Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 75 (1996)

Artikel: Testing of simple flowdrill connections

Autor: France, John E. / Kirby, Patrick A. / Davison, Buick

DOI: https://doi.org/10.5169/seals-56897

Testing of Simple Flowdrill Connections

John E. FRANCE
Research Student

Patrick A. KIRBY
Senior Lecturer

Buick DAVISON
Lecturer

University of Sheffield
Dept. Civil and Structural Engineering,
Sir Frederick Mappin Building,
Mappin Street,
Sheffield, UK

Summary

A series of tests has been conducted on joints where the connected members are open section beams and closed formed columns (SHS). The reported tests were specifically designed to investigate the use of flowdrill connectors for use in simple multi-storey frames. The details allow the use of traditional endplates, frequently used with open section columns, whereby the beam endplate is bolted directly to the face of the column section.

1. Introduction

The traditional steel framed building usually incorporates open sections for both the beam and column members. The use of open sections for columns where axial loads are predominant is recognised as being structurally inefficient compared with closed formed members (SHS-structural hollow sections) as the column section is usually determined by the buckling resistance about the weaker minor axis.

The success of steel framed buildings in maintaining market dominance in the UK, stems in part from the ease with which site bolted connections of the pre-fabricated elements of the steel frame can be achieved. A major problem which results from the use of SHS columns is the difficulty of devising a satisfactory joint detail. Previous examples of use of tubular columns have often been associated with areas of seismic activity where rigid and full strength joint details are normally adopted. This often involves site welding the open section beams directly to the face of the column which is then further reinforced by the addition of an internal or external diaphragm plate welded to the column and to the top flange of the beams. The use of welding in this manner greatly increases the fabrication costs and frequently outweighs the original benefit brought about by the use of SHS columns, especially in areas of non-seismic activity where simple site bolted connections are used in conjunction with braced frame construction.

1.1 Blind bolt connectors

A useful alternative to site welding is the use of blind bolt connectors which avoids the need to weld obtrusive fittings to the column exterior and enables traditional endplates to be site bolted from the outside of the SHS column. To date there are three systems (excluding the welded threaded stud) commercially available; Lindapter Hollo-bolt[1], Huck Ultra- twist[2] and Flowdrilling[3]. The first two are mechanical in operation which allows the column to be drilled by plain but oversized holes. Special bolts are then inserted through the endplate and drilled column. The tightening process expands the back of the bolts and clamps the endplate and column face together. If the wall thickness of the SHS is greater or equal to 16 mm, then the section can be drilled and tapped to accept ordinary structural bolts up to 20 mm in size. However the structural efficiency of the SHS column usually results in the selection of the largest practical plan size resulting in relatively thin walls which do not have adequate thickness to tap a thread into the section. In this case flowdrilling may be employed as an alternative to the mechanical bolts mentioned previously.

Flowdrilling is a system which locally increases the wall thickness of the closed section by rotating a tungsten carbide drill bit at high speed on the face of the tube. This heats the section locally by friction allowing the drill bit to be forced through the wall of the section to form a conical lobe on the inside of the tube which is of sufficient depth to allow a thread to be cold formed into the section allowing ordinary structural bolts to be used.

2. Experimental flowdrill research

A programme of flowdrill joint tests which incorporated the welded endplate detail has recently been completed. The endplates investigated were the flexible (partial depth- PD) endplate, the flush endplate (FE) and finally the extended endplate (EE). This selection enabled the full range of joint behaviour to be investigated, from assumed simple joint details

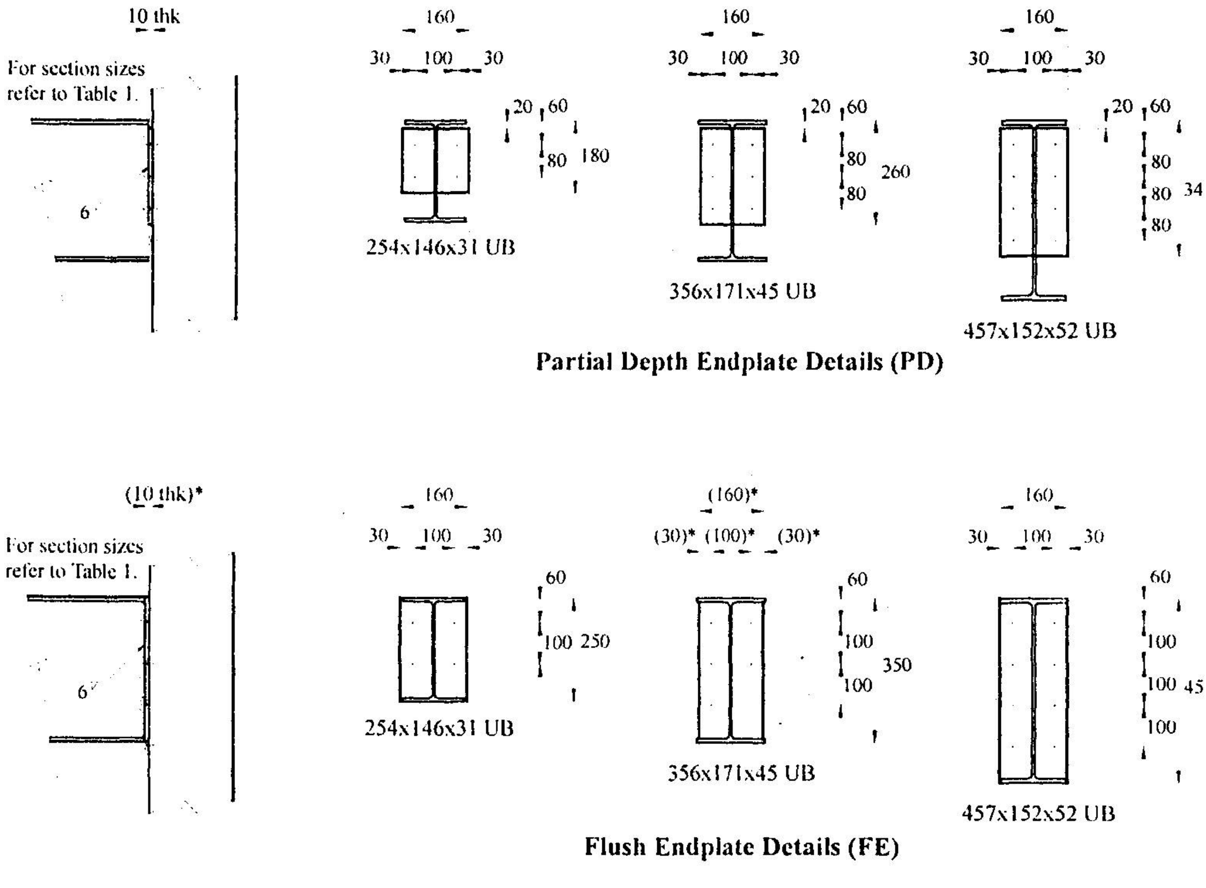
Test Reference	Column Section	Column Yield Strength (N/mm^2)	Beam Section	Endplate Type	Endplate width and Thickness (mm)	Bolt Cross Centres (mm)
PD-254-100/8	200x200x8.0 SHS	318	254x146x31 UB	Flexible	160x10	100
PD-356-100/8	200x200x8.0 SHS	313	356x171x45 UB	Flexible	160x10	100
PD-457-100/8	200x200x8.0 SHS	313	457x152x52 UB	Flexible	160x10	100
FE-254-100/8	200x200x8.0 SHS	318	254x146x31 UB	Flush	160x10	100
FE-356-100/8	200x200x8.0 SHS	313	356x171x45 UB	Flush	160x10	100
FE-457-100/8	200x200x8.0 SHS	313	457x152x52 UB	Flush	160x10	100
FE-356-80/8	200x200x8.0 SHS	318	356x171x45 UB	Flush	160x10	80
FE-356-120/8	200x200x8.0 SHS	318	356x171x45 UB	Flush	180x10	120
FE-356-100/6.3	200x200x6.3 SHS	336	356x171x45 UB	Flush	160x10	100
FE-356-100/12.5	200x200x12.5 SHS	307	356x171x45 UB	Flush	160x15	100

Table 1. Flowdrill joint parameters

(PD) to the rigid joints (EE), with the flush endplates acting in between these two extreme cases.

The aim of the work is to investigate the semi-rigid action of the joint under moment rather than the performance of the connector which has already been investigated by Sherman[4], Banks[5] and Balleria[6]. This paper presents the moment-rotation characteristics for simple joint details associated with braced frame construction, namely partial-depth and flush endplates. The flush endplate has been included within this selection in accordance with normal practice which assumes it to act as a simple shear connection even though substantial fixity and moment transfer may sometimes be provided at the column joint.

Figure 1. shows details of the test programme with joint parameters specified in table 1. All steel used in the tests was specified as grade S275 (nominally 275 N/mm^2 yield), subsequent coupon test results from the SHS members are also presented in table 1.



NOTES: (1) M20(8.8) bolts used throughout.
(2) Where values are bracketed thus ( )*, refer to table 1 for variations to dimensions shown.

Figure 1. Details of tests specimens

2.1 Experimental set-up and fabrication of specimens

The endplate and beam components of the specimens were fabricated in the departmental workshop. Endplates were attached to the beams with nominal 6 mm fillet welds. All the flowdrilling of the column specimens was carried out by an experienced fabrication company.

All the test specimens adopted the cantilever test arrangement with slow cyclic loading using a point load at a 1.0 m to 1.3 m leverarm (details of the test procedure together with further results can be found in France et al.[7]). Use of the cantilever arrangement simulated the joint of an edge column typically found in a frame. Such joint arrangements subject the column specimen to constantly increasing column moments when compared with the cruciform testing arrangement where some unloading may occur due to lack of symmetry. One disadvantage of the cantilever arrangement is the reduced severity of the buckling of the side walls induced by only one sided compression from the beam compression flange.

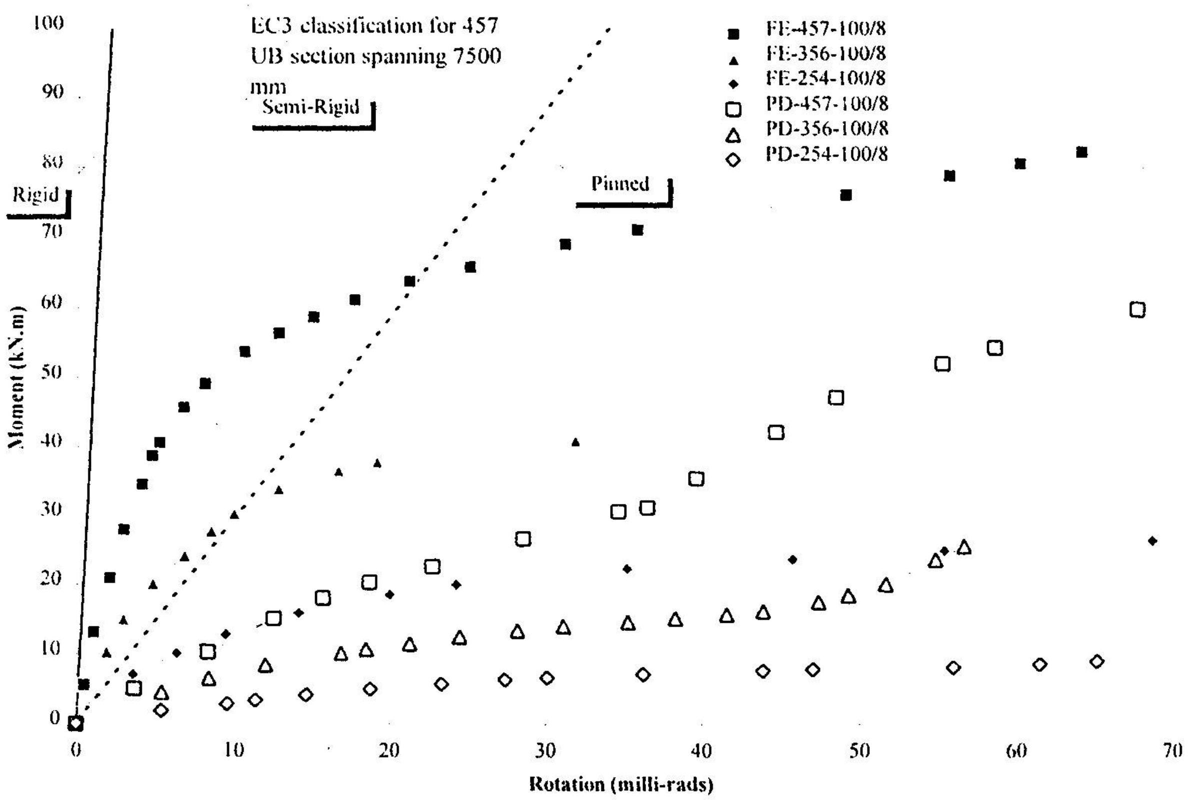


Figure 2. Comparison of moment-rotation curves for flush and partial depth endplates.

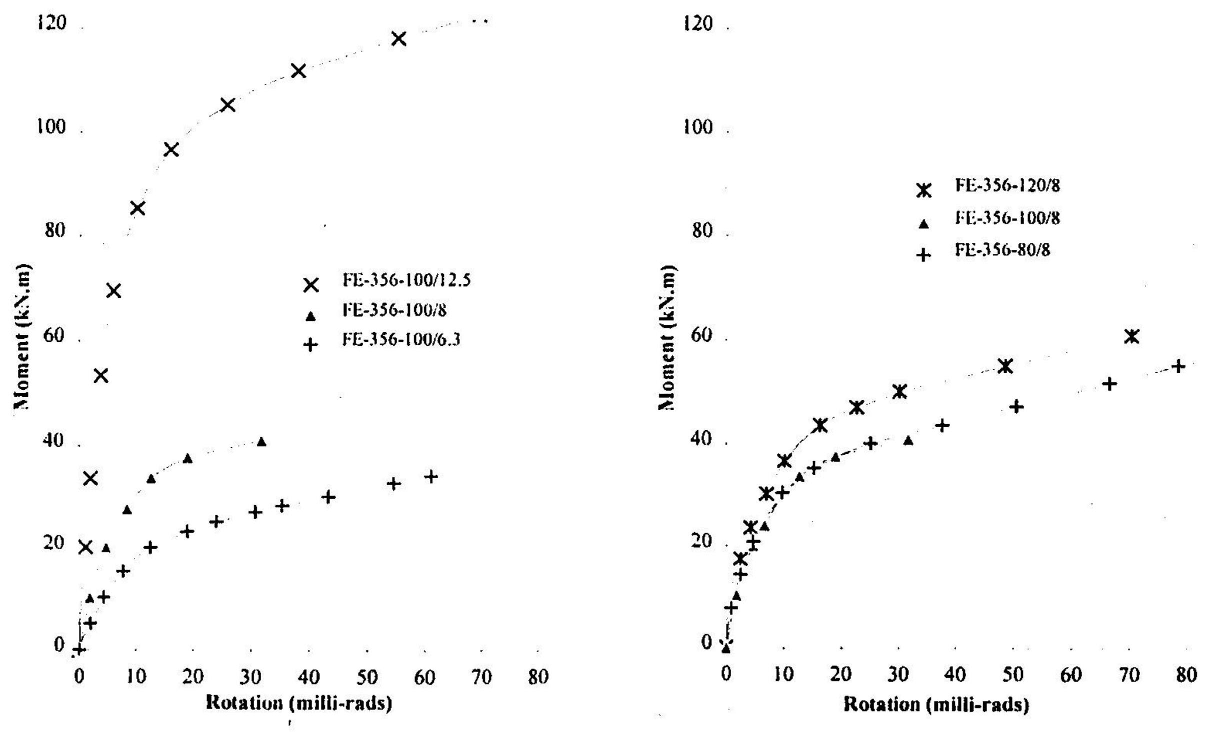
3. Moment-rotation response

Figure 2 indicates the moment-rotation responses for both the flush and partial depth endplates attached to the 254, 356 and 457 UB beam depths. All the joints showed a ductile and safe failure mechanism resulting from the top tension bolts deforming the SHS face. Although the deformation of the flowdrilled thread was significant at the end of the test, the bolts did not exhibit any signs of thread stripping.

The comparisons between the two types of endplates indicate that partial depth endplates exhibit reduced initial stiffness and moment resistance compared with their flush endplate counterparts. As the test proceeded, the moment rotation characteristic for the partial depth endplate connections changed abruptly when the rotation had increased to such an extent that the compression flange of the beam was bearing against the face of the box section, for the most flexible of these joints this occurred at a rotation in excess of 70 milli-radians. This would be unlikely to occur in practice as the beam member would fail before such large end rotations develop.

EC3 (revised annex J) gives guidance for acceptable limits to the stiffness and rotation capacity of joints. Limits to the joint capacity depend on the geometry of the frame and whether the frame is constructed as braced or unbraced. To highlight the differences between the two types of endplate the classification limits for the 457 UB beam spanning 7500 mm have been incorporated into figure 2. As seen, the flexible endplate response is suitable for pin-jointed frames whereas the flush endplate is placed in the semi-rigid category during the initial stages of the loading history.

In separate tests the wall thickness and bolt cross-centres were varied to investigate the sensitivity of the flush endplate moment rotation response to these changes. The 200x200x8 SHS column and 356 UB beam (test FE-356-100/8) with the 10 mm flush endplate was selected as the bench mark. Figure 3(a) illustrates the differences in the moment-rotation characteristics when tube wall thickness is varied between 6.3, 8 and 12.5 mm while figure 3(b) highlights the difference when 80, 100 and 120 bolt cross centres are adopted. The results show that the characteristic is highly sensitive to changes in tube wall thickness but less so to bolt cross-centres.



(a) (b)

Figure 3(a) and 3(b) comparison of Moment-rotation characteristics for variation to tube wall thickness and bolt cross centres respectively

4. Effect of Endplate Bending on Moment-rotation Response

Frequently the flexibility of a joint is determined as the summation of the flexibilities of the component parts. To check the validity of this approach for joints to tubular columns, additional tests were undertaken.

4.1 Isolated Endplate tests

Where flush endplates are used as pin joints, the thickness of the endplate is selected to ensure that the majority of the deformation occurs in the endplate rather than in the column flange. Tests were conducted on endplates, nominally identical to those used in the flowdrill joint tests FE356-100 and FE356-120, to determine the contribution of endplate bending in the overall rotational deformation of the joint.

The two types of endplate with 100 mm and 120 mm bolt cross centres (nominally identical in construction to those used in the flowdrill joints) were each tested by either bolting the endplate directly to a rigid base or by testing the endplate with packs inserted between the flanges and the rigid base as shown in figure 4(a) and 4 (b). Packs used in this way allowed the edge of the endplate to be either restrained or unrestrained. Figures 5(a) and 5(b) show the moment rotation results of the tests for the 100 mm and 120 mm endplate bolt cross-centres respectively.

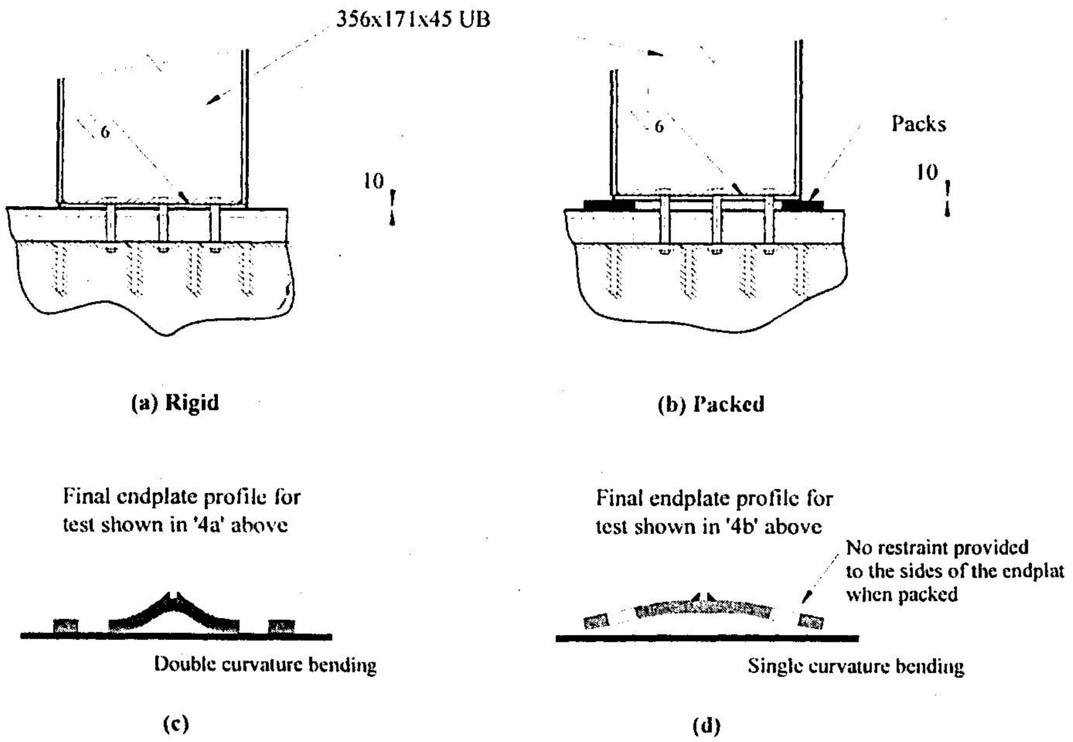


Figure 4. Details of rigid base and endplate deformations

The differences in the responses of each pair of tests shown in figure 5 are attributed to the restraint afforded to the edge of the endplate by the rigid base. Endplates in direct contact with the rigid base develop double curvature bending (figure 4c), increasing the initial stiffness of the joints in comparison to the endplates which are packed from the base (figure 4d). Both endplate details attained a similar ultimate moment of resistance regardless of being packed or unpacked.

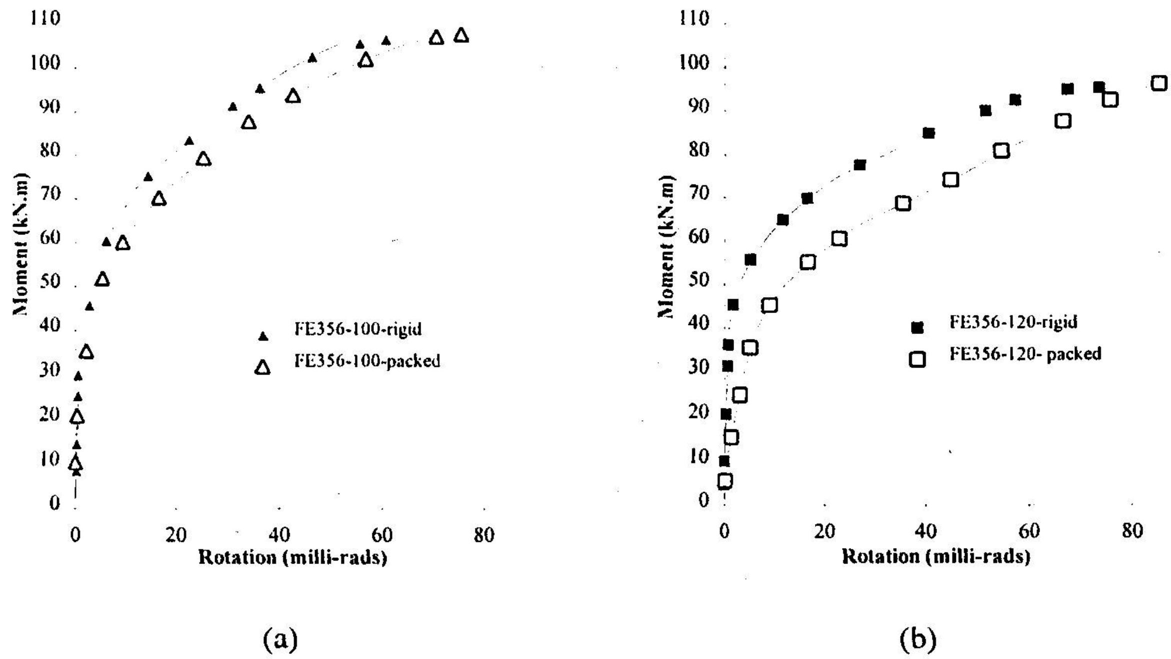


Figure 5. Comparison of Endplate moment rotation characteristics

4.2 Contribution of endplate bending to the flexibility of Flowdrill joints

Figure 6 plots the moment-rotation characteristics of test FE356-120/8 (from figure 3b) and the corresponding endplate test FE356-120-packed (from figure 5b). The 'packed' test was selected as the deformation pattern (figure 4d) most closely resembled that in the flowdrill test. The moment-rotation curve for this test is taken to represent the contribution of endplate deformation only. The upper curve shown on figure 6 is the moment rotation curve obtained in a flowdrill test with an overthick (25 mm) endplate (denoted as test 26). This curve represents the contribution of SHS deformation only to overall joint rotation. The summation of these two curves is also shown on figure 6 and may be taken as representing the total response using the concept of component distortion. It is immediately apparent that this curve does not correspond with the result of test FE356-120/8, resulting in a significant error at large rotations. Part of this discrepancy is due to the difference in endplate depth in test 26 which was 395 mm rather than 350 mm. This has the effect of increasing the lever arm to the upper most bolts by 30 mm (approximately 10% increase). A further 9% discrepancy was found in the yield strength of the two SHS columns. Whilst these differences are significant they will not account for the large discrepancy shown between the two moment rotation curves in figure 6.

A more likely explanation for the large difference in the two curves is that the isolated endplate tests did not pivot about the same point as the endplate in the flowdrill tests. Furthermore, the separation of the endplate and column face effects obviously removes the interaction of column face and endplate stiffness which is present in a real flowdrill

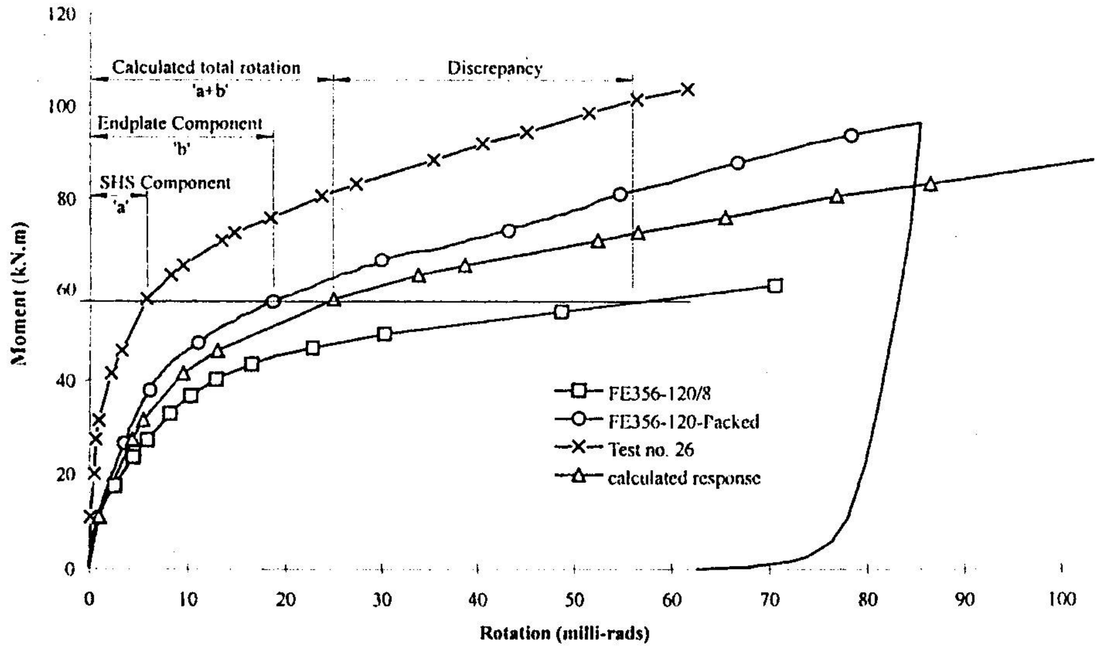


Figure 6. Moment rotation response with the effect of endplate contribution

connection and which is the cause of the movement of the pivot point. This suggests that in certain circumstances care must be exercised in adopting an approach in which flexibilities are individually calculated and assumed to determine overall response.

5. Conclusions

All joint details responded in a ductile manner with no unexpected behaviour. The tests have shown that partial depth endplates can be used to simulate a pinned joint but some tube wall deformation will be present. Flush endplates may also be suitable for simple construction but are likely to fall outside the EC3 classification boundaries for assumed pin jointed frames.

6. Acknowledgements

The authors would like to extend their gratitude to British Steel Tubes and Pipes for their technical and financial support throughout this series of tests.

7. References

1. Manufacturer's literature, Lindapter Hollo-bolt specification. UK.
2. Sadri, S-M. & Wang, H-T. 1995. Advanced technique for joining of hollow steel structures. *Proc. Nordic Steel Construction Conference* : Vol.-II, 757-764: Swedish Institute of Steel Construction.
3. Flowdrill, 1993. Flowdrill technical guide. Flowdrill B.V. Holland.
4. Sherman, D. R., 1993. 'Framed connections to HSS columns'. *Proc. Fifth International Symposium Tubular Structures*: pp 241-248. London: E & FN Spon.
5. Banks, G., 1993. 'Flowdrilling for tubular structures'. *Proc. Fifth International Symposium Tubular Structures*: pp 117-124. London: E & FN Spon.
6. Ballerini, M., Bozzo, E., Occhi, F. & Piazza, M., 1993. 'Flowdrill connections in RHS elements: Experimental results and design evaluations'. *Proc. XIV Congresso C. T. A.*: pp 87-98.
7. France, J. E., Davison, J. B. & Kirby, P. A. 1995. Behaviour of flowdrilled connections in mult-storey frames with tubular columns. *Proc. Nordic Steel Construction Conference* : Vol.-II, 773-780: Swedish Institute of Steel Construction.