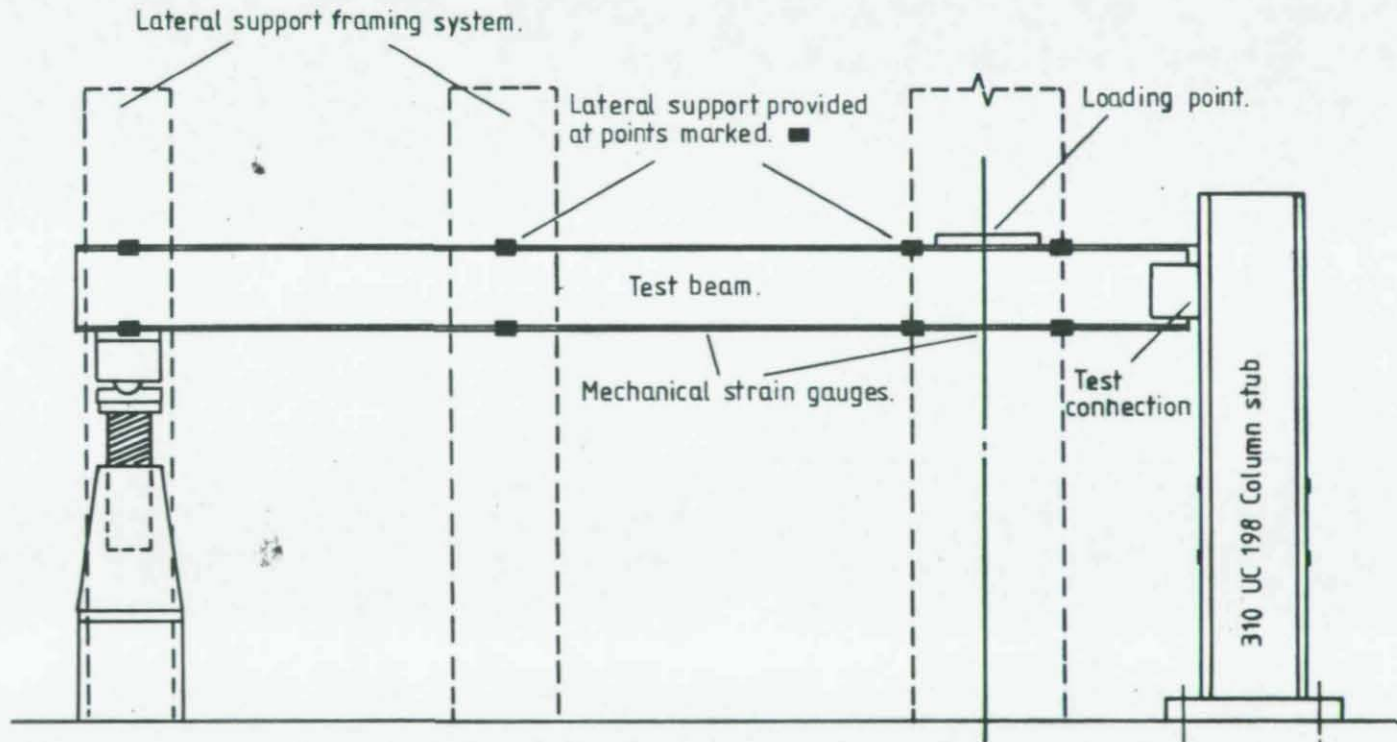


FIG.11. GENERAL ARRANGEMENT OF TEST SET-UP USED FOR WEB SIDE PLATE TESTS OF REFS. 28, 34.

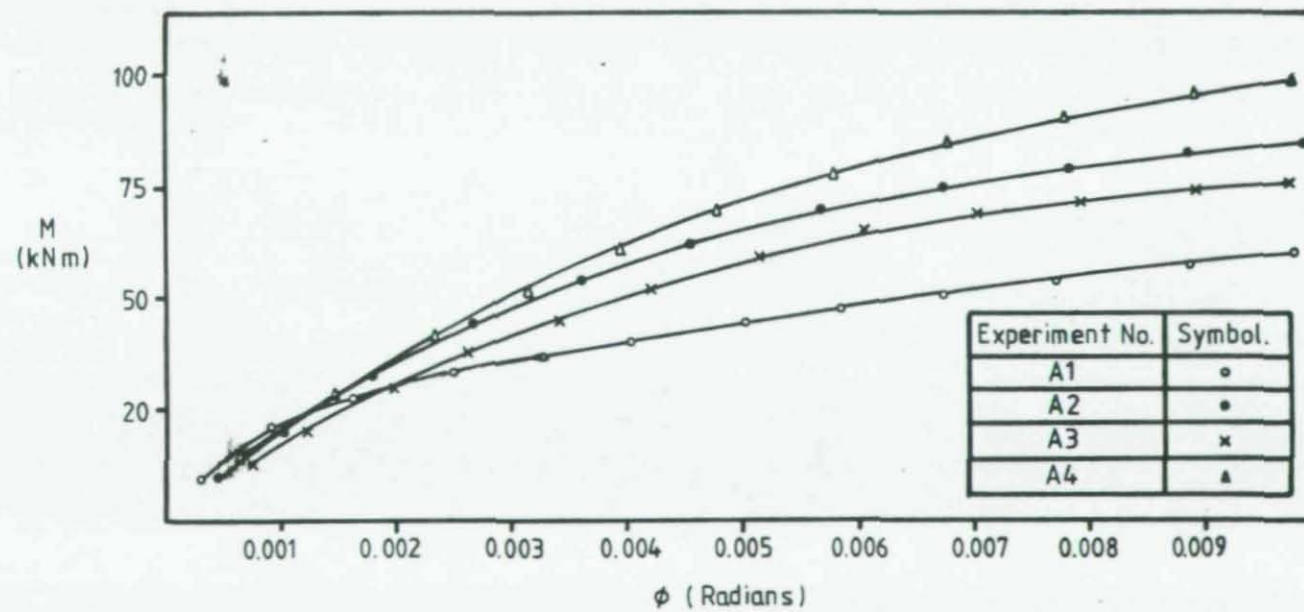
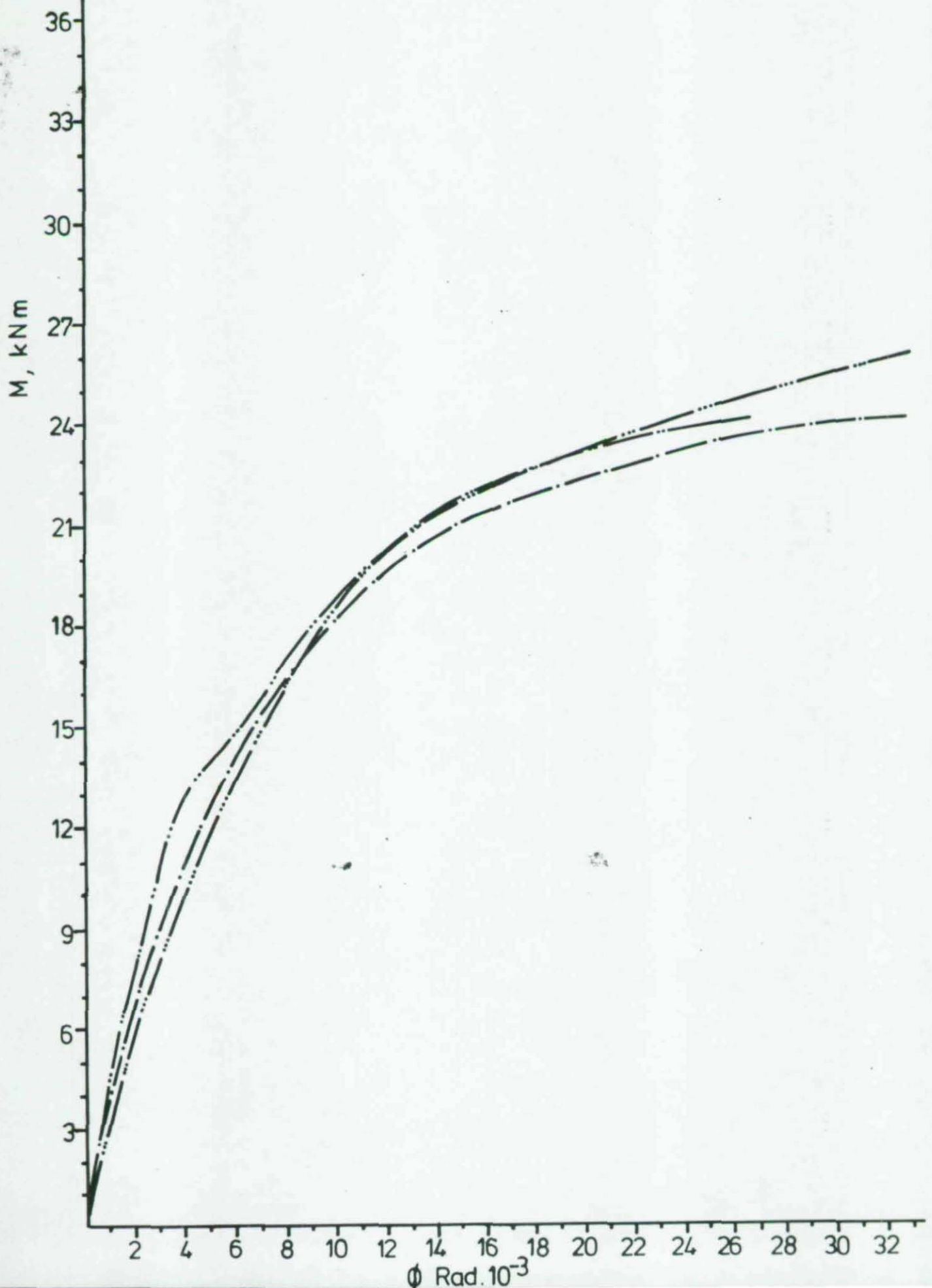


FIG. 12. EXPERIMENTAL MOMENT ROTATION CURVES GROUP A - 10MM CLEATS , REF. 35.

FIG. 13. TYPICAL SET OF 3 M- ϕ CURVES FOR TEST SERIES D OF REF. 37.

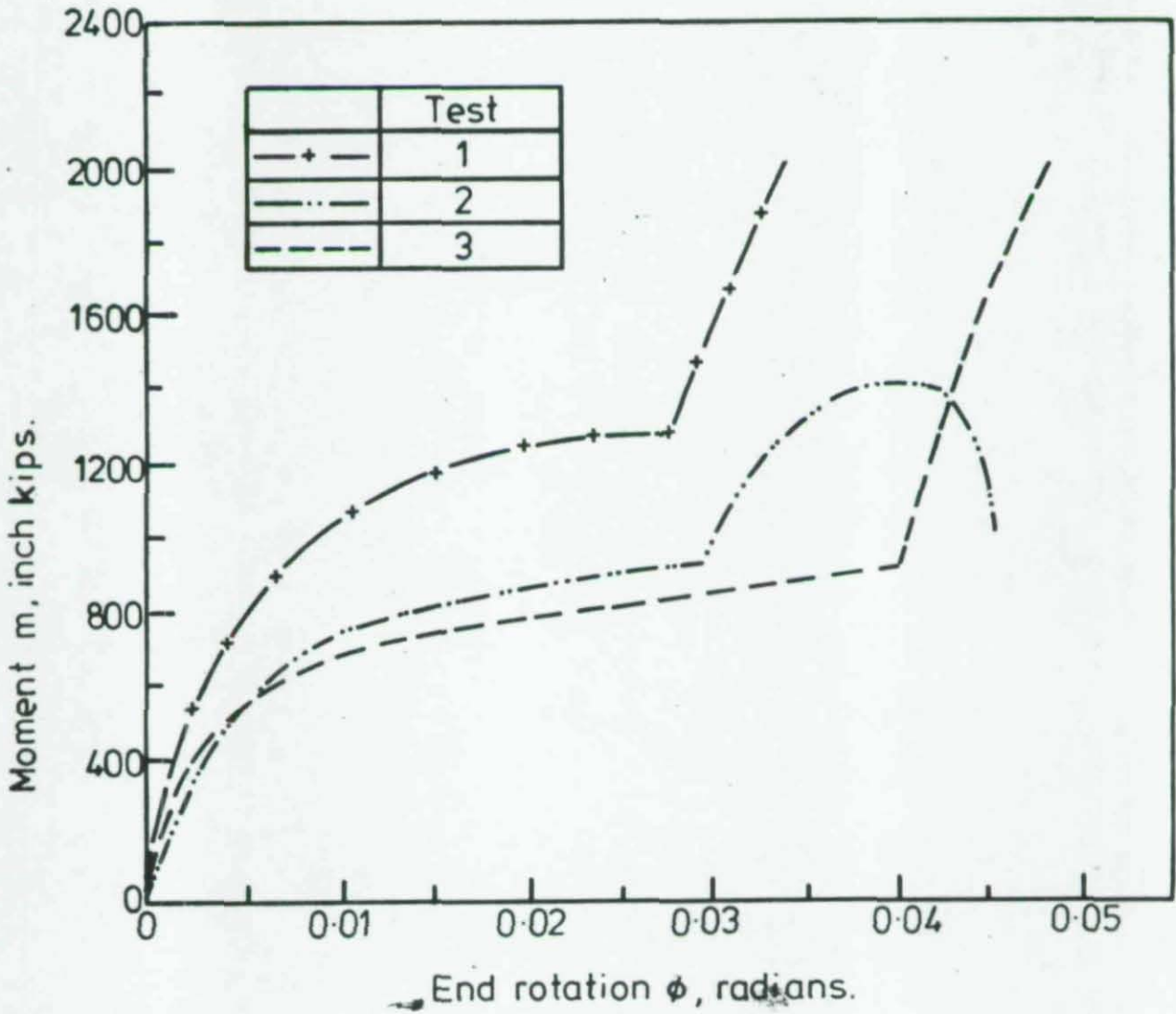


FIG.14. TYPICAL RESULTS FOR HEADER PLATE CONNECTIONS
REF. 41.

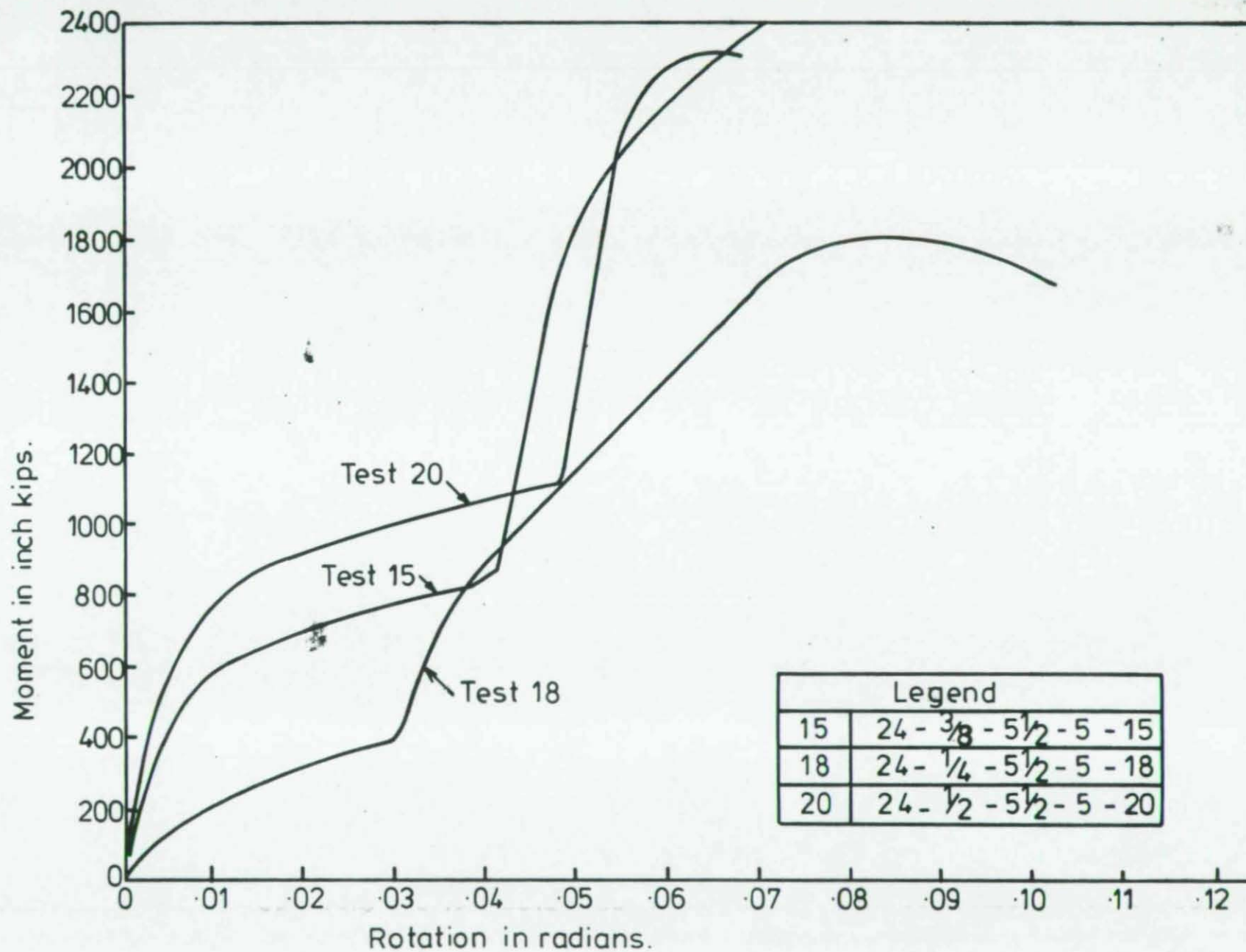


FIG. 15. VARIATION OF M- ϕ CURVES WITH THICKNESS, TESTS 15, 18, 20 OF REF. 39.

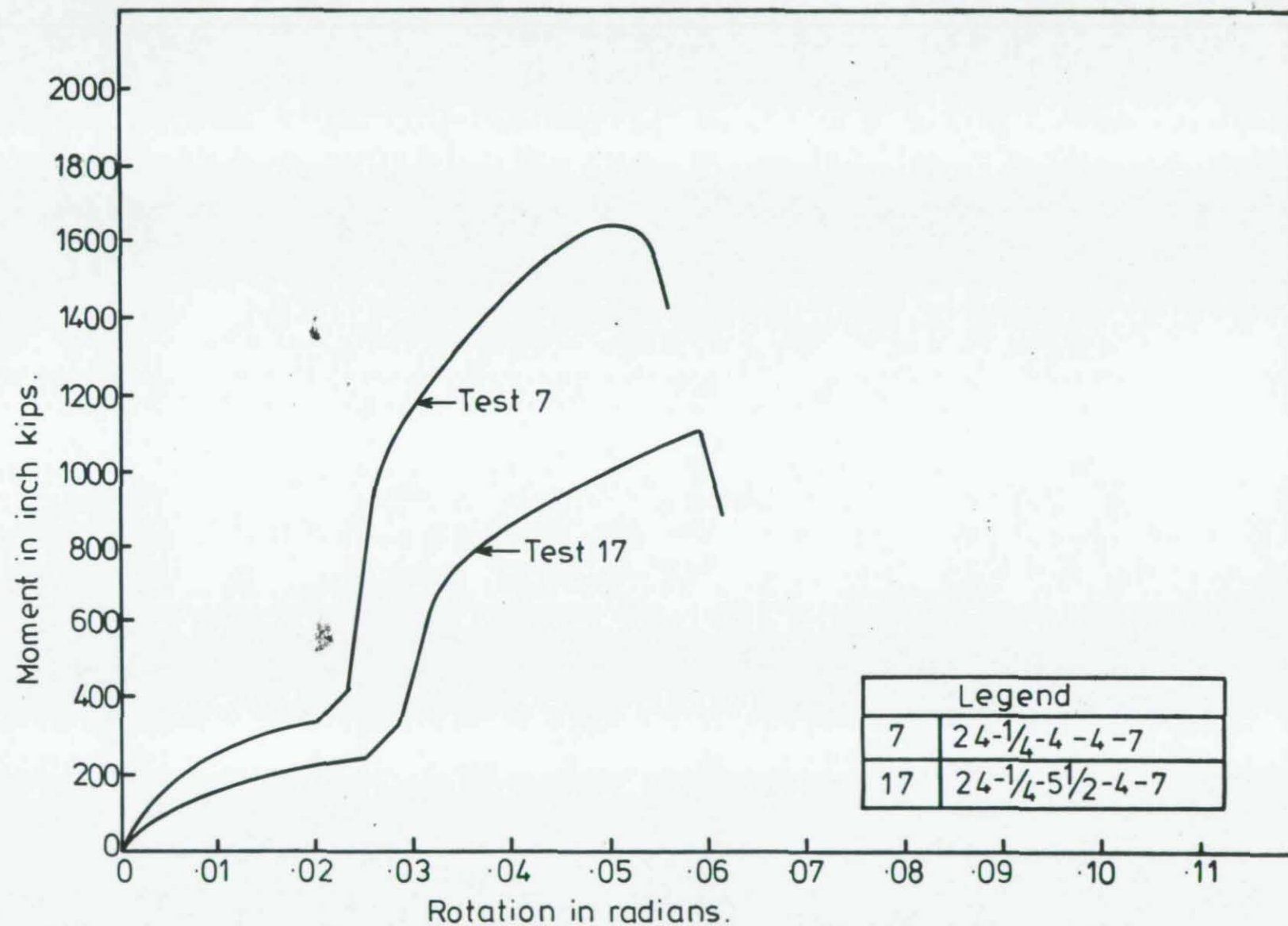


FIG. 16. VARIATION OF M- ϕ CURVES WITH GAUGE, TESTS 7,17 OF REF. 39.

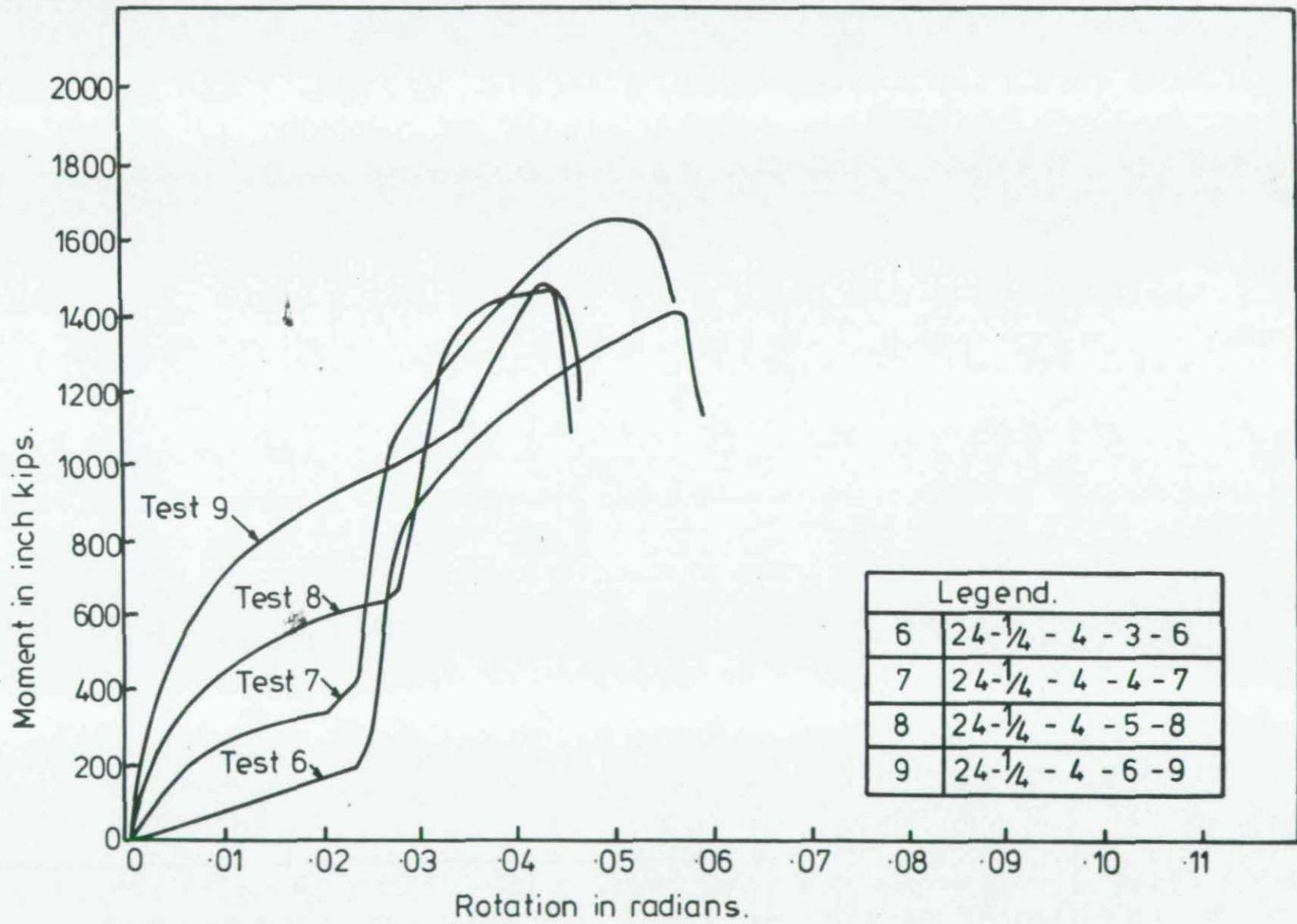


FIG.17. VARIATION IN M- ϕ CURVES WITH DEPTH, TESTS 6,7,8,9 OF REF. 39.

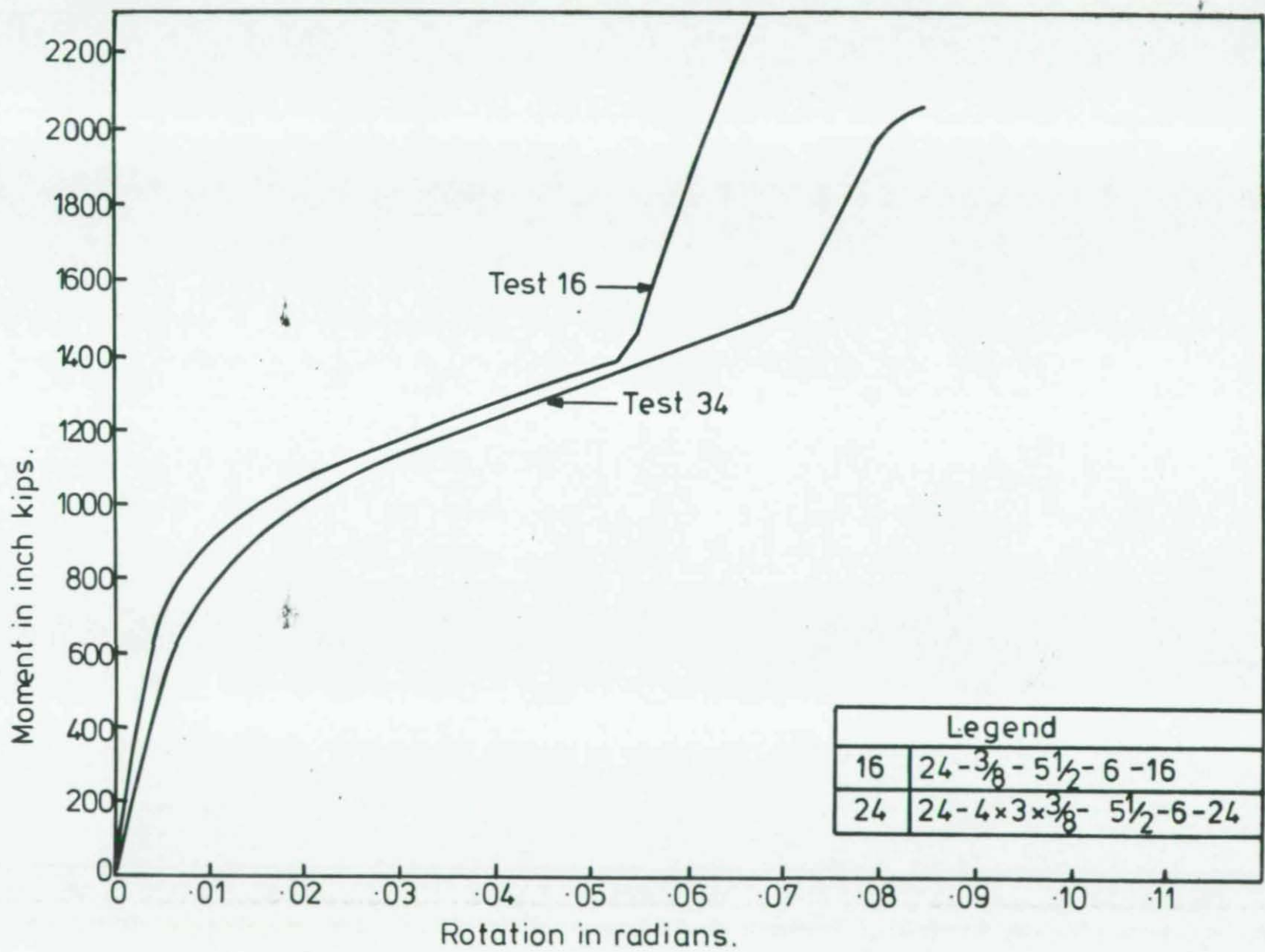


FIG.18. COMPARISON OF M-φ CURVES OF HEADER PLATE CONNECTIONS WITH DOUBLE WEB ANGLE CONNECTIONS, TESTS 16, 34. OF REF. 39.

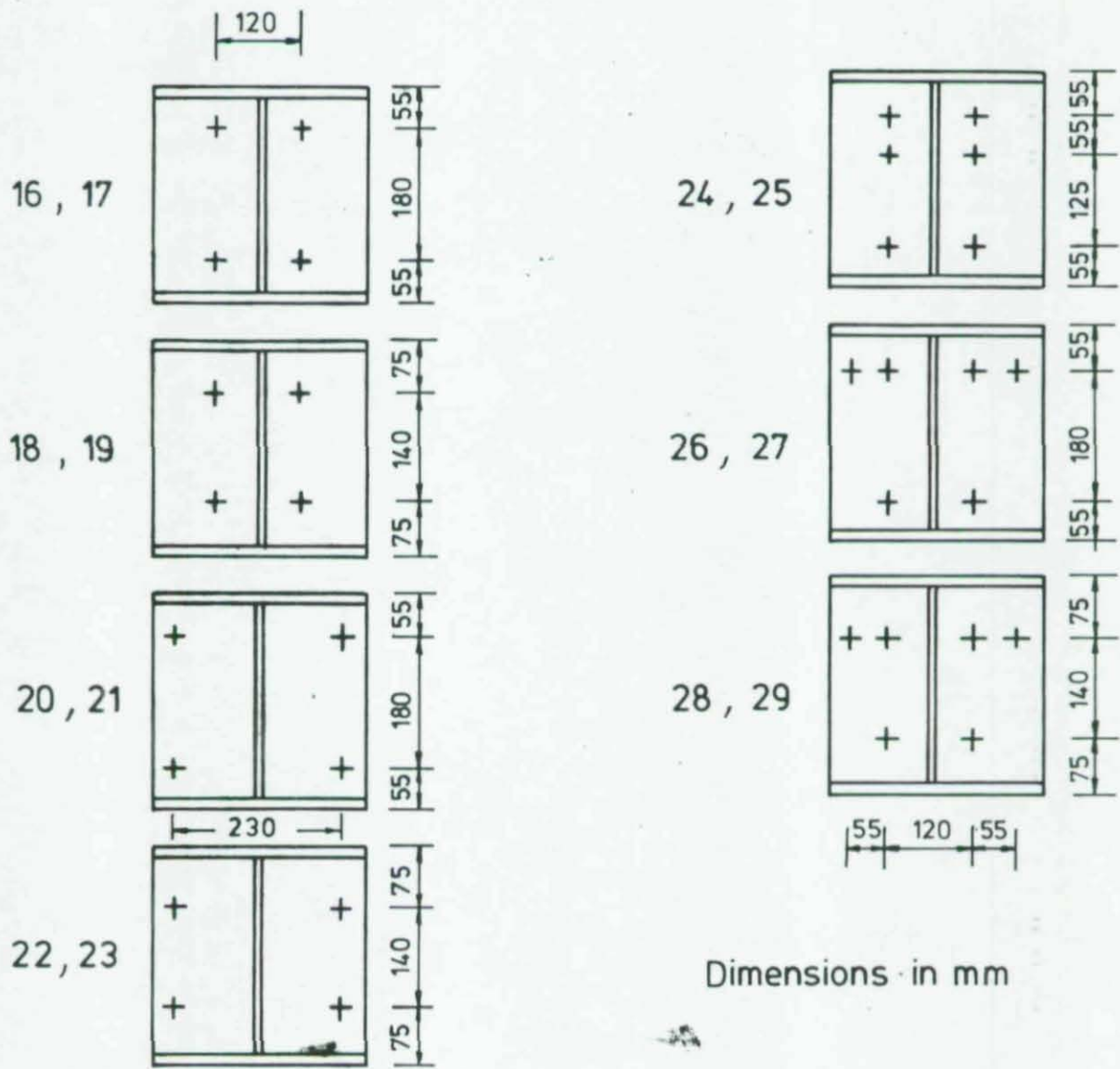


FIG. 19 BOLT ARRANGEMENTS FOR TESTS ON FLUSH END PLATES OF REF. 43

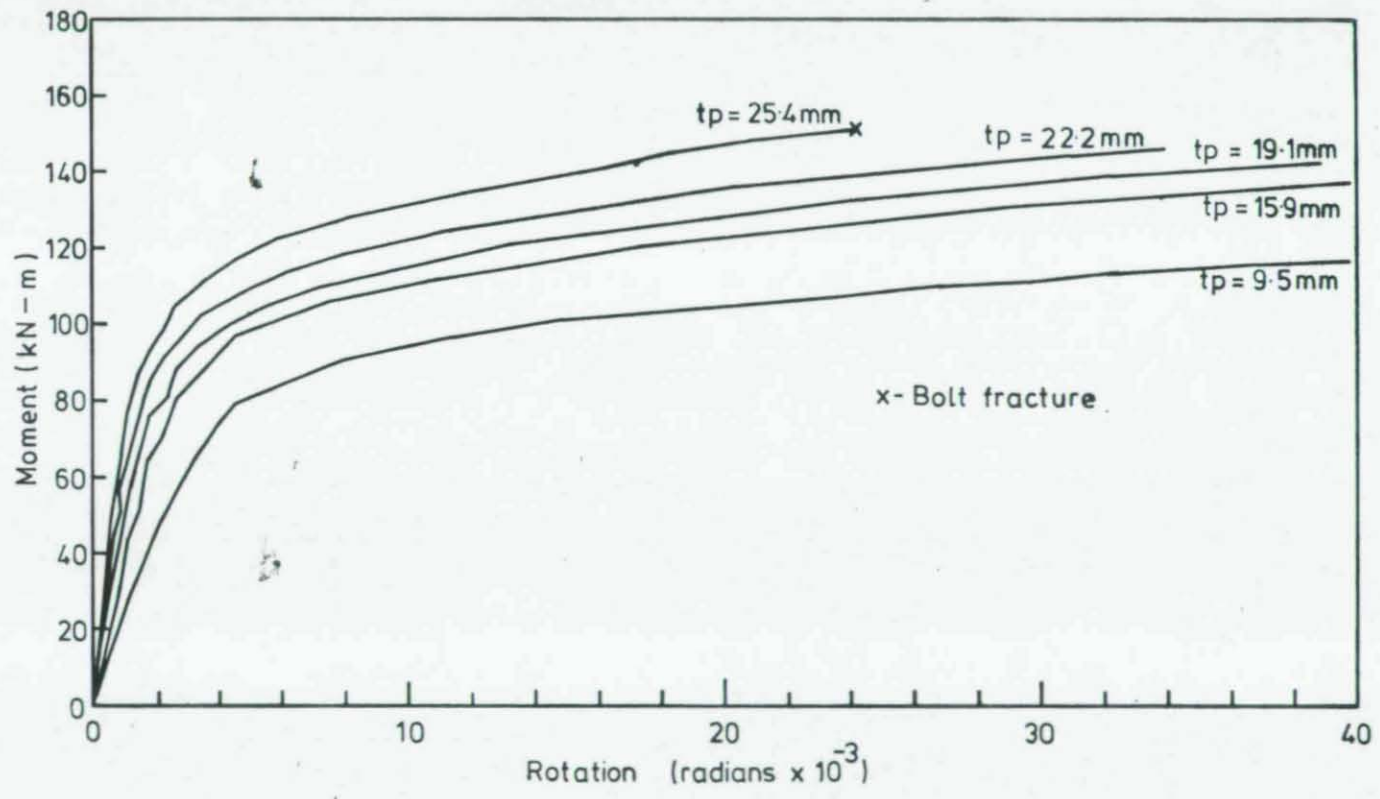


FIG. 20 MOMENT ROTATION CURVES FOR FLUSH END-PLATE CONNECTIONS

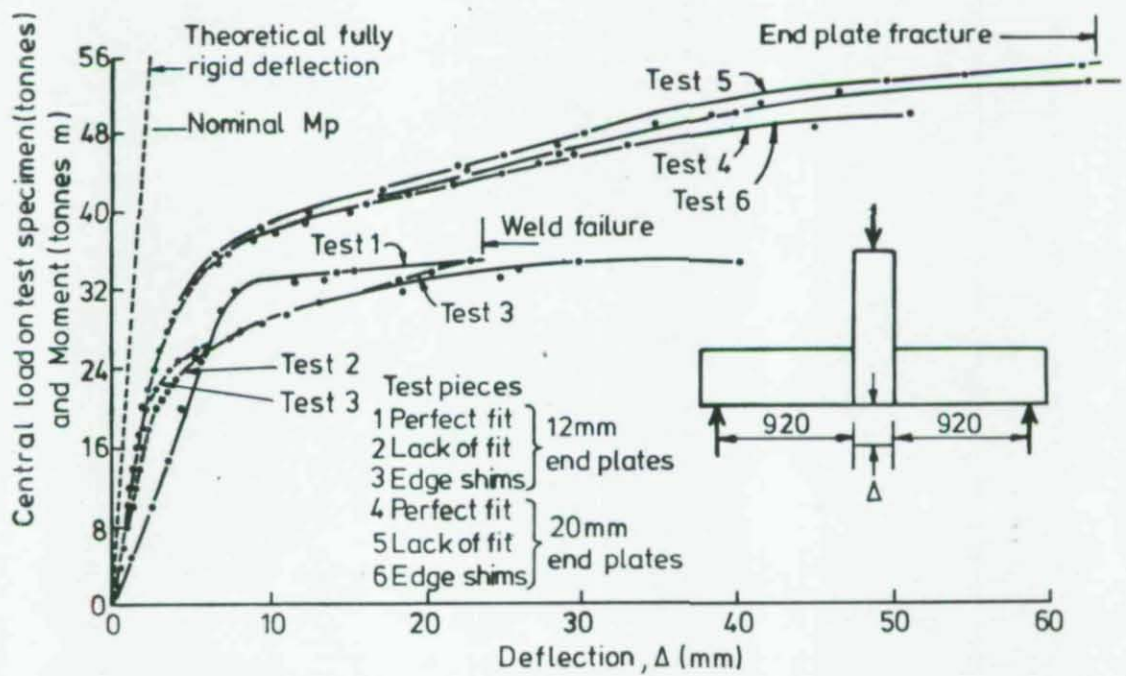


FIG. 21 EFFECT OF LACK OF FIT ON LOAD-DEFLECTION BEHAVIOUR OF FLUSH END PLATE CONNECTIONS, REFS. 44, 45.

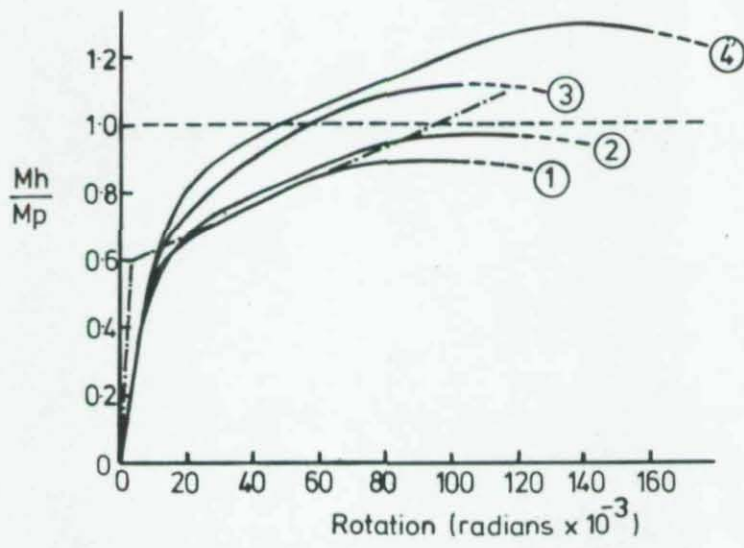


FIG. 22 a MOMENT-ROTATION CHARACTERISTICS FOR FLUSH END PLATE CONNECTIONS WITH THE FORMS OF STIFFENING SHOWN IN FIG.21b, REF.48

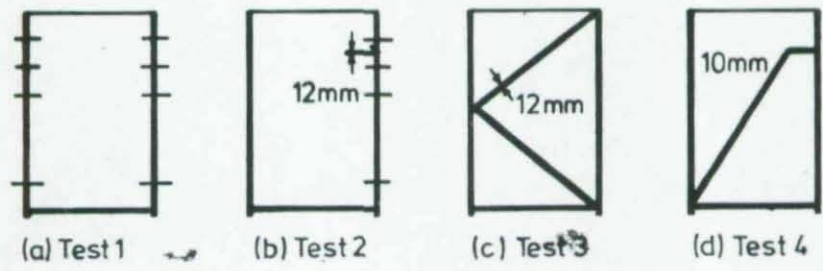


FIG. 22 b FORMS OF STIFFNESS USED FOR THE TEST SPECIMENS OF REF.48.

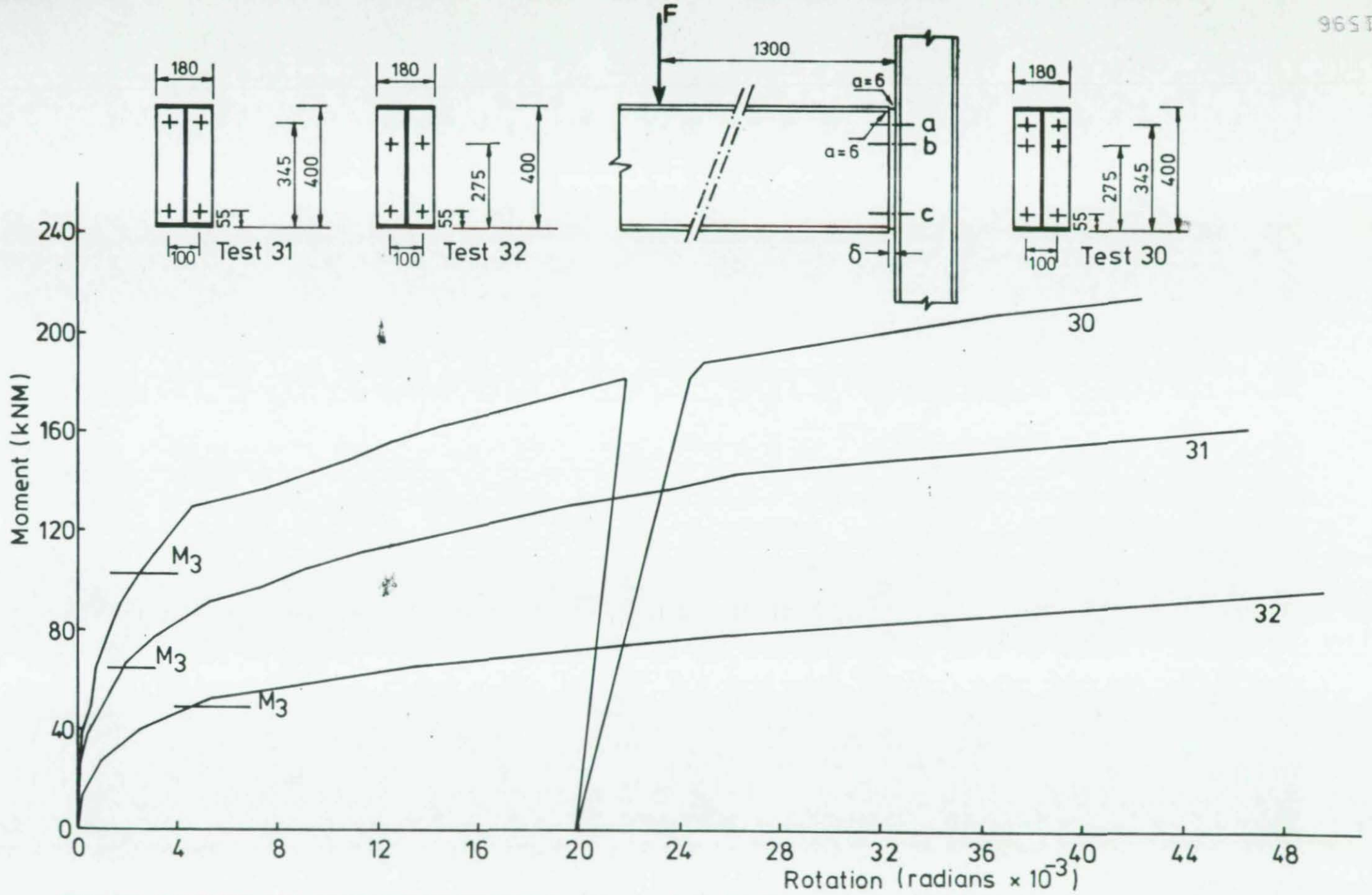


FIG. 23 EFFECT OF BOLT ARRANGEMENT ON M- ϕ CURVES FOR FLUSH END PLATES, REF. 43

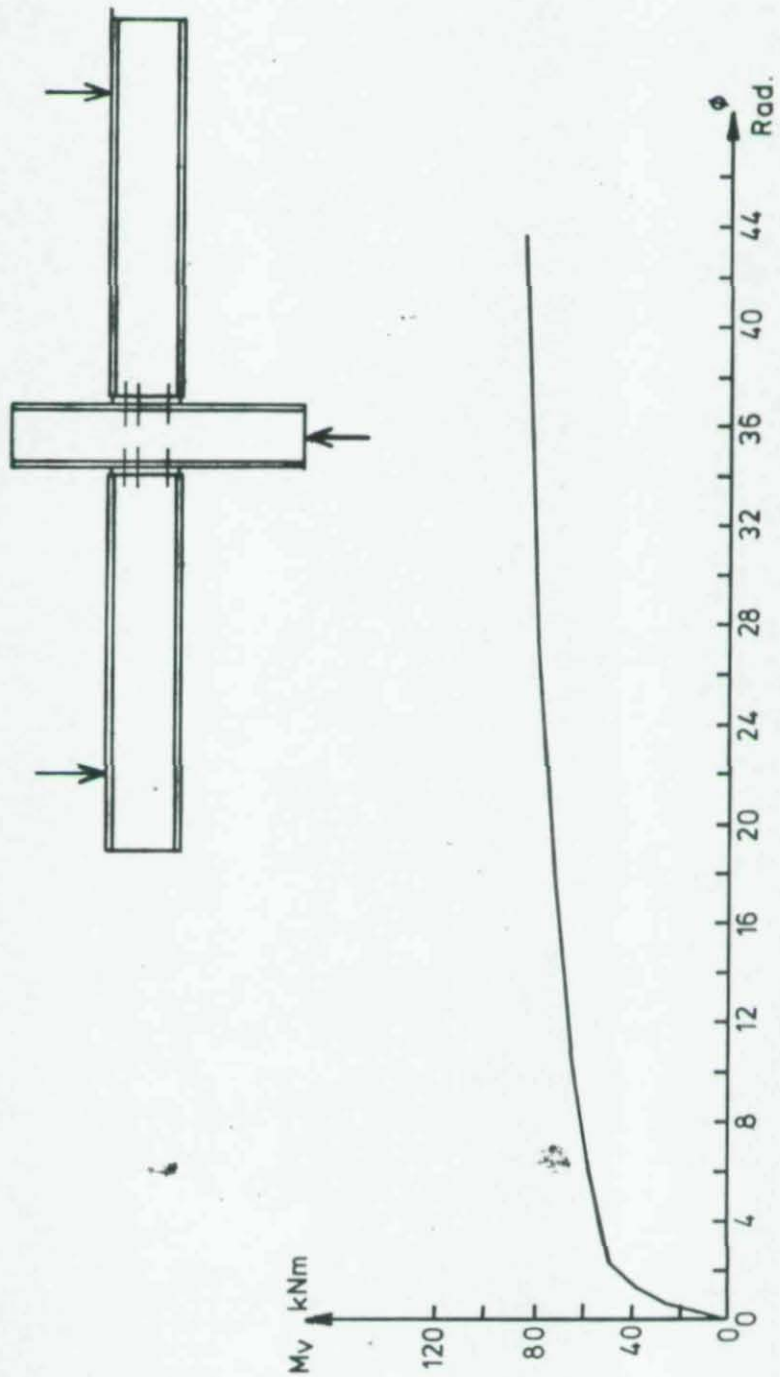


FIG. 24a M - ϕ CURVE FOR BASIC FLUSH END PLATE CONNECTION, REF. 47

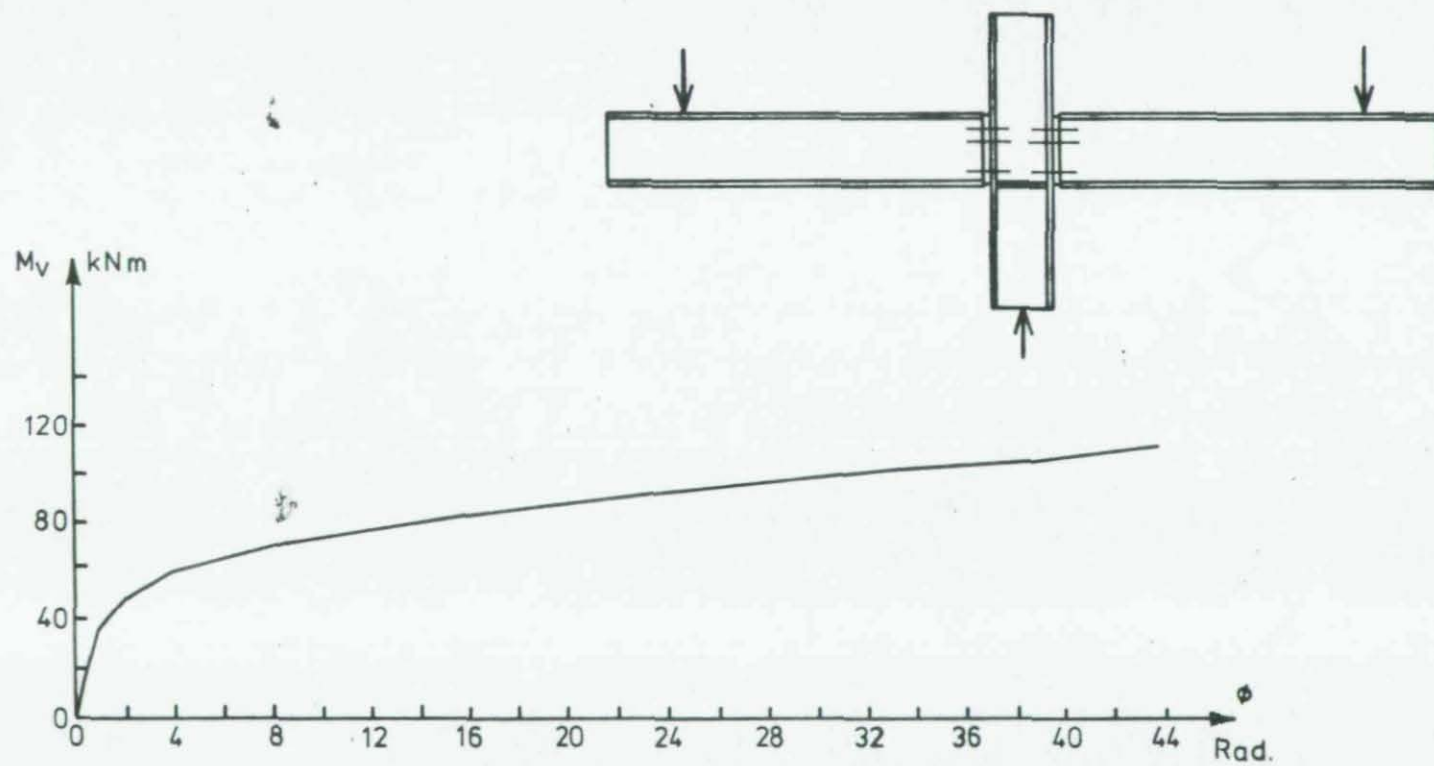


FIG. 24b M- ϕ CURVE FOR FLUSH END PLATE AND COLUMN STIFFENERS, REF. 47

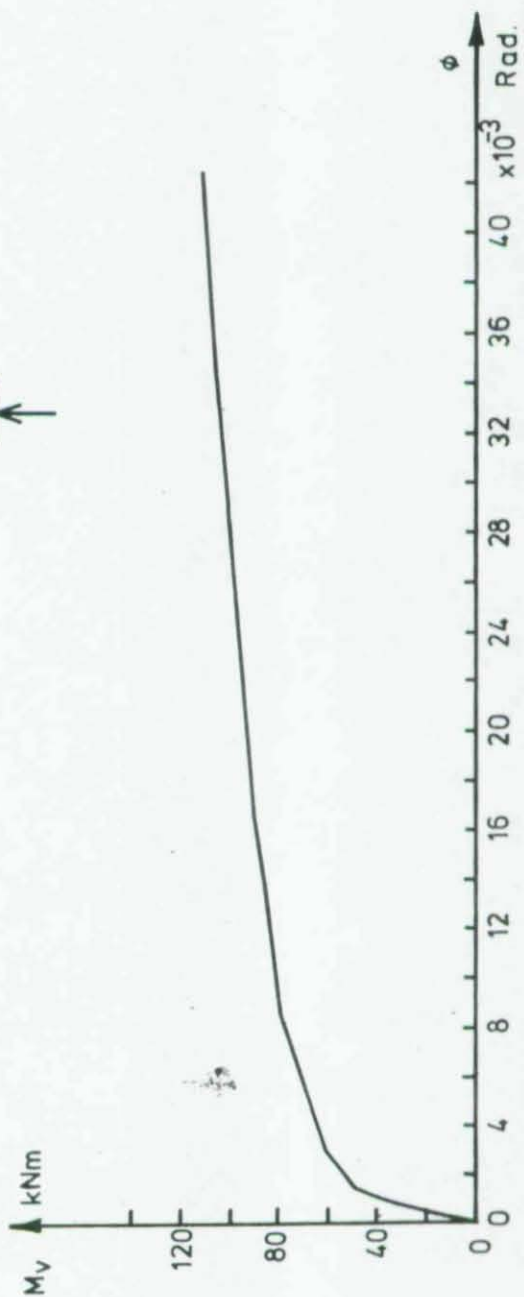
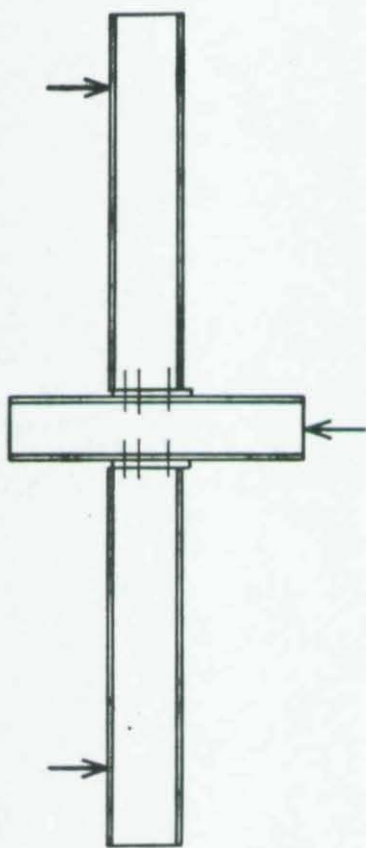


FIG. 24c M- ϕ CURVE FOR OVER-DEPTH FLUSH END PLATE CONNECTION, REF. 47

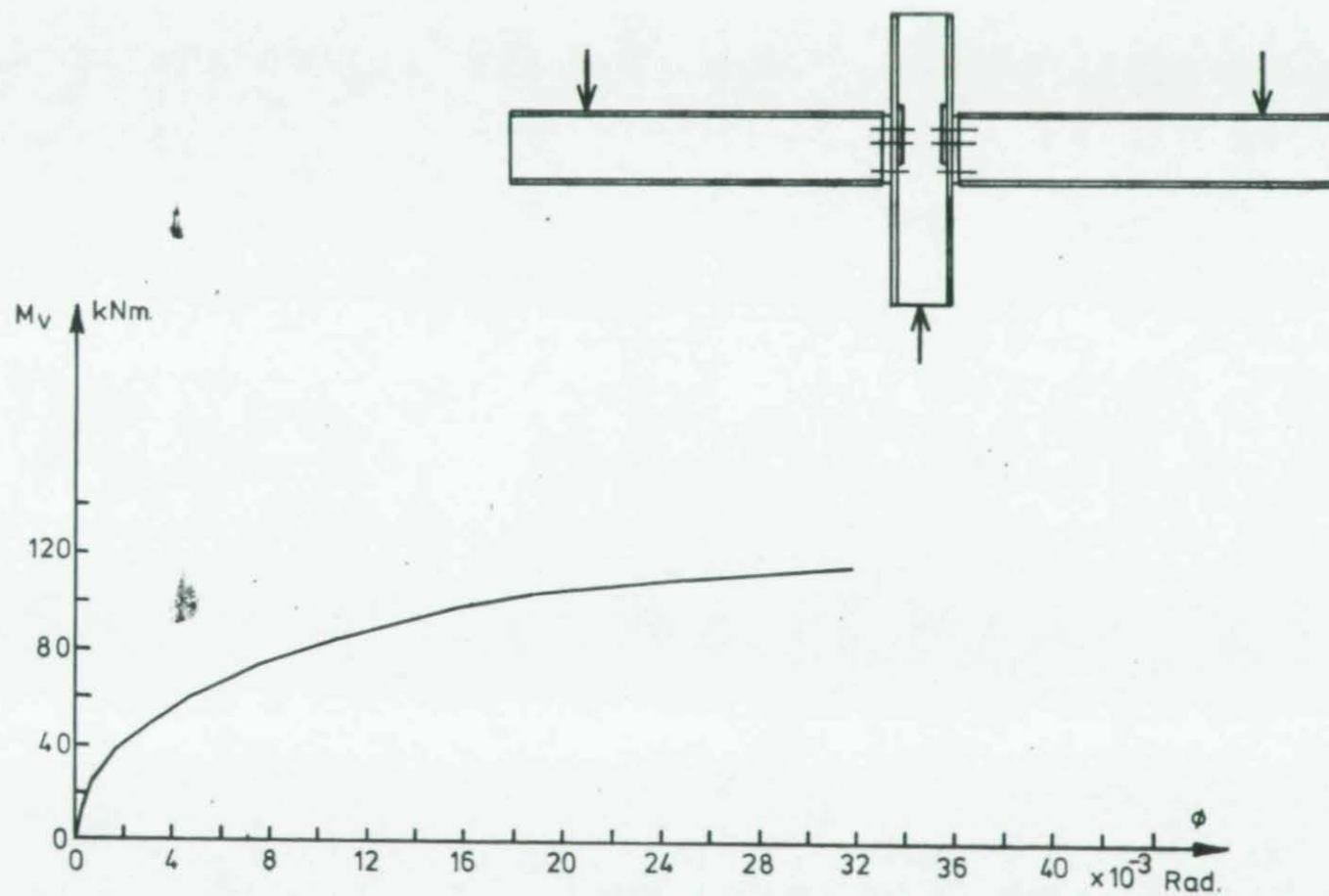


FIG. 24d M- ϕ CURVE FOR FLUSH END PLATE AND BACKING PLATES, REF. 47

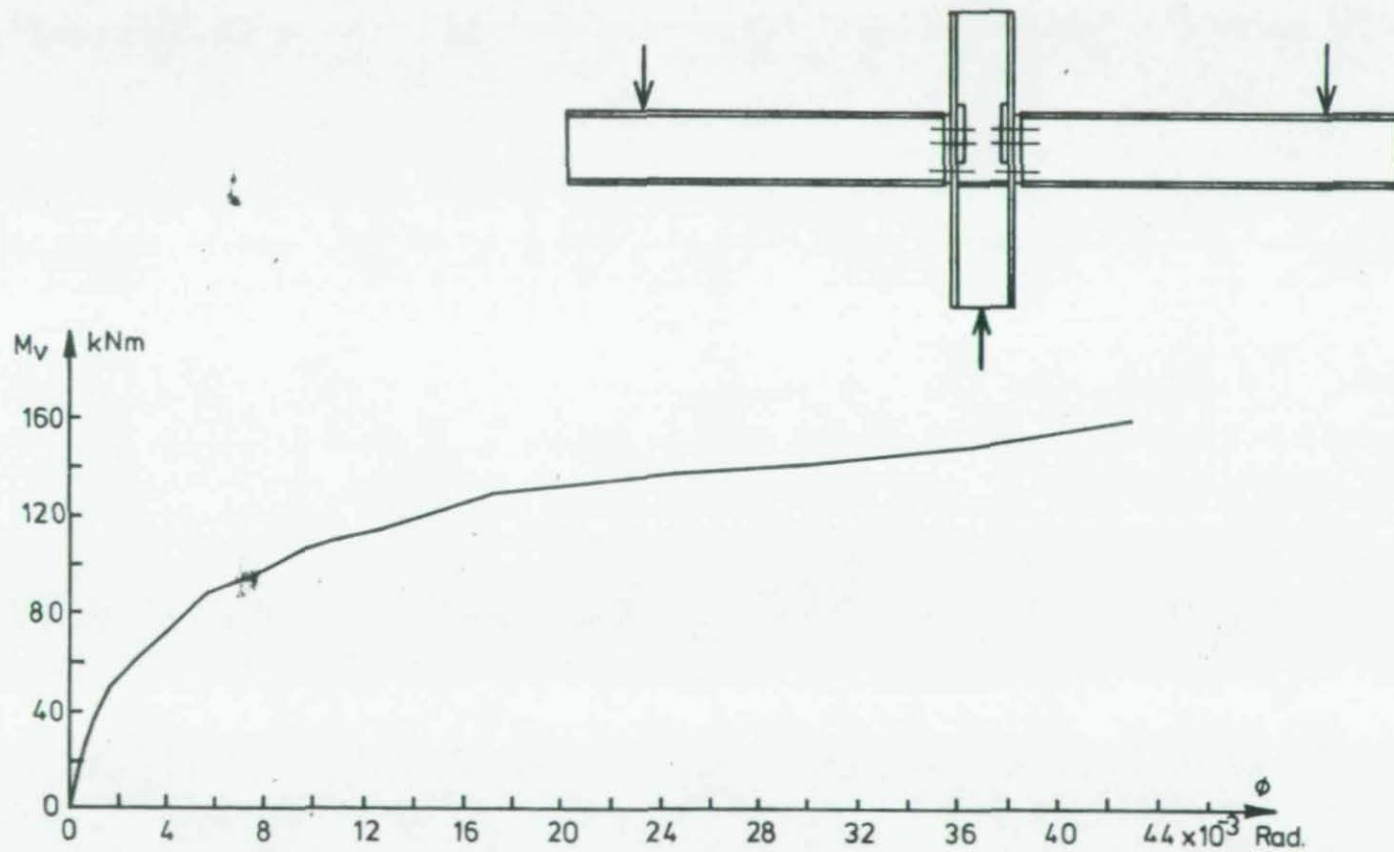


FIG. 24e M- ϕ CURVE FOR FLUSH END PLATE + COLUMN WEB STIFFENERS + BACKING PLATES, REF. 47

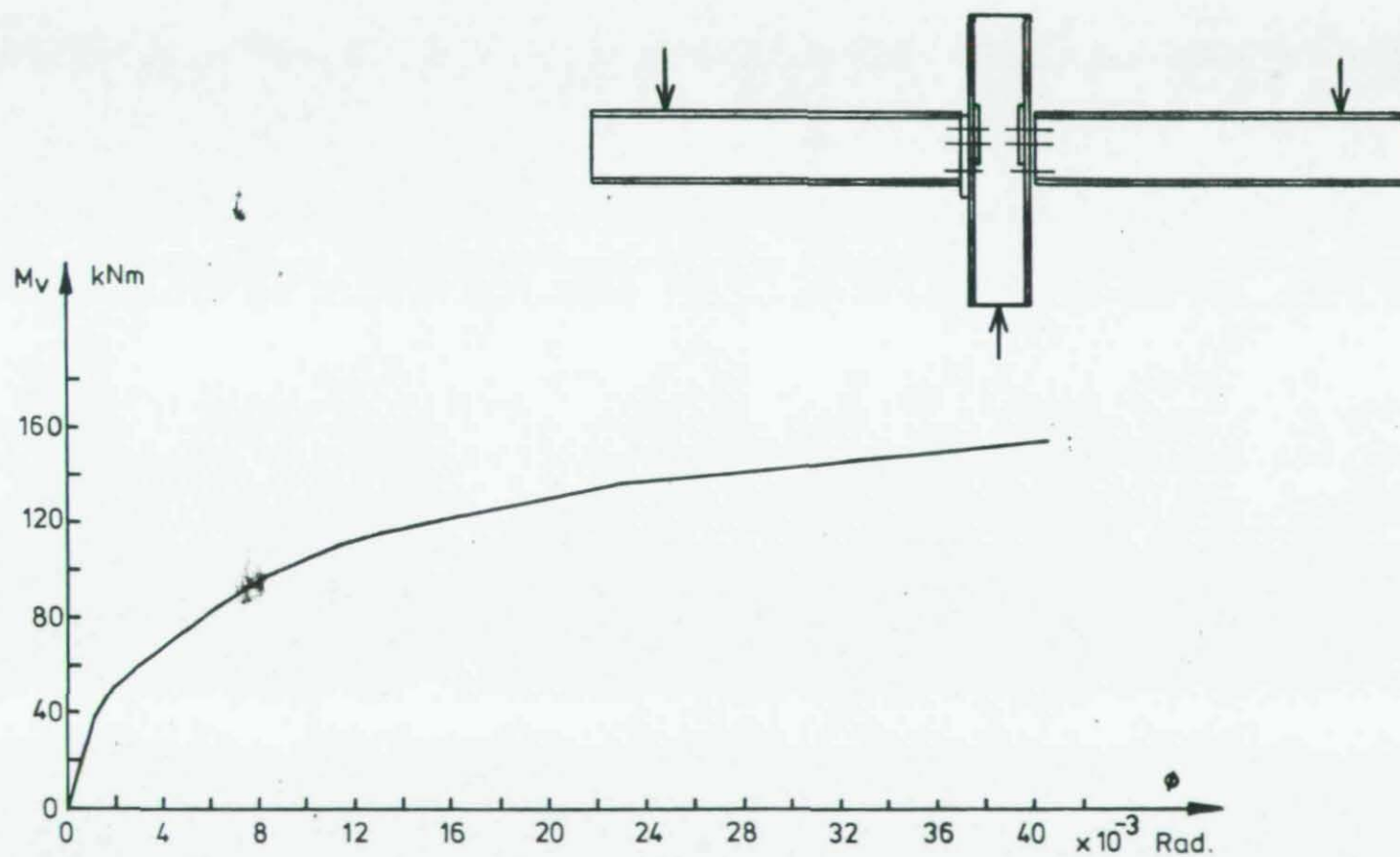


FIG. 24f M- ϕ CURVE FOR OVER DEPTH FLUSH END PLATE + BACKING PLATES, REF. 47

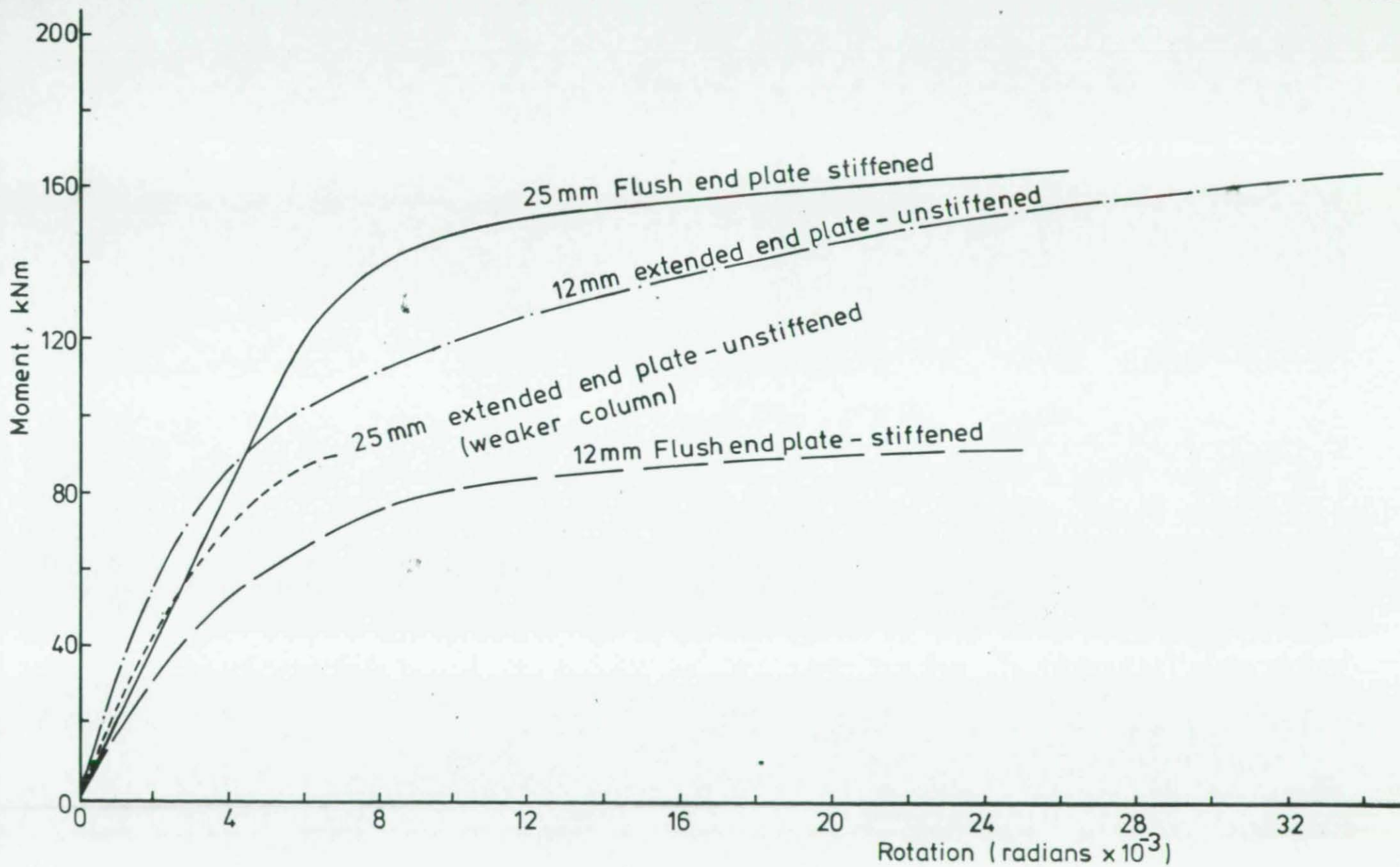


FIG. 25 MOMENT-ROTATION CURVES FOR FLUSH AND EXTENDED END PLATES, REF. 49

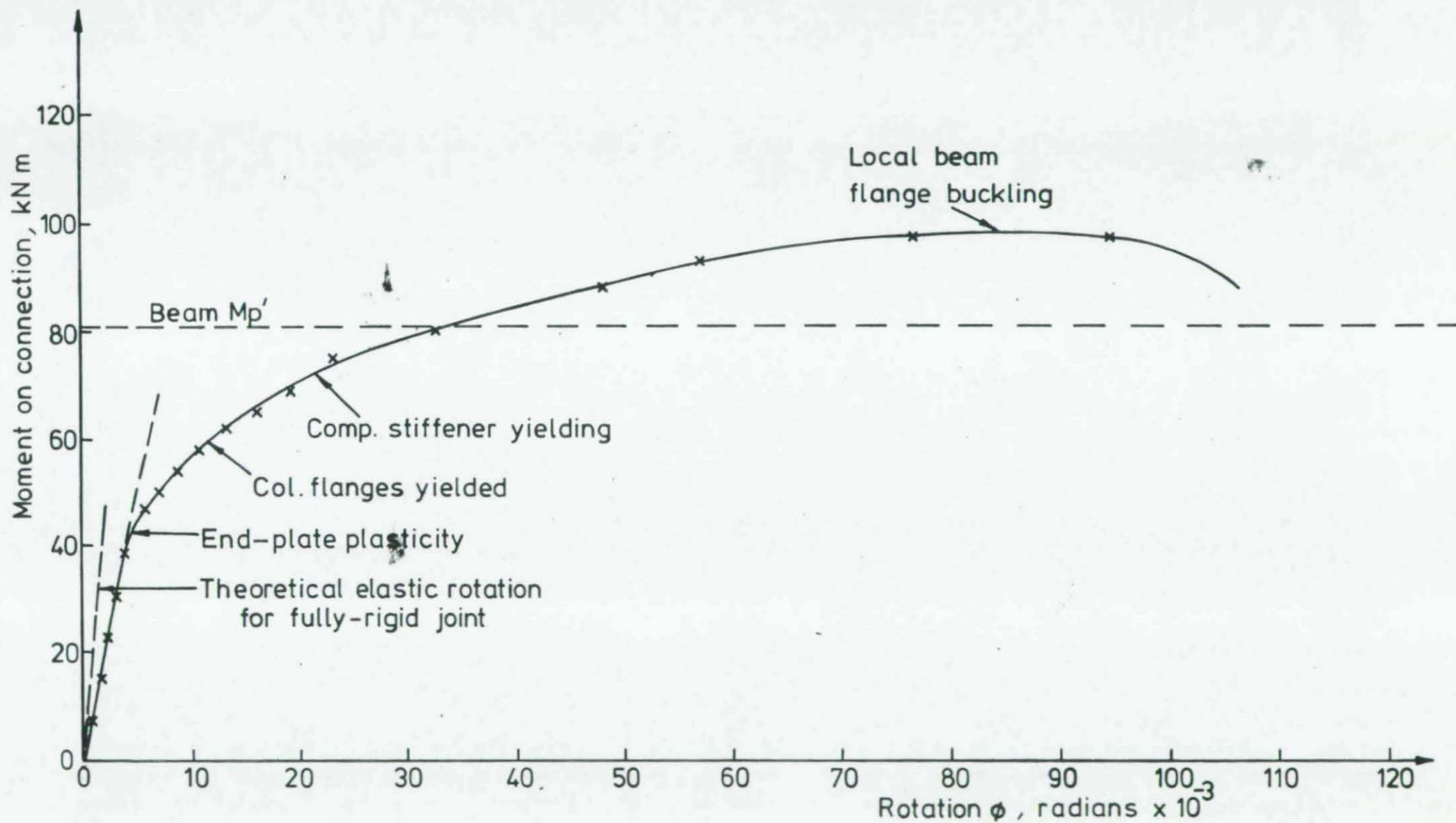


FIG.26 M- ϕ CURVE FOR EXTENDED END PLATE SHOWING MAINTENANCE OF BEAM FULLY PLASTIC THROUGH A LARGE RANGE OF ROTATION TEST 51 OF REF.56

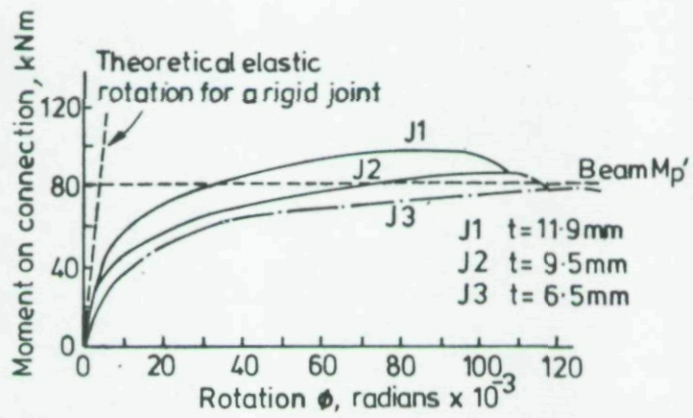


FIG. 27 MOMENT-ROTATION CHARACTERISTICS OF CONNECTIONS J1 TO J3 OF REF.56 SHOWING EFFECT OF COLUMN FLANGE THICKNESS

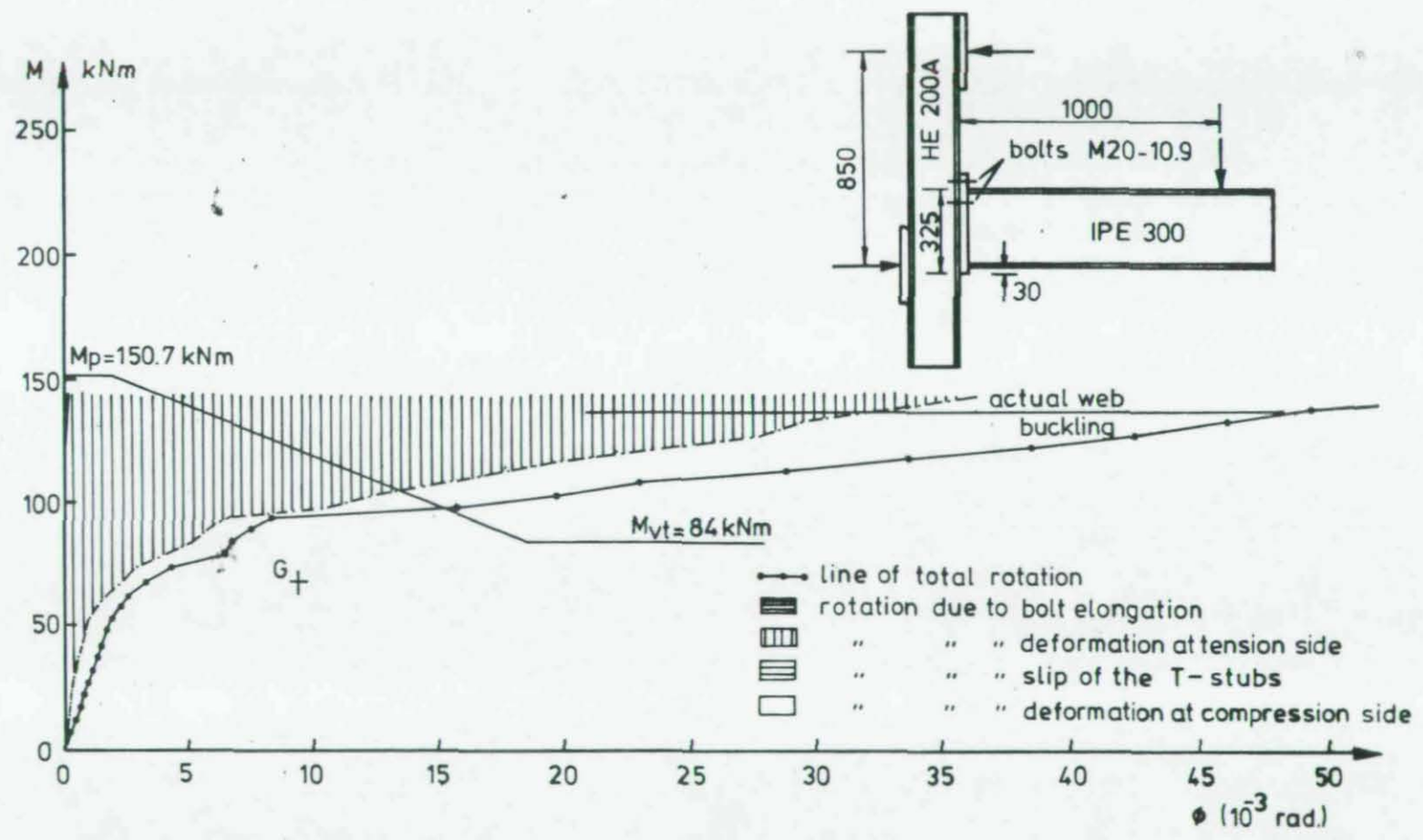


FIG. 28a M-φ DIAGRAM OF TEST SPECIMEN No.9 OF REF. 50

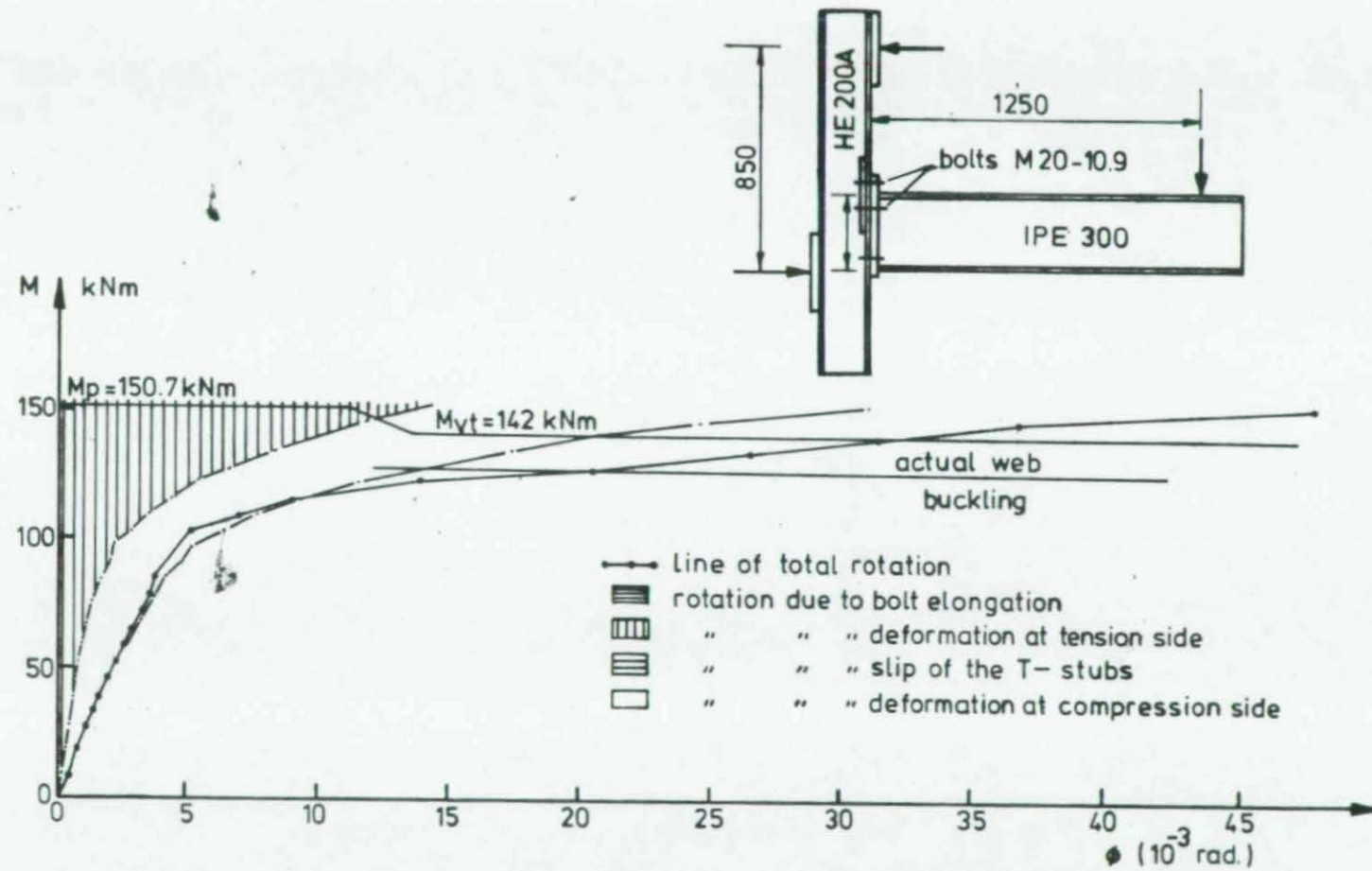


FIG. 28b M- ϕ DIAGRAM OF TEST SPECIMEN No.10 OF REF. 50.

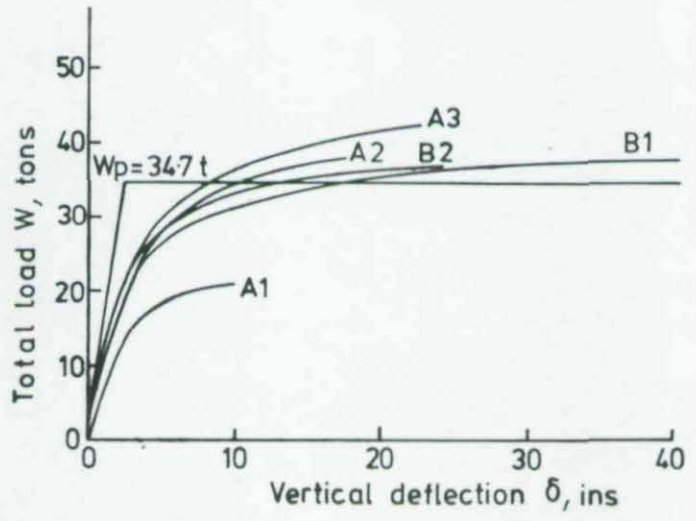


FIG. 29 TOTAL LOAD Vs END DEFLEXION - SERIES A AND B TESTS, REF. 51 .

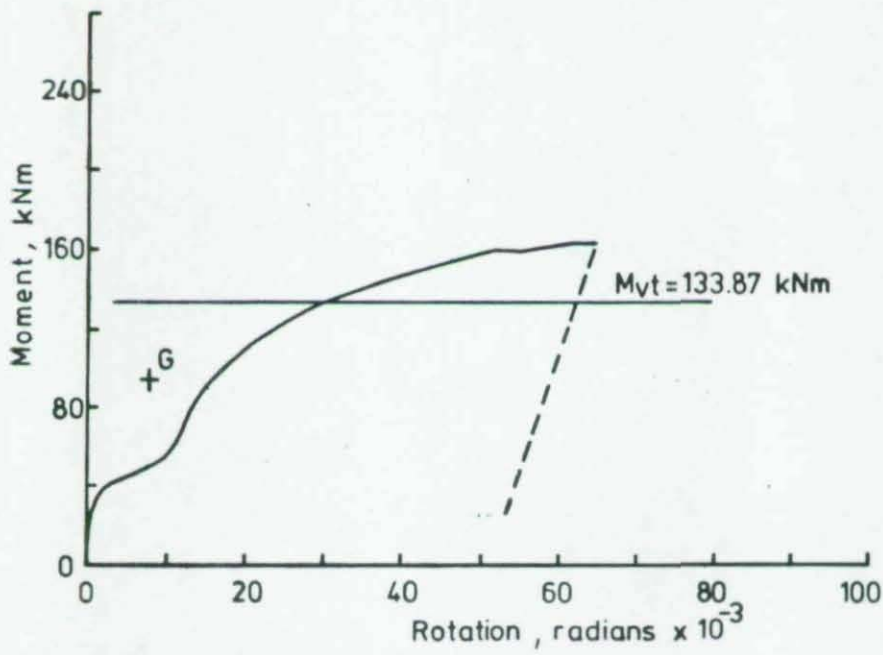


FIG.30a MOMENT-ROTATION CURVES FOR TESTS ON TEE-STUB CONNECTIONS OF REF. 50 SHOWING SLIP PART WAY THROUGH TEST

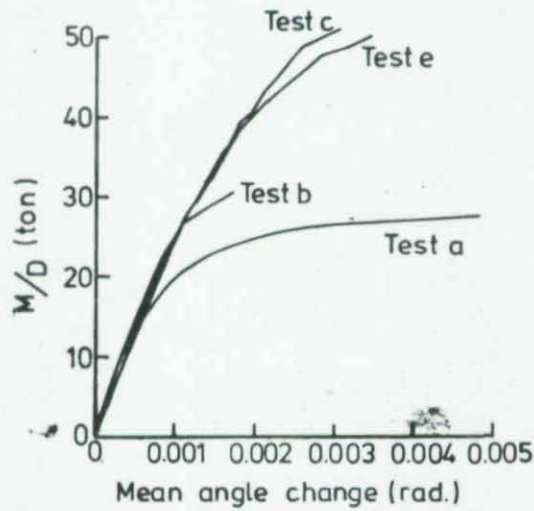


FIG.30b MOMENT-ROTATION CURVES FOR TESTS ON TEE-STUB CONNECTIONS OF REF. 65

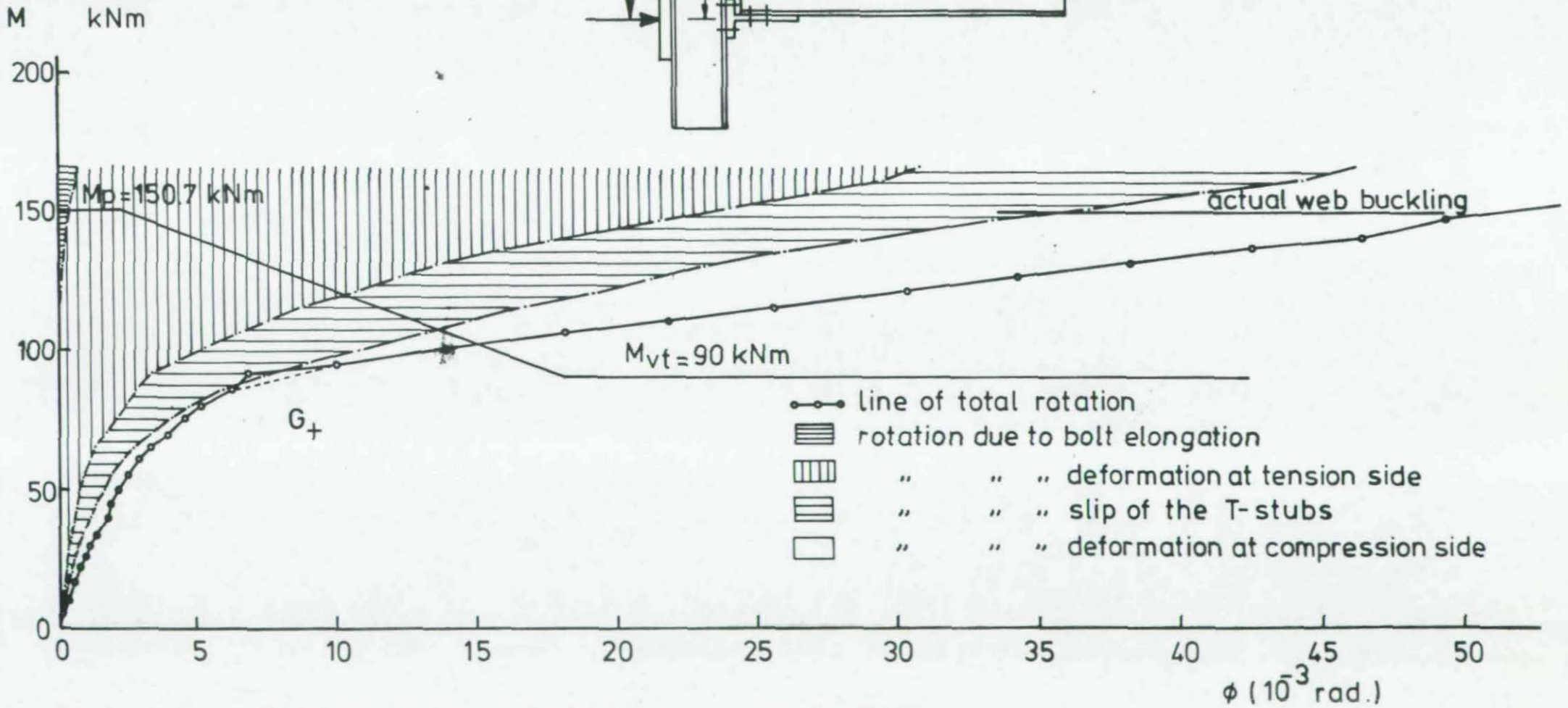
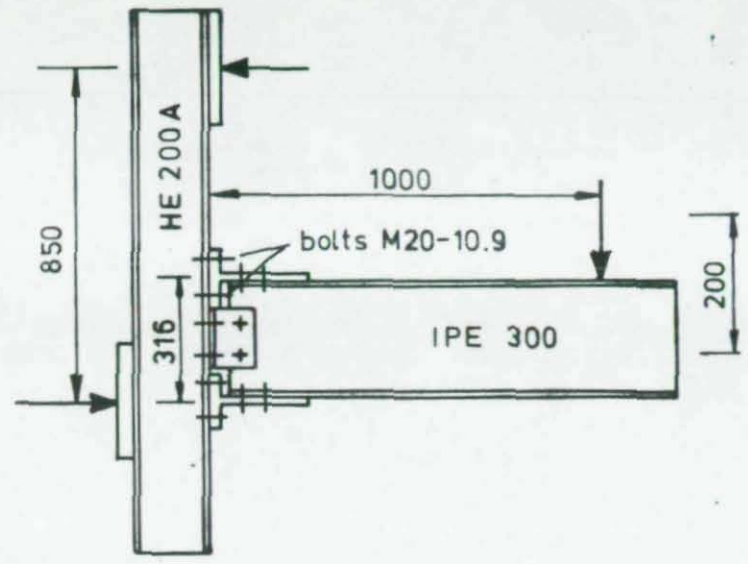
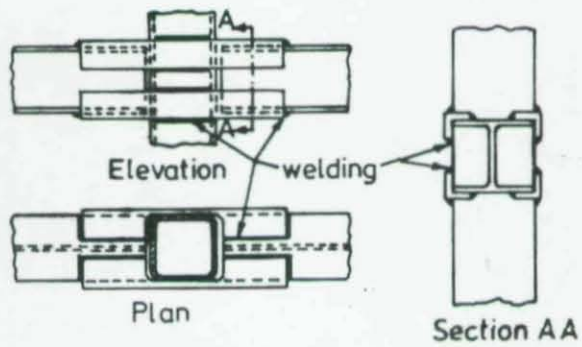
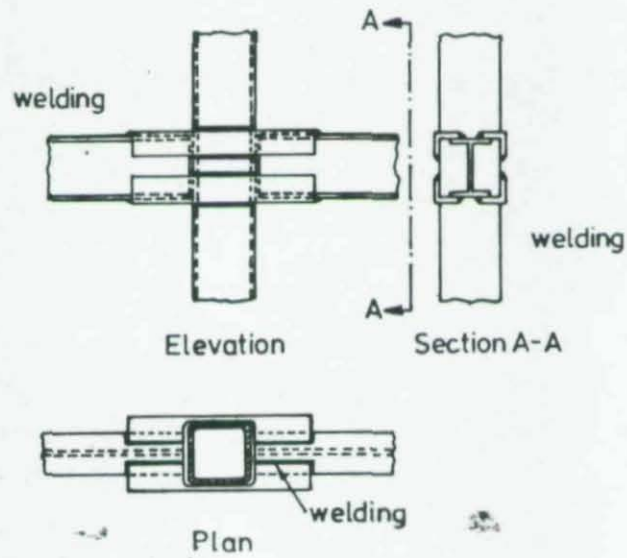


FIG.31 M- ϕ DIAGRAM OF TEST SPECIMEN No.1 OF REF. 50

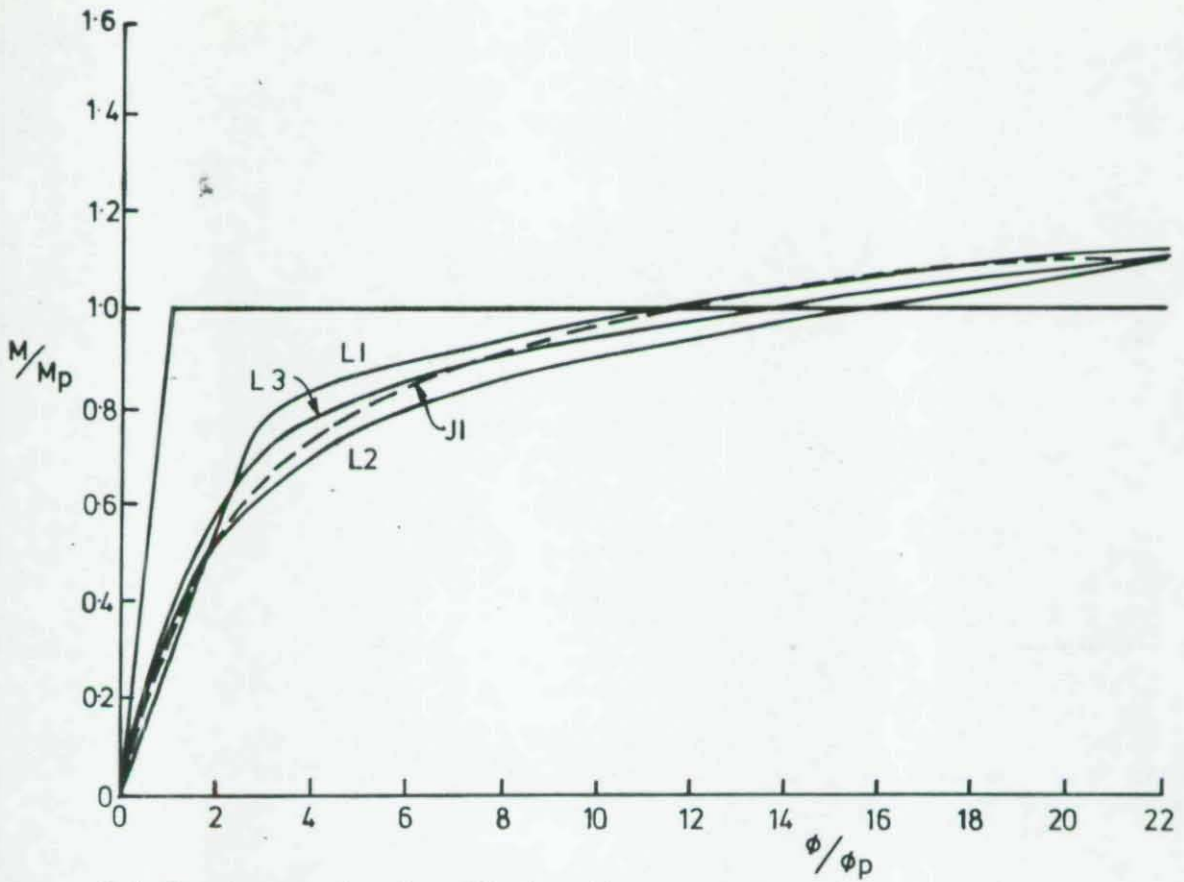


(a) Full width beam

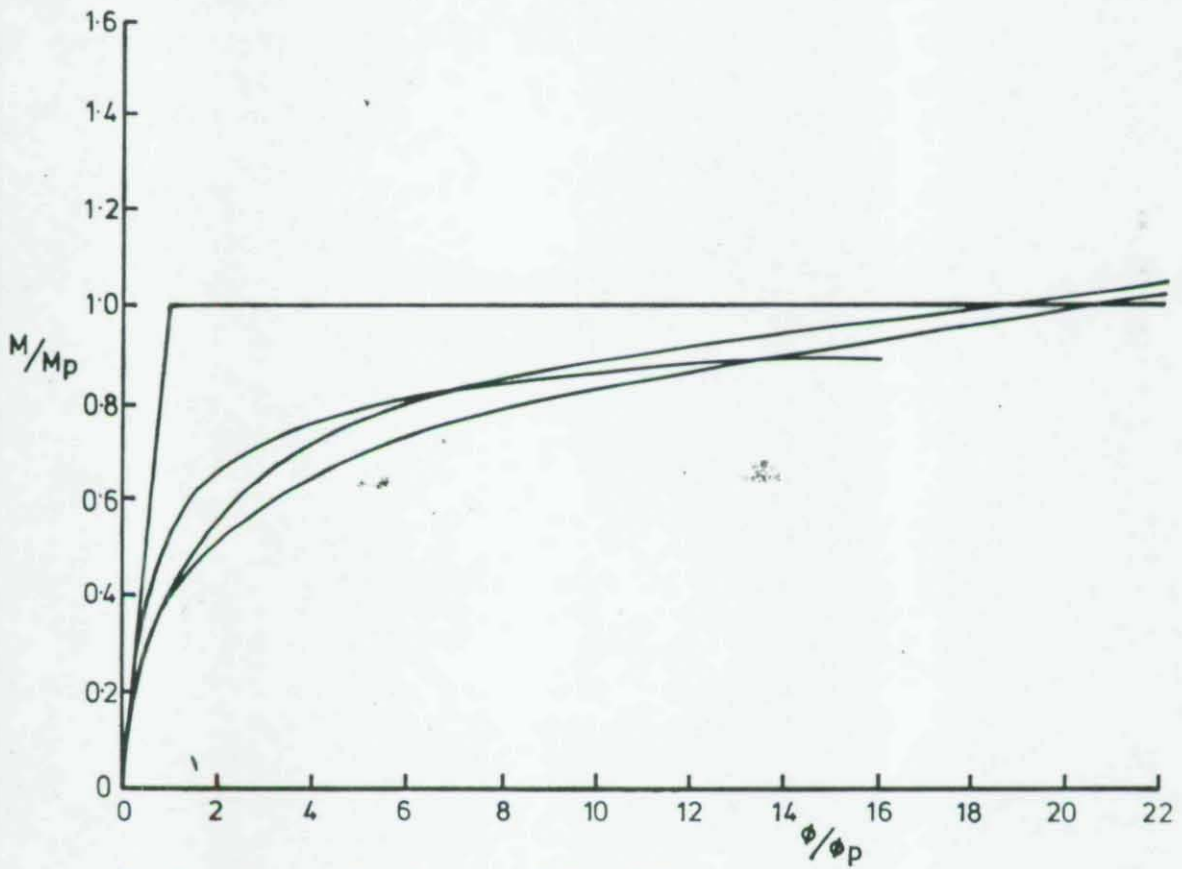


(b) Part width beam

FIG.32 STRAP ANGLES USED TO EFFECT A CONNECTION
BETWEEN AN RHS COLUMN AND AN I BEAM, REF. 71,72



(a) Specimens of categories J and L



(b) Specimens of categories I, K and M

FIG.33 MOMENT - ROTATION CURVES FOR STRAP ANGLE CONNECTIONS BETWEEN RHS COLUMNS AND I BEAMS

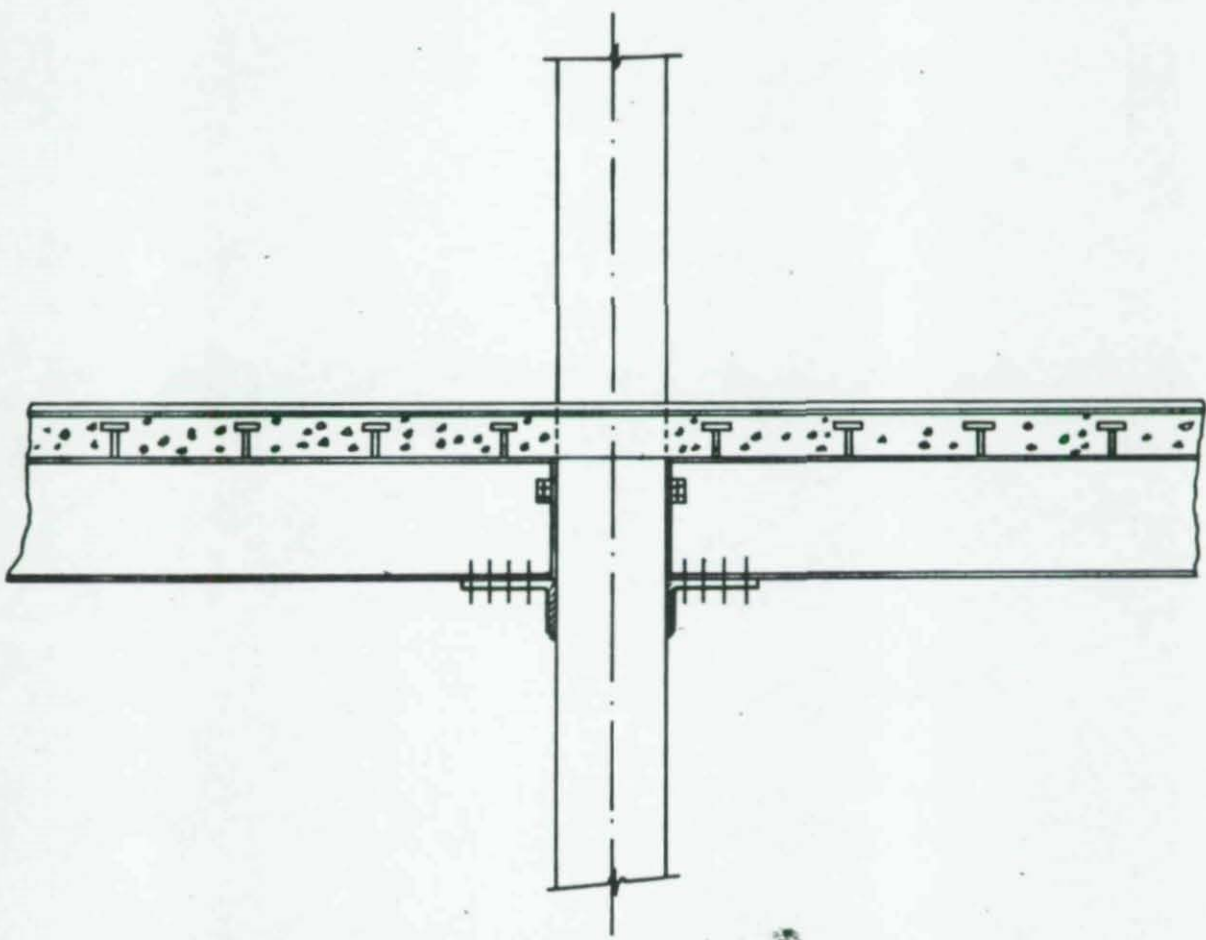


FIG.34 DETAILS OF THE CONNECTION FOR COMPOSITE FRAME,REFS.73,74

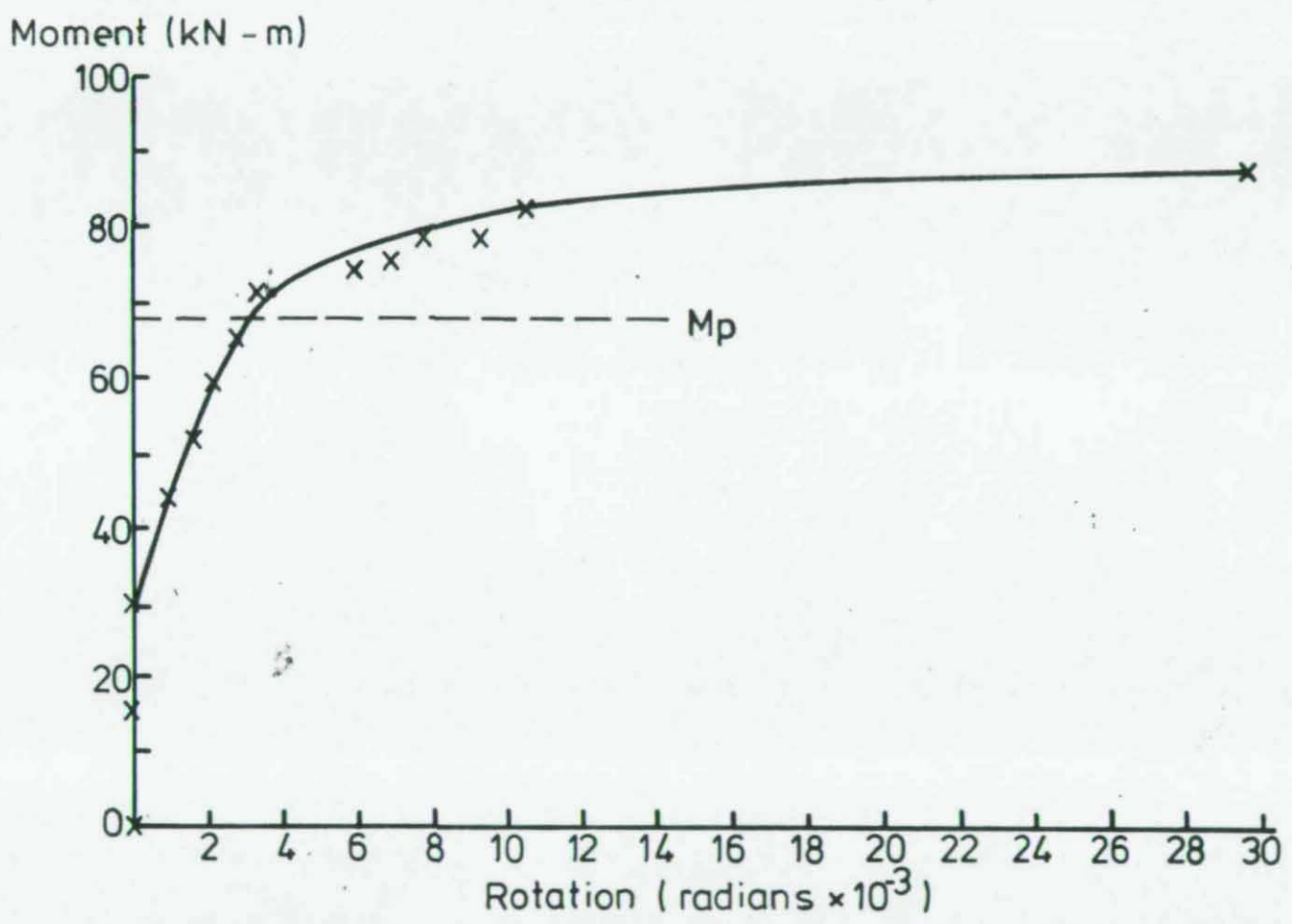


FIG.35 a MOMENT - ROTATION CURVE FOR BEAM 1BS - NO LACK OF FIT AT COLUMN FACE, REF. 73.

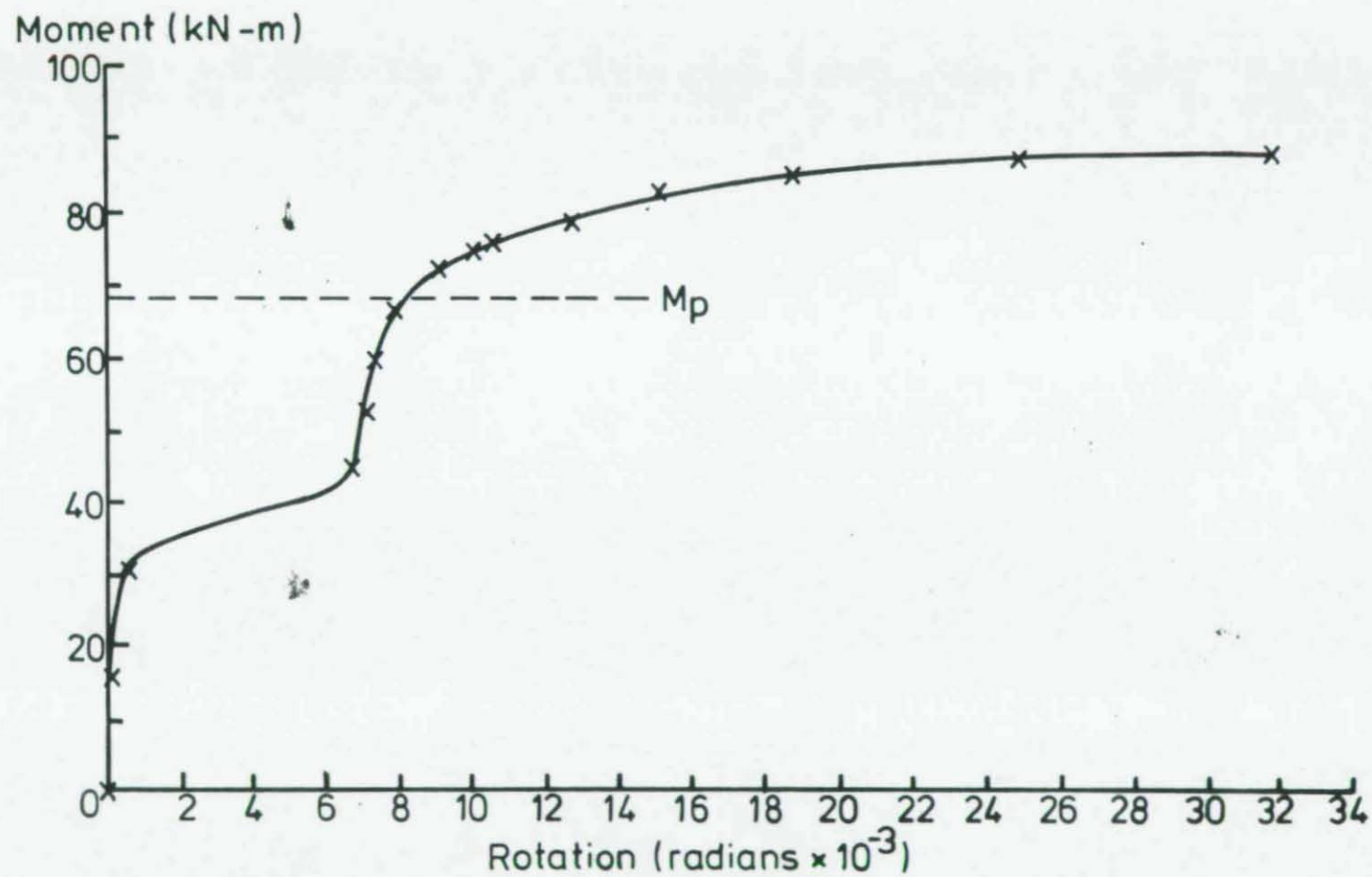


FIG. 35 b MOMENT - ROTATION CURVE FOR BEAM 1BN - WITH LACK OF FIT AT COLUMN FACE, REF. 73.

