Report No.	SL/HED/R/S2442/1/94/C
Date	3 June 1994
Classification	OPEN

BS476 : Part 21 Fire Resistance Tests

Summary of Data Obtained During Tests on Web Encased Columns

Swinden Laboratories
Moorgate
Rotherham, S60 3AR
Telephone: (0709) 820166
Telefax: (0709) 825337

British Steel Technical
A division of British Steel plc

CONTENTS

3 June 1994
OPEN

SUMMARY

BS476:PART 21 FIRE RESISTANCE TESTS

SUMMARY OF DATA OBTAINED DURING TESTS ON WEB ENCASED COLUMNS

D.E. Wainman and L.N. Tomlinson

During the five years 1989-1993 British Steel, (Sections, Plates and Commercial Steels), sponsored more than thirty standard fire resistance tests on hot rolled structural steel sections. The range of systems / component configurations investigated in these tests was much wider than in preceding years. Data arising from the tests are being summarised in a series of reports, each one dealing with either a different form of construction or generic group of test assemblies.

This is the second report issued as part of that series. It contains detailed descriptions of the design, instrumentation and construction for each of five web encased columns, (four concrete filled and one block-work filled), together with the data arising from them.

KEYWORDS

26
+BS 476
Fire Resistance
Fire Tests
+BS 4360
+BS 5950
+BS 449
+BS EN 10 025
Columns
Load (Mechanical)
Sections (Structural)
Lab Reports

British Steel Technical
Swinden Laboratories,
Moorgate,
Rotherham S60 3AR
Telephone : (0709) 820166
Telefax : (0709) 825337

Cover Pages :	1
Text Pages :	12
Figure Pages :	9
Appendix Pages :	33

INITIAL CIRCULATION

BS SECTIONS, PLATES & COMMERCIAL STEELS

Commercial Office
- Structural Sections

Mr J. Dowling
Mr J.T. Robinson (50 Copies)

British Steel Technical HQ

Dr R. Baker, Director Research & Development

Swinden Laboratories

Mr G. Banks
Mr T.R. Kay
Dr B.R. Kirby
Dr D.J. Latham
Dr M.J. May
Library

BS476 : PART 21 FIRE RESISTANCE TESTS

SUMMARY OF DATA OBTAINED DURING TESTS ON WEB ENCASED COLUMNS

1. INTRODUCTION

In 1987 and 1988 research staff based at British Steel Technical, Swinden Laboratories, prepared and published two Compendia[1],[2] in which data obtained from standard fire resistance tests were summarised. These documents covered all the British Steel sponsored fire tests which had been carried out in the UK since 1979 according to the requirements of either BS476:Part 8:1972, or the later revision, BS476:Parts 20/21:1987[3],[4]. Only tests on hot rolled structural steel sections in which the test members were completely unprotected, or were partially protected by materials used in the fabric of the structure, such as concrete, brick and block-work, were included. Taking the two documents together, details were given for a total of 62 full scale tests plus a further 31 separate indicative, i.e. unloaded, specimens.

Since the publication of the second compendium a further 40 full scale fire resistance tests have been carried out. The range of systems / component configurations which have been investigated in these tests has been much wider than in the preceding years and has included, for example, tests on:-

- 8 flange plated slim floor beams, (of which 7 were loaded and one was a full length indicative).
- 4 shelf angle floor beams, (of various types).
- 5 composite metal deck floors, (of various types).
- 6 pairs of beam / beam and beam / column connection assemblies.
- 4 composite columns with concrete infill between the flanges.
- 1 column with block-work infill between the flanges.

Plus, amongst others, three tests on concrete filled circular hollow section columns, two lattice girders formed from square hollow sections, an arched metal deck floor and two fully protected beams. Brief details of all these tests can be found in a recent Technical Note[5]. Tests have also been carried out on a number of indicative specimens. These were usually small assemblies which were included in the furnace alongside a full length member, though in some cases they were themselves full scale assemblies.

Much of the data generated from the individual test programmes have already been used extensively by British Steel staff and co-workers in other organisations. In particular, they have been used by the Steel Construction Institute[6],[7],[8], for the preparation of Design Guides and other documents covering various forms of construction. There is, however, a need to document the test configurations and data in more detail than is usually given in such publications. Having regard to the variety and complexity of the systems examined during the last few years it has been deemed impractical to attempt to present the data for all of them in one document at the present time. It has therefore been decided that a series of reports should be prepared, each one dealing with either a different form of construction or generic group of test assemblies, and that these will eventually be combined to form a third compendium. The first report in the series was issued in September 1993[9] and included material relating to the eight flange plated slim floor beams.

This is the second report issued as part of that series. It contains detailed descriptions of the design, instrumentation and construction for each of five web encased column assemblies, together with the data arising from them which are included in Appendix 1. The data are presented in a format which is generally consistent with that introduced in the previous compendia. No analyses of the data are included since these have already been incorporated into other publications dealing with design aspects of this form of construction. The numerical sequence of the data sheets has been maintained, those in this document being numbered from 107 to 111 inclusive. As in the previous compendia, the thermal data are reduced to summary values at various times throughout the duration of each test. It should be noted, however, that all the thermal data, usually recorded at one minute intervals, can be made available on PC disks. These may be obtained, on request, from British Steel Technical, Swinden Laboratories.

As before, the fire tests reported here form part of an ongoing research programme concerned with the evaluation and prediction of the performance of constructional steelwork in fire. Readers are therefore reminded to exercise caution when using any single test result and not to take it out of context with data for other tests of a similar nature.

2. CHANGES TO STANDARDS

The following changes to British Standards have occurred since the publication of the previous compendia.

2.1 BS4360:1986 'Weldable Structural Steels'

This standard was withdrawn with effect from March 30th 1990. The parts of BS4360 pertaining to hot rolled sections and plates were replaced from that date by EN 10025 'Hot Rolled Products of Non-Alloy Structural Steels - Technical Delivery Conditions'. BS EN 10025:1990 is the English Language version of that standard. The specification requirements for those products and grades not within the scope of EN 10025 were simultaneously re-published unchanged as BS4360:1990.

As far as the present work is concerned it should be noted that two of the tests were carried out after March 30th 1990. Steel quality BS4360:Grade 43A should therefore be referred to as BS EN 10025:1990 Grade Fe430A. However, this grade only appears in the UK edition of the standard under the heading 'Non Conflicting National Standards'. Similarly, steel quality BS4360:Grade 50B should be referred to as BS EN 10025:1990:Grade Fe510B.

The requirements of the two specifications were compared in the previous report(9). A detailed comparison of the two standards is given in Ref. 10.

2.2 BS476:Parts 20/21:1987

No changes were made to the standard during the period covered by this report. However, discussions are ongoing concerning certain aspects of the standard fire test procedures.

2.3 BS449:Part 2:1969 and BS5950:Part 1:1985

BS449:Part 2 was significantly amended in December 1989, (AMD 6255), in order to reflect the revised increased yield strength of Grade 43 steels included in BS4360. These, and earlier amendments, were incorporated into the standard which was re-issued during 1990. As far as the present work is concerned the major difference between the 1990 edition and its predecessor is to be found in the higher values for the 'Allowable stress on gross section for axial compression' given in Table 17a, (Grade 43A steel). For the sake of consistency in the calculation procedures the earlier version of the standard, which was current at the commencement of the test programme, was used throughout. It is these calculations which are summarised in Appendix 2. It should be noted that this standard has now been declared 'obsolescent' but has not yet been withdrawn.

Those parts of the loading calculations which involved reference to BS5950:Part 1 used the data given in the 1985 version of the standard. During the currency of the work described here that standard was withdrawn and replaced by BS5950:Part 1:1990. However, as far as the present work is concerned it makes no difference to the calculated values since the compressive strength data given in Table 27c of both standards are the same.

3. FIRE TESTS ON WEB ENCASED COLUMNS

In this section details are given for tests performed on five loaded column assemblies. All the tests were carried out in accordance with the requirements of BS476:Parts 20/21:1987 at the Loss Prevention

Council, (Borehamwood), between November 1989 and January 1991. The major features of the tests are summarised in Table 1.

Details describing fire resistance tests on loaded column assemblies were given in the first two compendia(1),(2) and it is not, therefore, proposed to cover these items again in the present report.

The design and preparation of the five assemblies are described individually in the following sections. A number of features are, however, common to all of them and these are described here.

3.1 Features Common to all the Test Assemblies

3.1.1 Steel Quality

Unless specifically indicated to the contrary, all the steel members used in the construction of the test assemblies were manufactured by British Steel and were supplied to the requirements of the following specifications:-

(a) - in the case of the three tests carried out during 1989, BS4360:1986 Grade 43A.

(b) - in the case of the two tests carried out during 1990 and 1991, BS EN 10025:1990 Grades Fe430A or Fe510B.

Details of their chemical compositions and mechanical properties are included in the appropriate Data Sheets in Appendix 1.

3.1.2 Dimensions and Section Properties

The nominal dimensions and section properties, as specified in BS4:Part 1:1980, for the steel members used in the construction of the test assemblies are included in the Data Sheets. The actual dimensions of the members are also given, together with calculated section properties.

3.1.3 Structural Calculations

In Compendium No. 1 the load resistance calculations were based upon the design rules given in BS449. Compendium No. 2 was published following the introduction of the new limit state design philosophy and the calculated loads were also presented in terms of BS5950. However, because it is impossible to know how a member will be used in practice, the factored loads cannot be defined and therefore the loads calculated using BS449 were presented as a proportion of the members capacity. This is referred to as the load ratio and is given by:

$$\text{Load Ratio} = M_f / M_c$$

where: M_f = the applied moment at the fire limit state
and: M_c = the moment capacity at 20°C

In calculating M_c, the design strength, p_y, corresponding to the minimum guaranteed yield strength for the grade of steel is normally used. However, for the purpose of evaluating the effect of load ratio on, for example, the limiting temperature, the influence of variations in the strength of the as-received material can be diminished by adopting the measured yield strength for p_y. These have been determined from samples removed from the members under test.

The loads to be applied to the various assemblies were calculated on the basis of the nominal dimensions and section properties for the steel members concerned. These initial calculations were subsequently repeated to take account of the actual dimensions and mechanical properties of the sections used in the construction. It should be noted that in the case of the blockwork filled column, (Test No. TE 7436), no mechanical properties data for the section have so far been traced. Loading calculations for each of the five assemblies are presented in Appendix 2.

The columns were subjected to loads of 0.35 to 0.55 times the 'cold' capacity of the steel section. In the case of the four concrete filled sections varying numbers of shot fired shear connectors were used in order to develop 'composite' action during the fire. In two of the tests this behaviour was further enhanced by welding web stiffeners at the top end of the columns.

3.1.4 Fabrication

All the test assemblies were formed from 3400 mm long universal column sections. 'Standard' LPC bearing plates, (406 mm square × 19 mm thick), were welded to both ends of the section using four cleats formed from 90 × 90 × 12 mm rolled steel angle. These were placed on either side of the web and on the outer flange faces. Attachment of the plates to the section was effected only via the angle cleats, i.e. there was no direct connection between the column and the plates. Welding was by the MMA process using 4 mm diameter basic coated, hydrogen controlled, general purpose welding rods. The welds were intermittent 8 mm fillets. The only other fabrication work required was the placing of the web stiffeners in the final two assemblies. This item is covered in the test descriptions, (see Section 3.2).

3.1.5 Instrumentation

3.1.5.1 Temperature Measurement

The test assemblies were instrumented such that the temperatures attained by the steel section could be recorded throughout the duration of the heating period. For this purpose 3 mm diameter mineral insulated 'K' type thermocouples, (Ni-Cr / Ni-Al), with insulated hot junctions and Inconel 600 sheaths were used. These thermocouples were embedded to the mid-thickness position of the relevant steel section. Temperatures were also monitored in other parts of the assemblies, such as, for example, the concrete infill. The thermocouples used for these situations were again 'K' type but were usually formed from glass fibre covered Ni-Cr / Ni-Al conductors.

3.1.5.2 Column Extension

The longitudinal extension of the column was monitored throughout each test, (by LPC personnel), using a linear displacement transducer situated below the centre of the crosshead transmitting the load from the hydraulic jacks to the column. The data are included in the appropriate Data Sheets in Appendix 1.

3.1.6 Assembly / Loading

Each complete test assembly was positioned vertically between the upper and lower column furnace crossheads, to which they were attached by bolting through the holes in the welded on end plates. Both ends of the column were protected by the application of a mineral fibre blanket so that the length of column actually exposed to the heating conditions of the test was 3100 mm.

The load was applied to the column by means of two hydraulic jacks acting through the lower crosshead member. It was applied at least 15 minutes prior to the commencement of the heating period, and was kept constant throughout the test by allowing the column to expand against the applied load.

3.1.7 Failure Criteria

The performance of all five test assemblies was judged against the load bearing capacity criterion outlined in Section 6 of BS476:Part 21:1987 and in accordance with the general principles embodied in BS476:Part 20:1987.

The standards state that a column is regarded as having a fire resistance rating, (expressed in minutes), that is equal to the elapsed time, (in completed minutes), between the commencement of heating and the termination of heating or until failure to meet the load bearing capacity criterion occurs, whichever is the sooner.

3.1.8 Additional Data

In some cases heating of the test assembly continued beyond the time at which 'failure' was deemed to have occurred and the load was removed from the column. This was done to enable further data to be recorded concerning the heating rates of the various members of the assembly.

3.2 Loaded Test Assemblies

The following sections describe in greater detail aspects concerning the construction, instrumentation and loading of the five test assemblies.

3.2.1 Test No. TE 7436

The test assembly consisted of a universal column section of serial size 305 × 305 mm × 240 kg/m which was partially protected by block-work cemented into the flange / web cavities. The column was BS4360:Grade 43A material. The protection comprised 28 'Celcon' aerated, autoclaved concrete blocks, each nominally 260 mm long × 210 mm deep × 135 mm thick, which were cemented into the section cavities, (14 each side), and finished flush with, or slightly proud of, the flange tips. A nominal 10 mm thick mortar joint was maintained between adjacent blocks and the block / steel interfaces. The arrangement is shown schematically in Fig. 1. The blocks were positioned so as to leave a 300 mm long portion of the web exposed at the top end of the column. The lower half of this was protected throughout the duration of the test by an infill of insulating ceramic fibre blanket material. The ends of the column were additionally protected with mineral fibre blanket, (see Section 3.1.6).

The following properties were quoted by the manufacturer for the 'Celcon' blocks.

-	Typical stabilised water content		3%
-	Density (at 3% moisture level)		680 kg/m^3
-	Density (fully dried)		650 kg/m^3
-	Compressive Strength		4.0 N/mm^2
-	Coefficient of expansion		8 × 10^{-6} mm/°C
-	Nominal dimensions,	length	440 mm
		depth	210 mm
		thickness	150 mm

A total of 18 thermocouples were used to monitor the temperature of the steel section throughout the 60 minute heating period of the test. The thermocouple positions were as shown in Fig. 2.

A load of 4370 kN was applied to the column. This was calculated to be the maximum permissible load, assuming nominal dimensions and properties for the steel section, when calculated in accordance with BS449:Part 2:1969. Loading calculations are given in Appendix 2.1. It should be noted that no mechanical properties data are available for the steel section and so it has not been possible to carry out a proper retrospective calculation using a measured value for the design strength, p_y. However, the calculations in Appendix 2.1 indicate that the load ratio, as defined by BS5950:Part 1:1985 was at least 0.599.

Data for this test are summarised in Data Sheet No. 107.

3.2.2 Test No. TE 7381

The test assembly consisted of a universal column section of serial size 254 × 254 mm × 73 kg/m which was partially protected by a concrete infill in the flange / web cavities. The column was BS4360:Grade 43A material. Hilti HVB110 shear connectors were attached to both faces of the web using ENP3-21L15 shot fired pins. The fixing locations for each connector were offset from the vertical centre line of the web by an amount equal to half the connector width. This resulted in one shear connector on each face of the web set at the same vertical height, but with a horizontal fixing displacement relative to one another equal to the connector width. The location of the connectors was as shown in Fig. 3 and comprised ten connectors secured to each face of the web with a vertical separation of 300 mm between them. The concrete, which was nominally Grade 30, comprised ballast and cement in a ratio of approximately 4:1. The ballast contained aggregate with a maximum nominal size of 20 mm. The concrete was finished flush with the flange tips and stopped approximately 270 mm from the top of the column. Samples of the concrete were taken at the time of filling the flange / web cavities for subsequent moisture, density and strength determinations. The following values were recorded at the time of the test:-

-	Density	2360 kg/m^3
-	Mean weight loss after drying at 105°C	4.96%
-	Density (dried at 105°C)	2243 kg/m^3
-	Compressive strength	62.5 N/mm^2

A total of 23 thermocouples were used to monitor the temperature of the steel section throughout the 60 minute heating period of the test. The thermocouple positions were as shown in Fig. 4. A further 22 thermocouples were used to monitor the temperatures within the concrete and on the 6th shear connector from the base. The positions were as shown in Fig. 5.

A load of 1132 kN was applied to the column. Based on nominal dimensions and properties for the steel section it was calculated that this represented approximately 87% of the maximum permissible load of 1300 kN, calculated in accordance with BS449:Part 2:1969. The reduction in load was required in order to test the assembly at a load ratio of 0.5, as defined by BS5950:Part 1:1985. A retrospective calculation using actual section properties data indicates that the load ratio was actually somewhat lower at 0.474. Loading calculations are presented in Appendix 2.2.

Data for this test are summarised in Data Sheet No. 108.

3.2.3 Test No. TE 7382

The test assembly was identical in construction to the previous one, (TE 7381), except for the number and position of the Hilti shear connectors. These were located as shown in Fig. 6 and comprised six connectors secured to each face of the web with a vertical separation of 500 mm between them. The concrete, which again was nominally Grade 30, stopped approximately 250 mm from the top of the column. The following values were recorded for the concrete at the time of the test:-

-	Density	2345 kg/m^3
-	Mean weight loss after drying at 105°C	5.0%
-	Density (dried at 105°C)	2236 kg/m^3
-	Compressive strength	62.5 N/mm^2

A total of 23 thermocouples were used to monitor the temperature of the steel section throughout the 73 minute heating period of the test. The thermocouple positions were as shown in Fig. 4. A further 22 thermocouples were used to monitor the temperatures within the concrete and on the 4th shear connector from the base. The positions were as shown in Fig. 5.

A load of 792.4 kN was applied to the column. Based on nominal dimensions and properties for the steel section it was calculated that this represented approximately 61% of the maximum permissible load of 1300 kN, calculated in accordance with BS449:Part 2:1969. The reduction in load was required in order to test the assembly at a load ratio of 0.35, as defined by BS5950:Part 1:1985. A retrospective calculation using actual section properties data indicates that the load ratio was actually somewhat lower at 0.332. Loading calculations are presented in Appendix 2.3.

Data for this test are summarised in Data Sheet No. 109.

3.2.4 Test No. TE 80470

The test assembly consisted of a universal column section of serial size 203 × 203 mm × 60 kg/m which was partially protected by a concrete infill in the flange / web cavities. The column was BS EN 10025

Grade Fe510B material. Hilti HVB80 shear connectors were attached to both faces of the web using ENP3-21L15 shot fired pins. All the connectors were positioned in the 'leg down' orientation with the exception of the uppermost one on each side of the web which was positioned 'leg up'. The fixing locations for each connector were offset from the vertical centre line of the web as described in Section 3.2.2. The location of the connectors was as shown in Fig. 7 and comprised eight connectors secured to each face of the web with a vertical separation of 423 mm between them. Web stiffeners, formed from nominally 10 mm thick Grade Fe510B plate, were welded into the flange / web cavities on each side of the web at a distance of 250 mm from the top of the section. All welds were 8 mm continuous fillets. The concrete, which was nominally Grade 30, filled the flange / web cavities up to the underside of the web stiffeners. As before it was finished flush with the flange tips. Samples of the concrete were taken at the time of filling the cavities. The following values were recorded at the time of the test:-

- Density	2223 kg/m^3
- Mean weight loss after drying at 105°C	4.75%
- Density (dried at 105°C)	2122 kg/m^3
- Compressive strength	Not given

A total of 23 thermocouples were used to monitor the temperature of the steel section throughout the 70 minute heating period of the test. The thermocouple positions were as shown in Fig. 8. A further 14 thermocouples were used to monitor the temperatures within the concrete and on the 4th, (SC1), and 5th, (SC2), shear connectors from the base, (on one side only). The positions were as shown in Fig. 9.

A load of 976 kN was applied to the column. Based on nominal dimensions and properties for the steel section it was calculated that this represented approximately 68.5% of the maximum permissible load of 1429 kN, calculated in accordance with BS449:Part 2:1969. The reduction in load was required in order to test the assembly at a load ratio of 0.45, as defined by BS5950:Part 1:1985. A retrospective calculation using actual section properties data indicates that the load ratio was actually somewhat lower at 0.420. Loading calculations are presented in Appendix 2.4.

Data for this test are summarised in Data Sheet No. 110.

3.2.5 Test No. TE 80471

The test assembly consisted of a universal column section of serial size 254 × 254 mm × 73 kg/m which was partially protected by a concrete infill in the flange / web cavities. The column was BS EN 10025 Grade Fe430A material. Hilti HVB80 shear connectors were attached to both faces of the web in the manner described for the previous test, (TE 80470). Web stiffeners, formed from nominally 10 mm thick Grade Fe430A plate, were welded into both flange / web cavities at a distance of 250 mm from the top of the section. All welds were 8 mm continuous fillets. The concrete, which again was nominally Grade 30, filled the flange / web cavities up to the underside of the web stiffeners. As before it was finished flush with the flange tips. Samples of the concrete were taken at the time of filling the cavities. The following values were recorded at the time of the test.

- Density	2240 kg/m^3
- Mean weight loss after drying at 105°C	4.36%
- Density (dried at 105°C)	2156 kg/m^3
- Compressive strength	Not given

A total of 23 thermocouples were used to monitor the temperature of the steel section throughout the 73.5 minute heating period of the test. The thermocouple positions were as shown in Fig. 8. A further 14 thermocouples were used to monitor the temperatures within the concrete and on the 4th, (SC1), and 5th, (SC2), shear connectors from the base, (on one side only). The positions were as shown in Fig. 9.

A load of 1244 kN was applied to the column. Based on nominal dimensions and properties for the steel section it was calculated that this represented approximately 95.6% of the maximum permissible load of 1300 kN, calculated in accordance with BS449:Part 2:1969. The reduction in load was required in order to test the assembly at a load ratio of 0.55, as defined by BS5950:Part 1:1985. A retrospective calculation using actual section properties data indicates that the load ratio was actually somewhat lower at 0.531. Loading calculations are presented in Appendix 2.5.

Data for this test are summarised in Data Sheet No. 111.

4. CONCLUSIONS

Data arising from five standard fire resistance tests carried out on web encased columns have been collected and reported. Details of the test assemblies are given, together with summaries of the material properties, structural calculations and the thermal data recorded.

L.N. Tomlinson
Investigator

D.E. Wainman
Investigator

D.M. Martin
Manager
Heavy Engineering & Design Department

D.J. Price
Research Manager
General Steel Products

REFERENCES

1. D.E. Wainman and B.R. Kirby: 'Compendium of UK Standard Fire Test Data - Unprotected Structural Steel (1)', Report SL/RS/RSC/S10328/1/87/B, British Steel Technical, Swinden Laboratories, 1987.

2. D.E. Wainman and B.R. Kirby: 'Compendium of UK Standard Fire Test Data - Unprotected Structural Steel (2)', Report SL/RS/R/S1199/8/88/B, British Steel Technical, Swinden Laboratories, 1988.

3. Fire Tests on Building Materials and Structures, Part 21 - Methods for Determination of the Fire Resistance of Load Bearing Elements of Construction, BS476:Part 21:1987, BSI London, 1987.

4. Fire Tests on Building Materials and Structures, Part 20 - Methods for Determination of the Fire Resistance of Elements of Construction, (General Principles), BS476:Part 20:1987, BSI London, 1987.

5. D.E. Wainman: 'Summary of All Fire Resistance Tests Carried Out by British Steel Since December 1988', Technical Note SL/HED/TN/2/-/92/A, British Steel Technical, Swinden Laboratories, 1992.

6. G.M. Newman: 'The Fire Resistance of Web Filled Columns', Steel Construction Institute, Document No. SCI/RT/254, November 1991.

7. G.M. Newman: 'The Fire Resistance of Partially Protected Structural Steelwork', Steel Construction Institute, Document No. SCI/RT/215, July 1992.

8. 'Fire Engineering Design for Steel Structures: State of the Art', Published by The International Iron and Steel Institute, Brussels 1993, ISBN No. 2-930069-00-7.

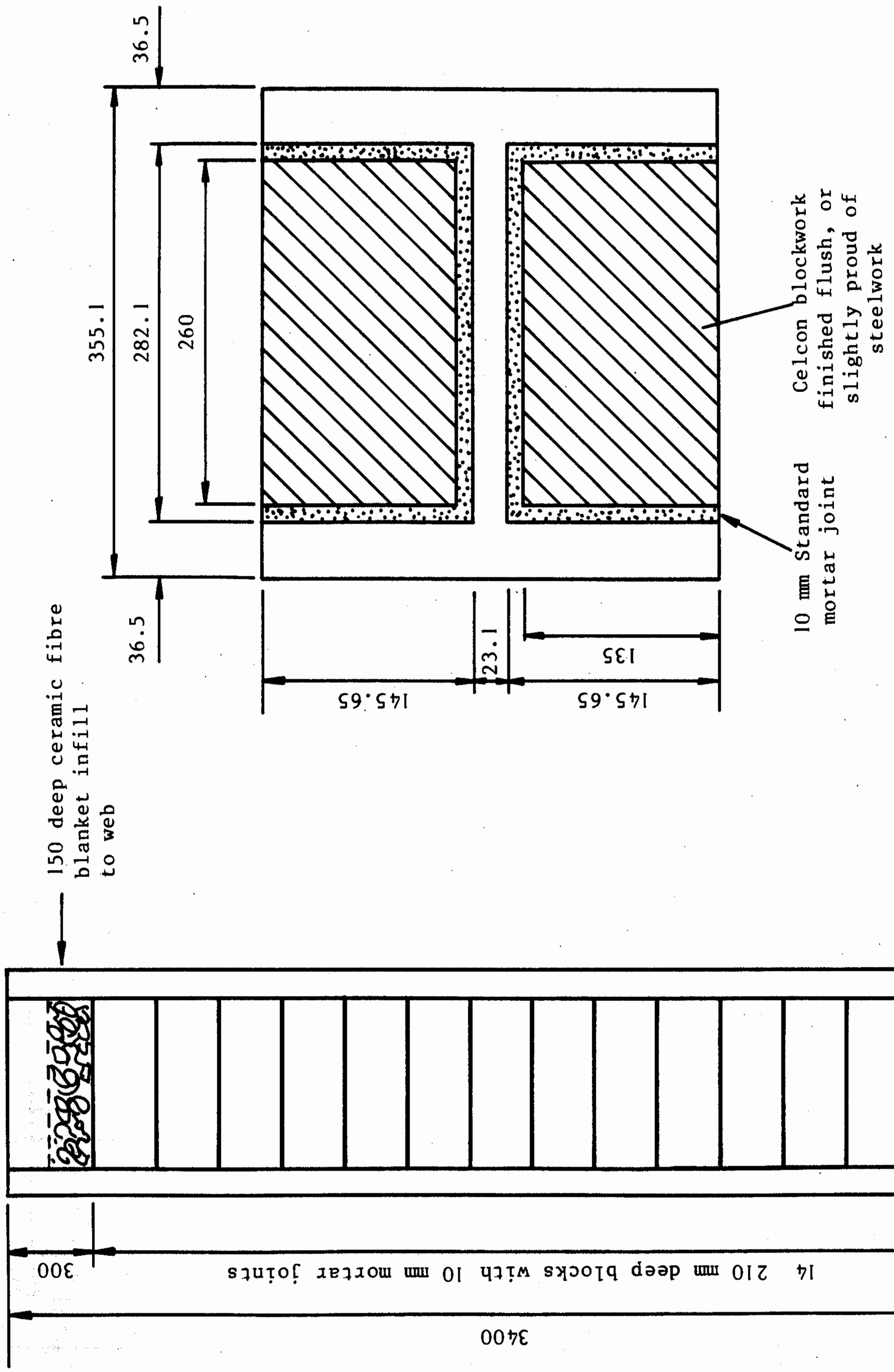
9. D.E. Wainman: 'BS476:Part 21 Fire Resistance Tests - Summary of Data Obtained During Tests on Flange Plated Slim Floor Beams', Report SL/HED/R/S2298/2/93/C, British Steel Technical, Swinden Laboratories, 1993.

10. 'BS EN 10025 v BS4360:1986, Comparisons and Comments', Technical Information Brochure Published by British Steel, General Steels, 1990.

EJF

TABLE 1
SUMMARY OF THE MAJOR FEATURES OF THE FIVE TEST COLUMNS

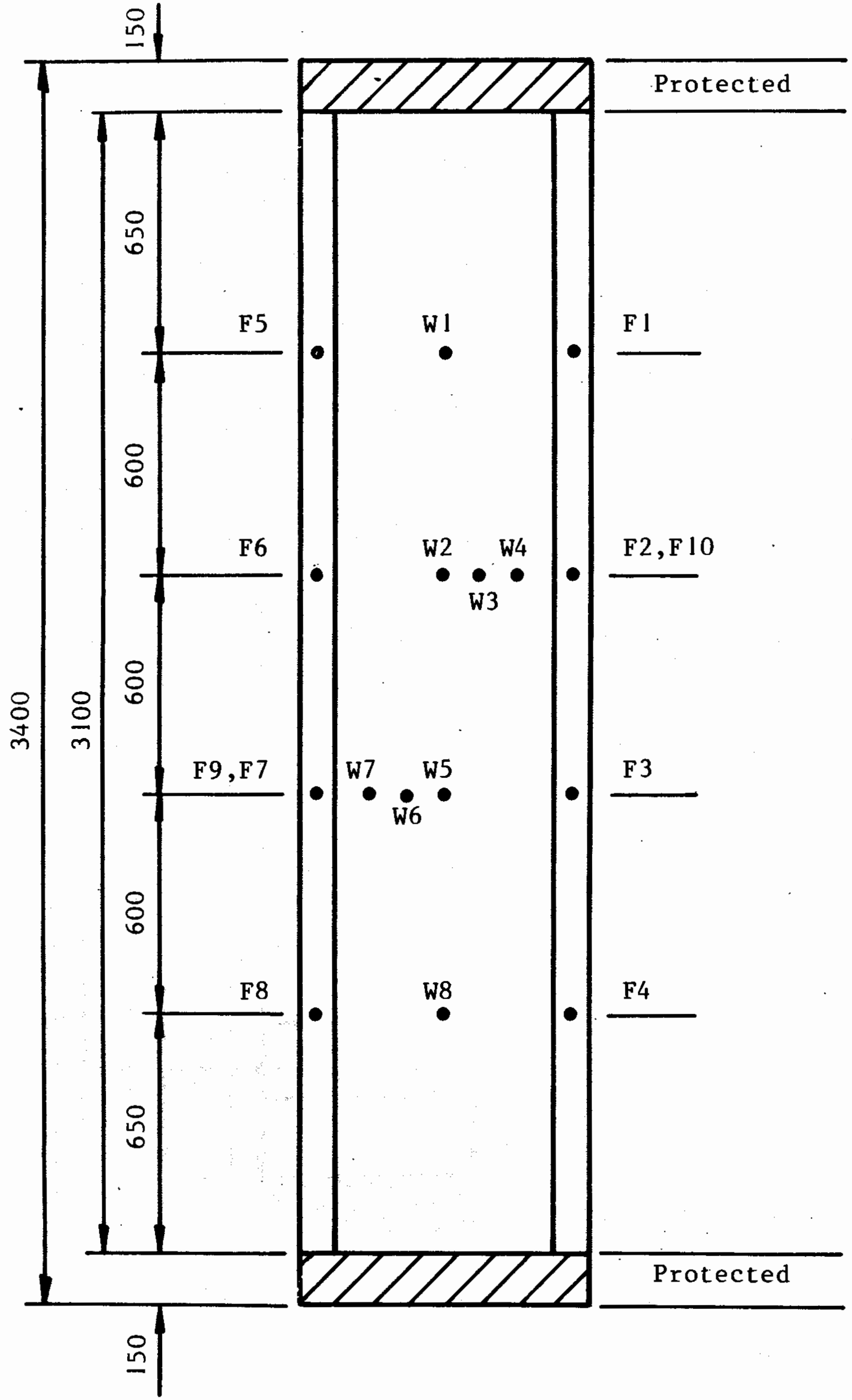
Test Date	LPC Test No.	Nominal Section Dimensions (mm × mm × kg/m)	Steel Grade	Construction Details	Load Bearing Capacity min.	Load Ratio		Comments	Data Sheet No.
						Nom.	Actual		
07.11.89	7436	305 × 305 × 240	43A	28 Standard density 'Celcon' blocks cemented into the flange/web cavities. (See Fig. 1)	48	0.579	0.599	No mechanical properties data available for the steel section. Heating continued to 60 minutes.	107
29.11.89	7381	254 × 254 × 73	43A	Grade 30 concrete infill to the flange/web cavities. (300 mm not filled at top end). 10 Hilti HVB110 shear connectors on each side of section web at 300 mm spacing. (See Fig. 3)	57	0.50	0.474	Heating continued to 60 minutes.	108
04.12.89	7382	254 × 254 × 73	43A	Grade 30 concrete infill to the flange/web cavities. (300 mm not filled at top end). 6 Hilti HVB110 shear connectors on each side of section web at 500 mm spacing. (See Fig. 6)	71	0.35	0.332	Heating continued to 73 minutes.	109
13.12.90	80470	203 × 203 × 60	Fe510B	Grade 30 concrete infill to the flange/web cavities up to the web stiffeners. 8 Hilti HVB80 shear connectors on each side of section web at 423 mm spacing. 10 mm thick web stiffeners at 250 mm from top of section. (See Fig. 7)	69	0.45	0.420	Uppermost connector on each side of web was 'leg up', all others were 'leg down'. Heating continued to 70 minutes.	110
23.01.91	80471	254 × 254 × 73	Fe430A	Grade 30 concrete infill to the flange/web cavities up to the web stiffeners. 8 Hilti HVB80 shear connectors on each side of section web at 423 mm spacing. 10 mm thick web stiffeners at 250 mm from top of section. (See Fig. 7)	72	0.55	0.531	Uppermost connector on each side of web was 'leg up', all others were 'leg down'. Heating continued to 73.5 minutes.	111



Based on Actual Section Dimensions

FIG. 1 **CONSTRUCTIONAL DETAILS FOR THE 'CELCON' BLOCKWORK USED ON TEST NO. TE 7436**
(All dimensions in mm)

(R4/2190)



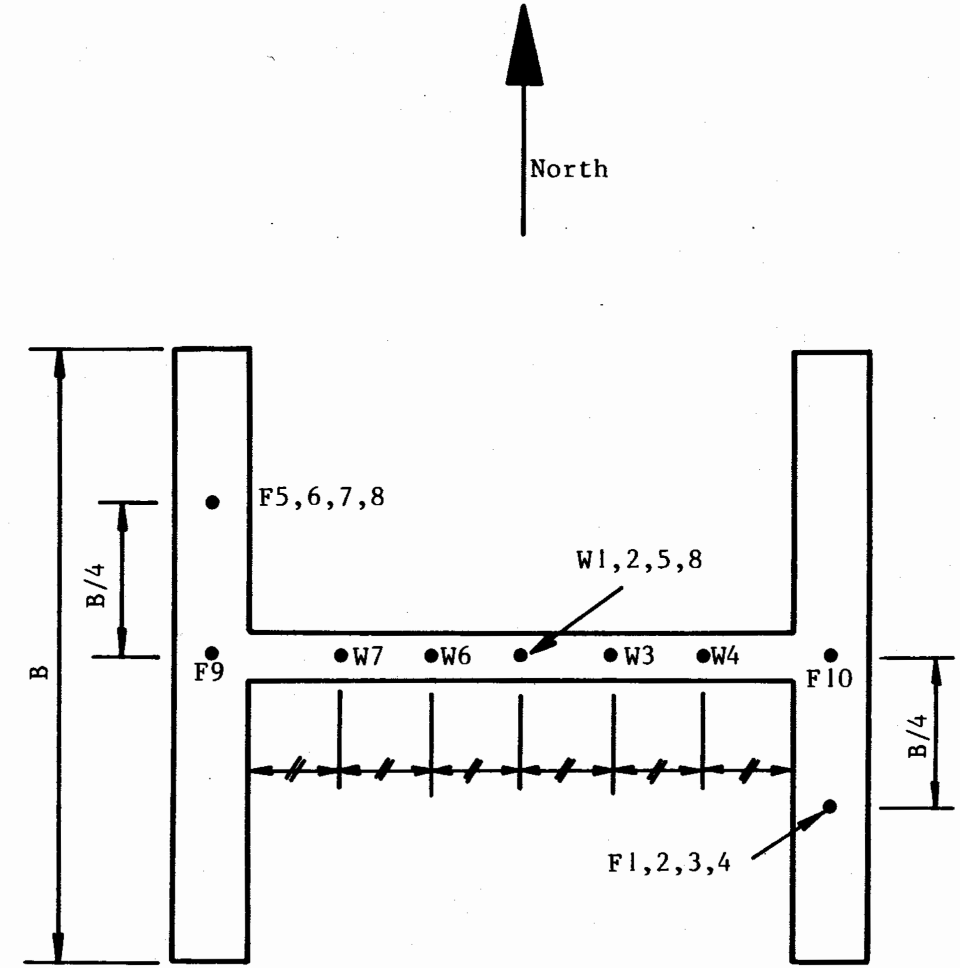


FIG. 2 **THERMOCOUPLE POSITIONS IN THE STEELWORK - TEST NO. TE 7436** (R4/2191)
(All dimensions in mm)

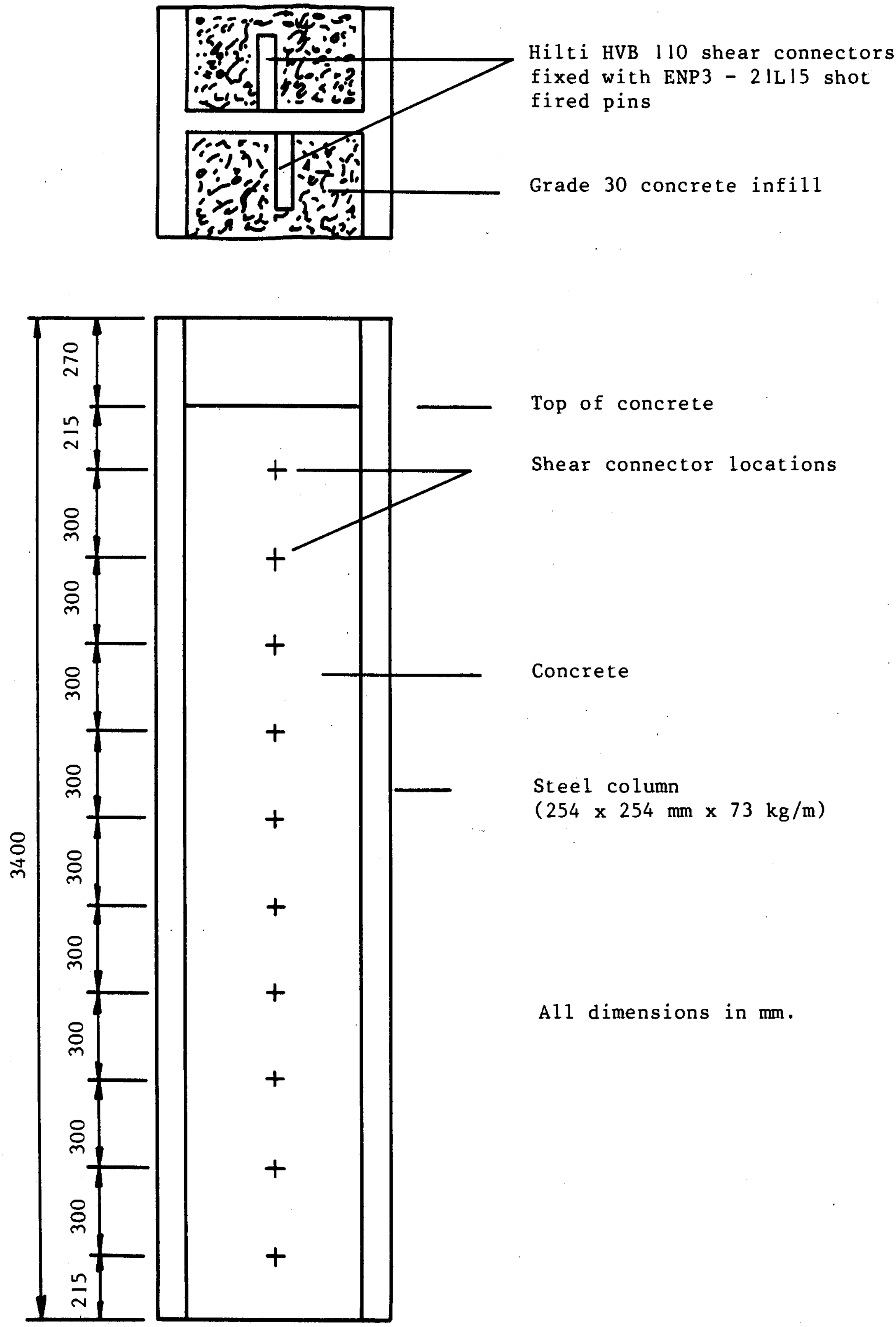


FIG. 3 DETAILS OF HILTI SHEAR CONNECTOR LOCATIONS AND CONCRETE INFILL - TEST NO. TE 7381 **(R4/2192)**

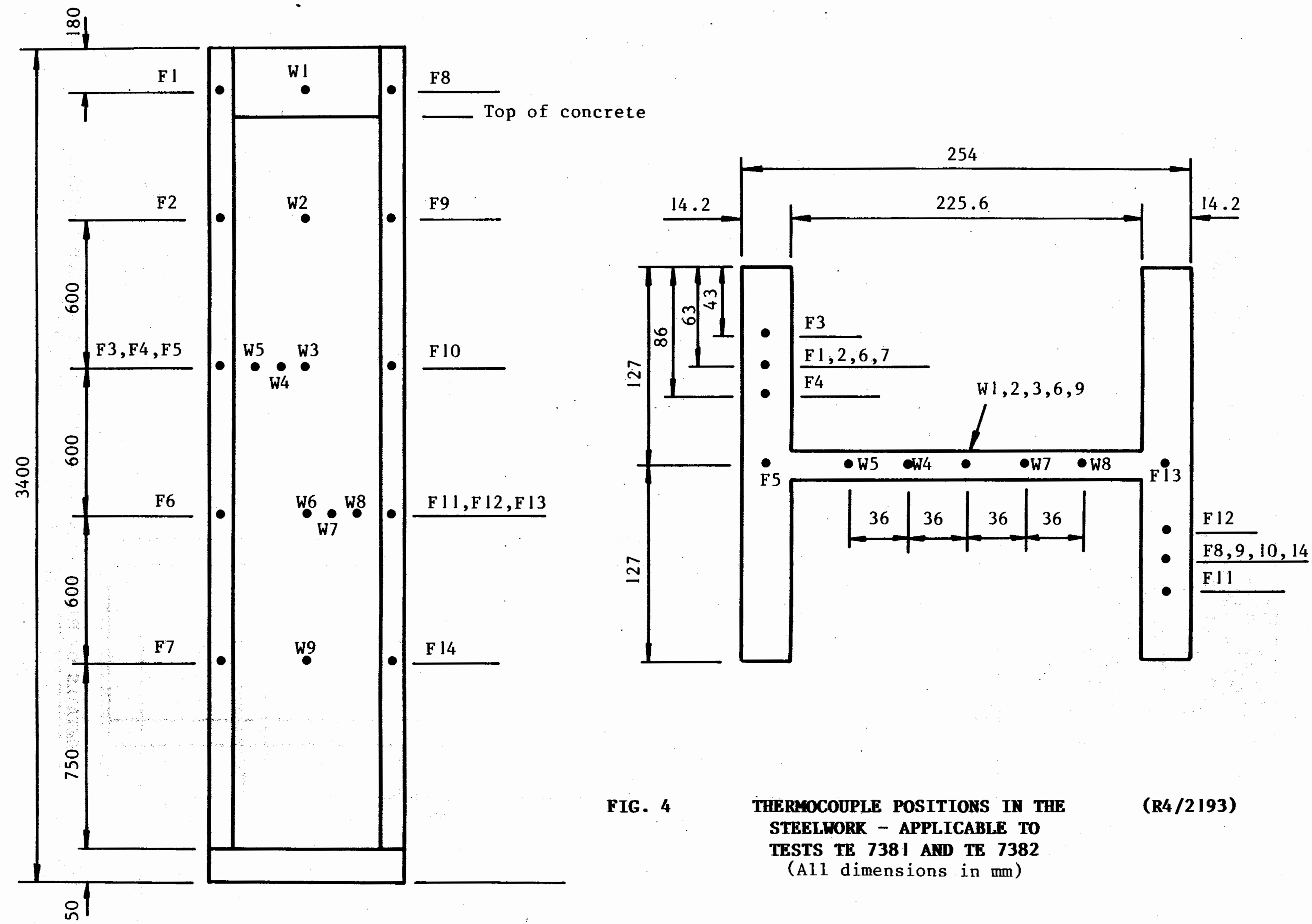
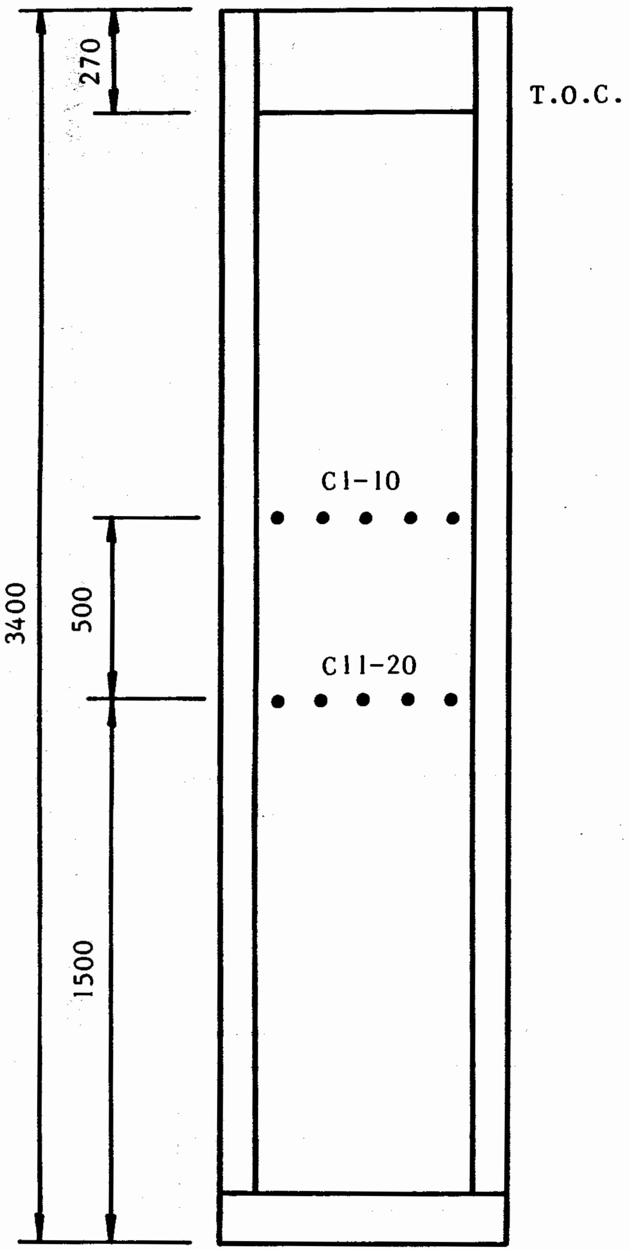


FIG. 4 THERMOCOUPLE POSITIONS IN THE STEELWORK - APPLICABLE TO TESTS TE 7381 AND TE 7382
(All dimensions in mm)

(R4/2193)



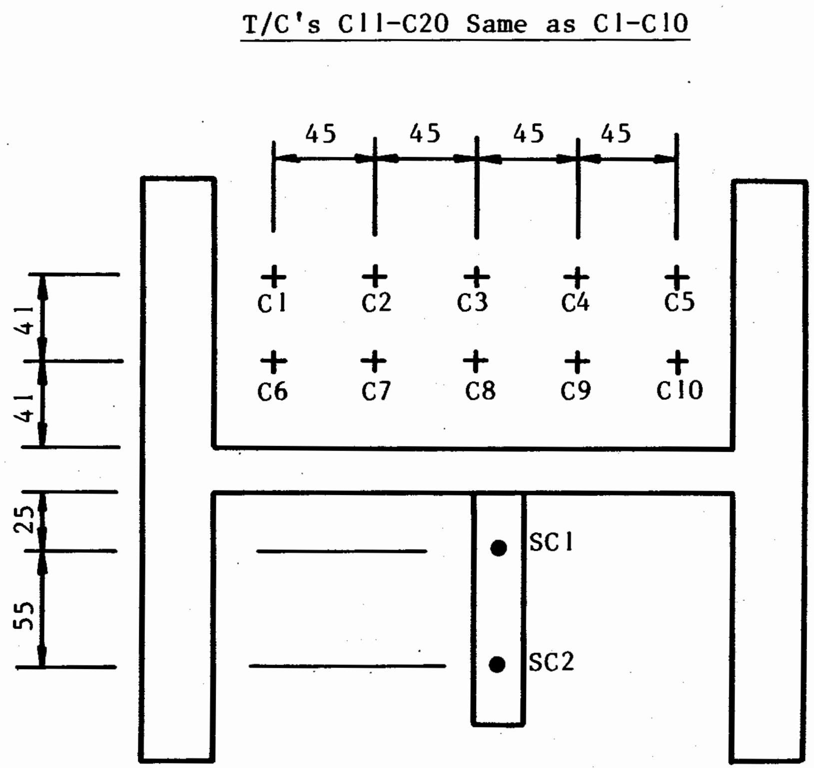


FIG. 5 **THERMOCOUPLE POSITIONS IN THE CONCRETE - APPLICABLE TO TESTS TE 7381 AND TE 7382** (R4/2194)
(All dimensions in mm)

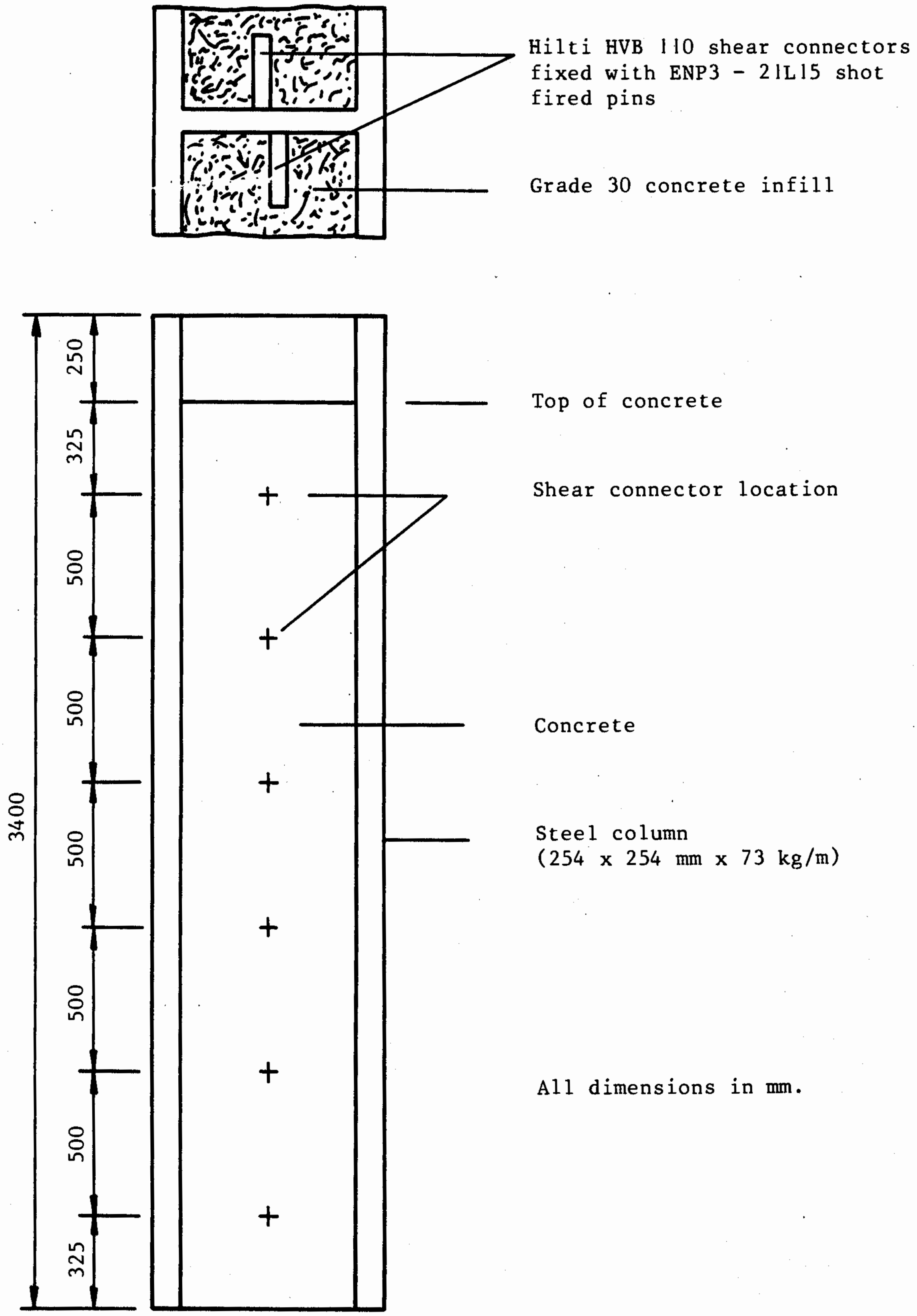


FIG. 6 DETAILS OF HILTI SHEAR CONNECTOR LOCATIONS AND CONCRETE INFILL - TEST NO. TE 7382 (R4/2195)

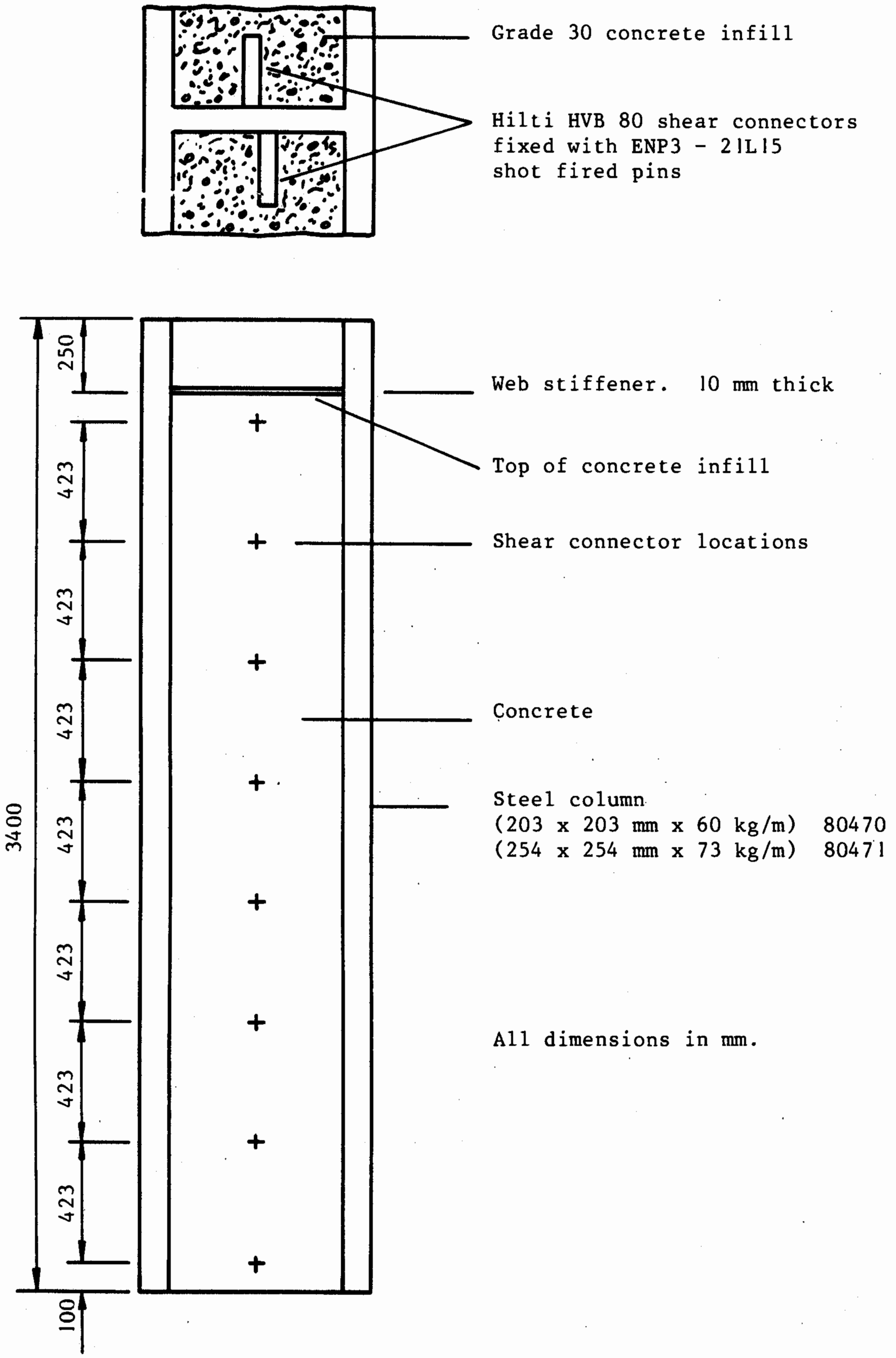
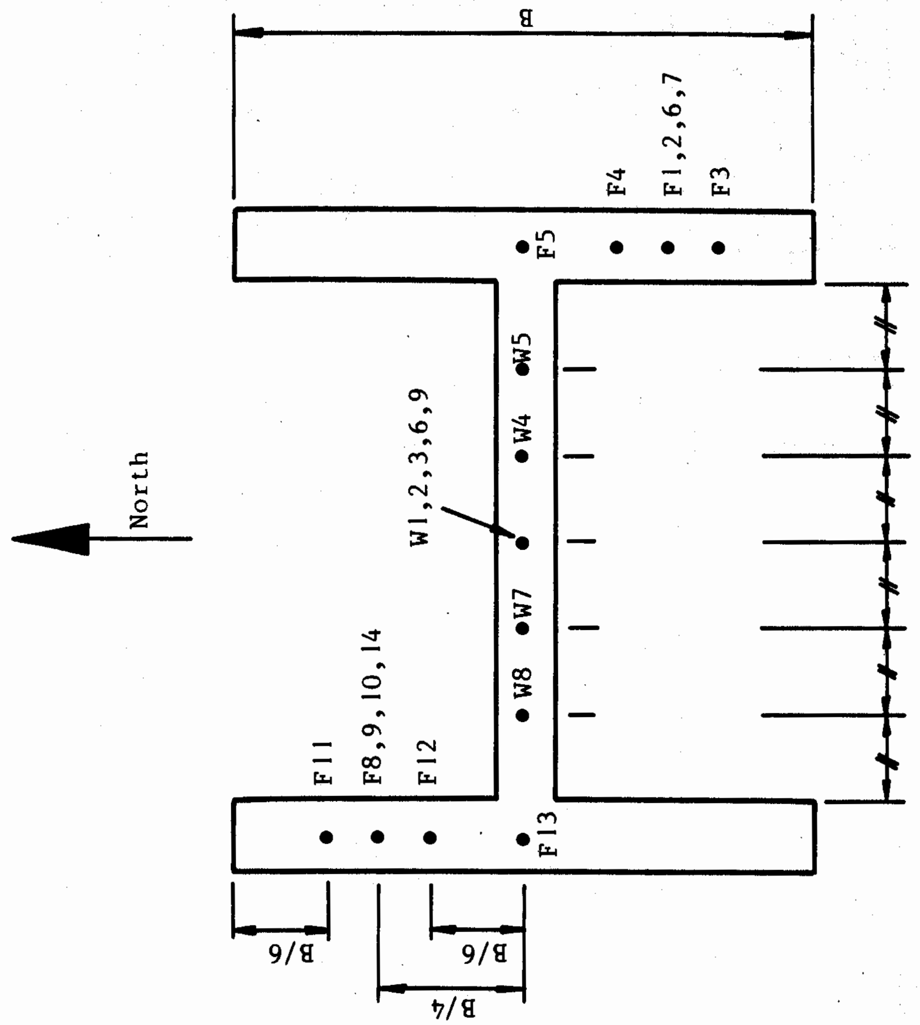


FIG. 7 **DETAILS OF HILTI SHEAR CONNECTOR LOCATIONS AND CONCRETE INFILL - APPLICABLE TO TESTS TE 80470 AND TE 80471** **(R4/2196)**



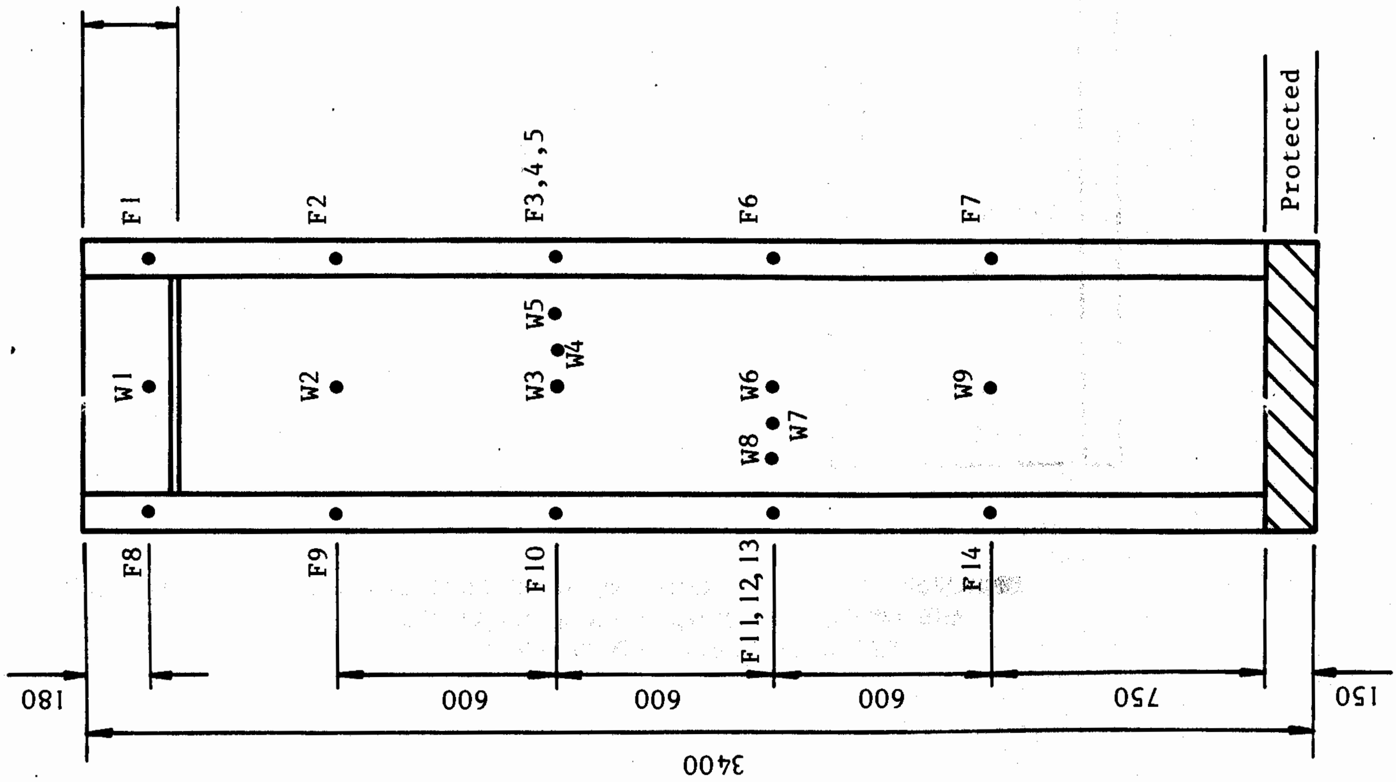
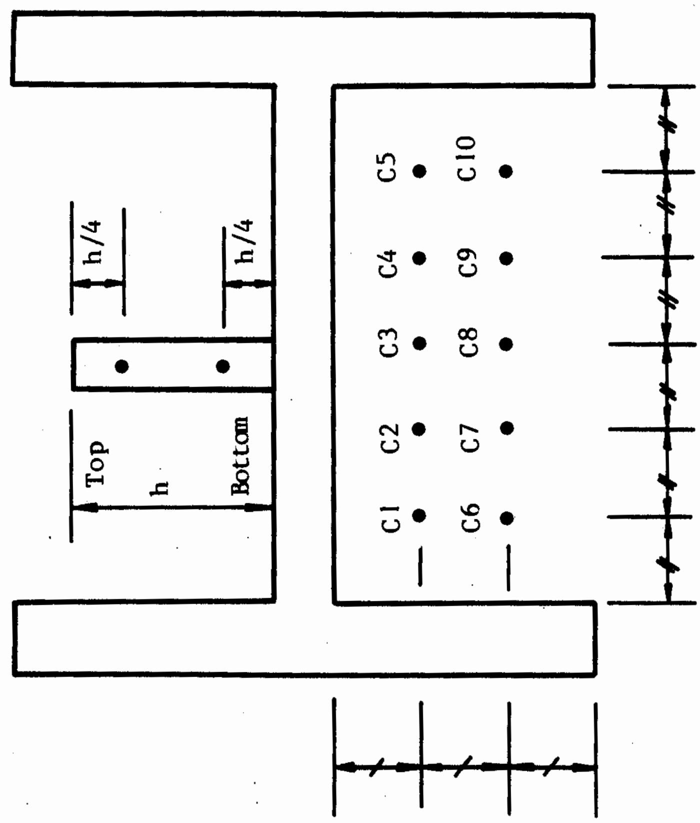


FIG. 8 **THERMOCOUPLE POSITIONS IN THE STEELWORK - APPLICABLE TO TESTS TE 80470 AND TE 80471** (All dimensions in mm) **(R4/2197)**



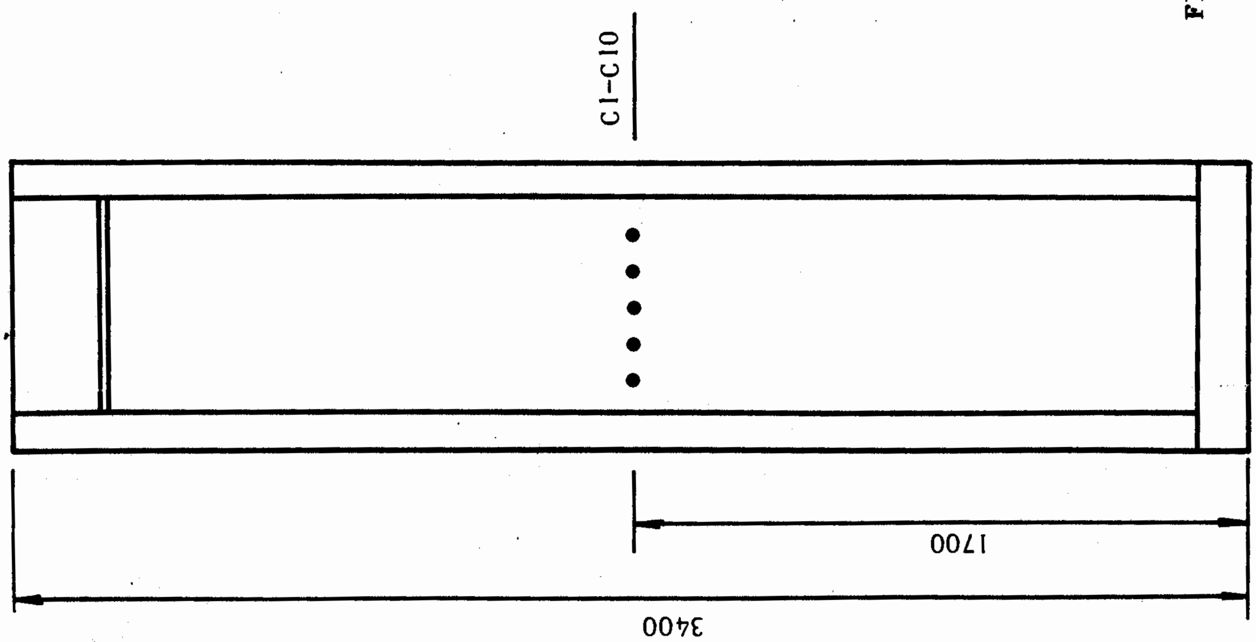


FIG. 9 THERMOCOUPLE POSITIONS IN THE CONCRETE - APPLICABLE TO TESTS TE 80470 AND TE 80471
(All dimensions in mm)

(R4/2198)

APPENDIX 1

DATA SHEET NUMBERS 107-111

DATA SHEET NUMBER **107A**

COLUMN WITH BLOCKED IN WEB

DIMENSIONS AND PROPERTIES

Section Serial Size and Type mm	Dimensions and Properties	Mass per Metre kg	Depth of Section mm	Width of Section mm	Thickness		Elastic Modulus		Plastic Modulus		Moment of Inertia	
					Web mm	Flange mm	Axis x-x cm^3	Axis y-y cm^3	Axis x-x cm^3	Axis y-y cm^3	Axis x-x cm^4	Axis y-y cm^4
305 × 305 Column	Nominal Actual	240 232.9	352.6 355.1	317.9 314.4	23.0 23.1	37.7 36.5	3639 3559	1272 1205	4243 4143	1945 1845	64151 63194	20219 18939

CHEMICAL COMPOSITION (PRODUCT ANALYSIS - Wt. %)

Section	Steel Quality	C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu	Nb	Al	N
Column	Grade 43A	0.16	0.27	1.12	0.014	0.019	<0.02	<0.005	<0.02	<0.005	0.02	<0.005	0.034	0.0051

ROOM TEMPERATURE TENSILE PROPERTIES

Position	LYS N/mm^2	TS N/mm^2	Elongation %
Flange	N/A	N/A	N/A

NOTES

(N/A) Not available.

(a) Since no LYS values were recorded.

(b) Heating continued with no applied load.

Initial Ambient Temperature = 12°C

TEST CONDITIONS

	NOMINAL	ACTUAL
Column Length, mm	3400	3400
Column Exposed Length, mm	3100	3100
Column Effective Length, mm	2380	2380
Area of Cross Section, mm^2	30543.6	29666.0
Least Radius of Gyration, mm	81.36	79.90
Slenderness Ratio	29.25	29.79
<u>BS449:Part 2:1969</u>		
Allowable Stress, N/mm^2	143	143
Maximum Permissible Load, kN	4367.7	4242.2
Load Applied, kN	4368	4370
<u>BS5950:Part 1:1985</u>		
Design Strength, N/mm^2	265	265 (a)
Compressive Strength, N/mm^2	247	246
Load Capacity, kN	7544.3	7297.8
Load Ratio	0.579	0.599

TEST CENTRE	: LPC-BOREHAMWOOD
TEST DATE	: 7th NOVEMBER 1989
TEST NUMBER	: TE 7436

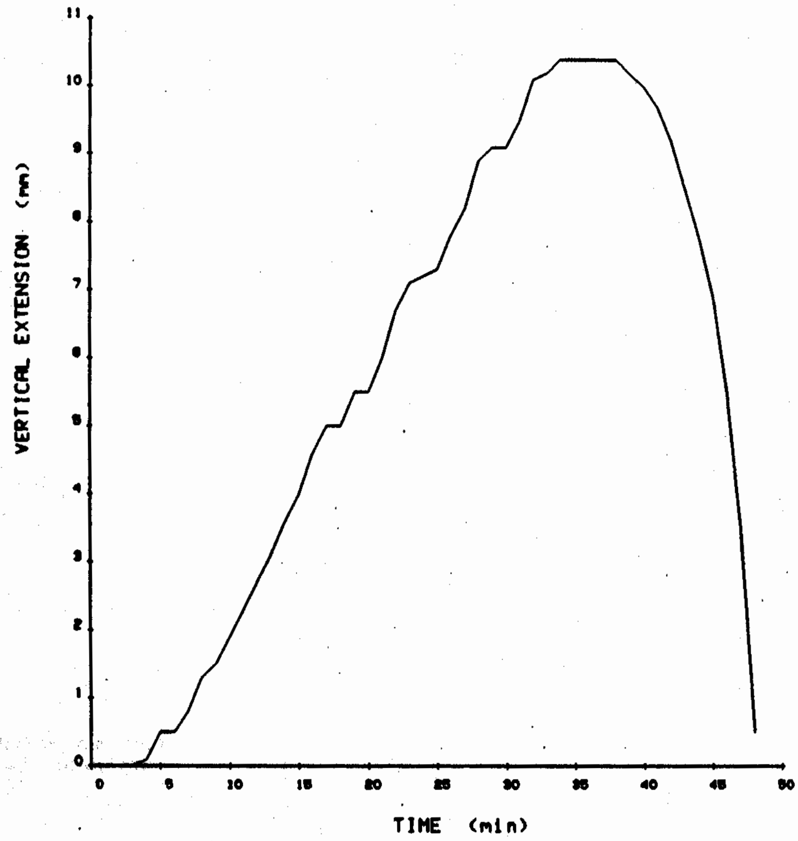
BS476 : PART 21 : 1987 ASSESSMENT	
LOAD BEARING CAPACITY	: 48 MINUTES
RELOAD TEST	: SATISFIED
FIRE RESISTANCE	: 48 MINUTES

DATA SHEET NUMBER **107B**

THERMOCOUPLE LOCATION		TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)																
		3	6	9	12	15	18	21	24	27	30	35	40	45	48	50	55	60
Exposed Flanges																		
East @ 2450 mm	F1	32	51	99	142	188	256	317	373	427	478	552	619	657	680	693	724	749
@ 1850 mm	F2	29	55	92	137	186	255	316	374	429	481	556	621	665	687	700	729	752
@ 1250 mm	F3	21	50	105	164	224	291	355	416	472	523	597	660	702	722	732	758	787
@ 650 mm	F4	20	52	97	149	197	253	304	356	406	455	526	595	648	678	695	731	753
Mean		26	52	98	148	199	264	323	380	434	484	558	624	668	692	705	736	760
West @ 2450 mm	F5	29	51	81	128	173	218	265	314	362	410	483	550	605	634	650	689	720
@ 1850 mm	F6	28	49	80	121	163	210	257	305	353	400	476	545	602	633	650	689	722
@ 1250 mm	F7	25	50	85	130	182	246	303	360	412	463	537	605	652	675	689	721	744
@ 650 mm	F8	27	56	95	138	182	229	276	324	371	416	483	554	611	639	655	690	720
Mean		27	52	85	129	175	226	275	326	375	422	495	564	618	645	661	697	727
Overall Mean		26	52	92	139	187	245	299	353	404	453	526	594	643	669	683	716	743
Flange/Web Junction																		
East @ 1850 mm	F10	24	45	73	109	150	204	253	304	354	402	475	543	590	617	631	670	702
West @ 1250 mm	F9	19	40	70	112	163	219	273	324	373	421	496	562	606	629	644	677	705
Mean		22	43	72	111	157	212	263	314	364	412	486	553	598	623	638	674	704
Unexposed Web																		
@ Mid-Depth	W1	11	12	16	22	31	45	62	84	108	133	173	211	251	276	289	323	354
	W2	8	10	12	18	27	40	57	79	104	128	170	212	252	279	293	331	365
	W5	8	9	13	20	30	46	68	92	116	143	184	223	258	285	297	335	367
	W8	10	11	16	22	35	50	68	93	116	142	180	217	254	278	291	327	360
Mean		9	11	14	21	31	45	64	87	111	137	177	216	254	280	293	329	362
@ W/6 from C/L	W3	10	12	18	26	38	54	75	100	127	153	197	240	282	308	323	362	396
	W6	9	11	15	25	38	58	84	109	135	164	207	251	291	319	333	373	404
Mean		10	12	17	26	38	56	80	105	131	159	202	246	287	314	328	368	400
@ W/3 from C/L	W4	13	18	29	43	63	89	117	149	180	212	263	314	358	386	398	434	469
	W7	13	18	30	48	71	103	133	167	201	234	287	339	385	413	428	465	497
Mean		13	18	30	46	67	96	125	158	191	223	275	327	372	400	413	450	483
Mean Furnace Gas		371	558	617	679	717	762	783	801	817	836	862	892	899	906	911	927	938
Standard Curve		502	603	663	705	739	766	789	809	826	842	865	885	902	912	918	932	945
Extension (mm)		0	0.5	1.5	2.7	4.0	5.0	6.0	7.2	8.2	9.1	10.2	10.0	6.9	0.5 (b)			

DATA SHEET NUMBER **107C**

COLUMN WITH BLOCKED IN WEB



A1/5

DATA SHEET NUMBER	108A

COLUMN WITH CONCRETE INFILL BETWEEN FLANGES

DIMENSIONS AND PROPERTIES

Section Serial Size and Type mm	Dimensions and Properties	Mass per Metre kg	Depth of Section mm	Width of Section mm	Thickness		Elastic Modulus		Plastic Modulus		Moment of Inertia	
					Web mm	Flange mm	Axis x-x cm^3	Axis y-y cm^3	Axis x-x cm^3	Axis y-y cm^3	Axis x-x cm^4	Axis y-y cm^4
254 × 254 Column	Nominal Actual	73 71.3	254.0 256.1	254.0 254.6	8.6 8.4	14.2 13.8	895.5 885.0	305.5 298.3	989.6 976.4	463.2 452.3	11373 11332	3880 3798

CHEMICAL COMPOSITION (PRODUCT ANALYSIS - Wt. %)

Section	Steel Quality	C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu	Nb	Al	N
Column	Grade 43A	0.12	0.27	1.34	0.010	0.016	<0.02	<0.005	<0.02	<0.005	N/A	N/A	<0.005	0.0066

ROOM TEMPERATURE TENSILE PROPERTIES

Position	LYS N/mm^2	TS N/mm^2	Elongation %
Flange	298	465	33.0

NOTES

(N/A) Not analysed.

(a) Equals 87.04% of the maximum permissible load according to BS449:Part 2:1969.

(b) Heating continued with no applied load.

(*) No data recorded.

Initial Ambient Temperature = 10°C

TEST CONDITIONS

	NOMINAL	ACTUAL
Column Length, mm	3400	3400
Column Exposed Length, mm	3100	3100
Column Effective Length, mm	2380	2380
Area of Cross Section, mm^2	9292.2	9084.8
Least Radius of Gyration, mm	64.62	64.66
Slenderness Ratio	36.83	36.81
BS449:Part 2:1969		
Allowable Stress, N/mm^2	140	140
Maximum Permissible Load, kN	1300.9	1271.9
Load Applied, kN	-	1132 (a)
BS5950:Part 1:1985		
Design Strength, N/mm^2	275	298
Compressive Strength, N/mm^2	243.7	262.6
Load Capacity, kN	2264.5	2385.7
Load Ratio	0.574	0.474
Load Ratio Required	-	0.50

TEST CENTRE	: LPC-BOREHAMWOOD
TEST DATE	: 29th NOVEMBER 1989
TEST NUMBER	: TE 7381

BS476 : PART 21 : 1987 ASSESSMENT

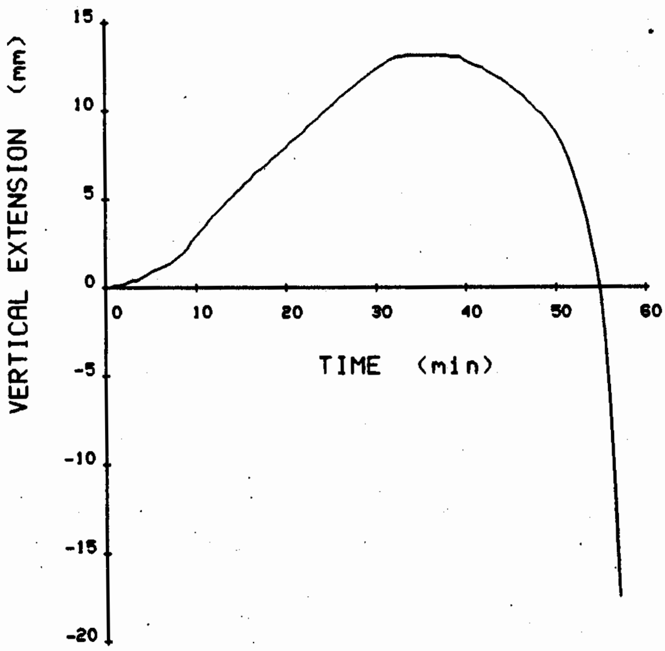
LOAD BEARING CAPACITY	: 57 MINUTES
RELOAD TEST	: SATISFIED
FIRE RESISTANCE	: 57 MINUTES

DATA SHEET NUMBER **108B**

THERMOCOUPLE LOCATION		TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)																
		3	6	9	12	15	18	21	24	27	30	35	40	45	50	55	57	60
Unexposed Flanges	F1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	F8	16	25	37	53	70	91	113	125	133	141	153	169	187	222	269	289	318
Mean		16	25	37	53	70	91	113	125	133	141	153	169	187	222	269	289	318
Exposed Flanges	F3	89	129	207	258	308	352	398	443	489	534	598	655	704	742	771	782	801
	F11	128	156	280	326	353	406	451	496	531	575	635	685	729	766	794	805	822
Mean		109	143	244	292	331	379	425	470	510	554	617	670	717	754	783	794	812
	F2	68	104	153	197	245	300	351	400	452	503	574	635	685	726	756	765	790
	F6	56	86	151	202	254	309	360	412	462	510	580	639	688	726	755	767	787
	F7	60	107	167	220	274	330	378	429	480	533	605	665	714	747	775	787	807
	F9	92	127	183	225	278	336	391	441	489	543	610	667	713	752	780	789	807
	F10	69	100	164	209	251	300	345	392	440	487	557	620	670	713	749	763	783
	F14	49	84	136	184	232	285	334	385	436	487	562	623	674	713	745	756	773
Mean		66	101	159	206	256	310	360	410	460	511	581	642	691	730	760	771	791
	F4	62	92	153	198	244	287	329	374	423	471	540	602	656	699	734	745	762
	F12	59	80	182	225	256	306	352	398	440	485	556	614	664	706	742	754	770
Mean		61	86	168	212	250	297	341	386	432	478	548	608	660	703	738	750	766
Overall Mean		73	107	178	224	270	321	369	417	464	513	582	641	690	729	760	771	790
Flange/Web Junction	F5	51	78	131	175	217	252	286	333	383	430	498	561	615	659	695	710	733
	F13	53	75	142	183	219	265	308	354	397	443	511	572	623	665	701	715	734
Mean		52	77	137	179	218	259	297	344	390	437	505	567	619	662	698	713	734
Unexposed Web	W1	14	13	14	17	20	25	33	101	102	103	101	102	102	103	103	103	104
Exposed Web	W2	13	15	20	27	37	48	85	113	120	124	164	198	226	253	281	284	318
	W3	13	15	20	28	35	45	68	117	123	126	166	196	223	249	277	294	313
	W6	13	14	19	28	36	47	77	121	127	133	174	206	234	262	290	301	316
	W9	13	14	18	26	36	51	62	117	125	130	185	216	244	271	297	308	322
Mean		13	15	19	27	36	48	73	117	124	128	172	204	232	259	286	297	317
	W4	14	17	24	36	46	60	87	119	125	136	184	217	249	280	311	330	348
	W7	13	16	23	34	45	62	97	120	128	156	197	232	262	292	321	333	349
Mean		14	17	24	35	46	61	92	120	127	146	191	225	256	286	316	332	349
	W5	17	26	42	64	94	104	109	134	177	208	259	305	348	388	427	446	468
	W8	17	24	38	59	86	107	112	136	163	209	258	303	344	381	414	427	445
Mean		17	25	40	62	90	106	111	135	170	209	259	304	346	385	421	437	457
Shear Connectors	SC1	14	14	16	21	28	38	66	114	126	131	127	142	170	191	213	241	255
	SC2	16	20	29	43	61	86	111	123	132	140	151	177	214	242	274	303	326
Mean Furnace Gas		454	558	644	687	723	757	776	797	821	843	866	888	908	919	933	939	948
Standard Curve		502	603	663	705	739	766	789	809	826	842	865	885	902	918	932	938	945
Extension (mm)		0.4	1.1	2.2	4.1	5.6	7.0	8.4	9.8	11.1	12.3	13.1	12.8	11.4	8.8	-0.4	-17.5 (b)	
Concrete	C1	18	31	51	83	108	121	*	*	*	*	*	*	*	488	542	*	*
	C2	17	24	37	57	90	108	114	131	149	169	210	276	*	*	*	*	*
	C3	15	21	31	47	88	103	111	124	130	135	158	203	245	287	343	380	414
	C4	14	20	31	48	76	97	111	122	129	141	180	223	263	312	367	396	433
	C5	16	26	42	68	107	118	122	149	180	214	265	328	392	452	516	549	592
	C11	21	36	61	104	116	127	163	205	237	266	309	367	424	477	530	547	571
	C12	17	26	41	67	102	111	122	137	155	177	209	245	289	329	374	390	410
	C13	18	29	46	73	103	112	128	148	170	194	229	267	311	352	397	410	425
	C14	18	27	43	70	98	111	120	137	157	181	217	253	291	335	383	396	415
	C15	19	32	53	91	109	124	138	164	201	241	301	359	427	480	532	543	550
	C6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	C7	*	*	*	*	*	*	*	*	*	*	*	*	*	190	236	273	320
	C8	13	13	14	17	22	32	68	90	101	121	131	133	150	172	205	239	255
	C9	14	13	14	18	24	39	93	107	117	125	128	129	141	174	207	225	260
	C10	15	19	27	41	63	92	110	123	137	147	166	210	266	313	362	393	423
	C16	17	24	37	60	84	111	124	141	158	179	229	273	318	365	412	429	454
	C17	14	14	17	22	32	94	106	117	123	127	126	128	141	167	200	215	232
	C18	14	14	16	20	28	61	99	111	120	126	127	124	131	144	164	177	200
	C19	14	14	17	23	34	93	110	120	125	128	126	130	141	162	196	216	250
	C20	16	23	36	57	87	107	117	132	146	163	200	246	292	336	378	397	422

DATA SHEET NUMBER	**108C**

COLUMN WITH CONCRETE INFILL BETWEEN FLANGES



DATA SHEET NUMBER	109A

COLUMN WITH CONCRETE INFILL BETWEEN FLANGES

DIMENSIONS AND PROPERTIES

Section Serial Size and Type mm	Dimensions and Properties	Mass per Metre kg	Depth of Section mm	Width of Section mm	Thickness		Elastic Modulus		Plastic Modulus		Moment of Inertia	
					Web mm	Flange mm	Axis x-x cm^3	Axis y-y cm^3	Axis x-x cm^3	Axis y-y cm^3	Axis x-x cm^4	Axis y-y cm^4
254 × 254 Column	Nominal Actual	73 71.3	254.0 256.1	254.0 254.6	8.6 8.4	14.2 13.8	895.5 885.0	305.5 298.3	989.6 976.4	463.2 452.3	11373 11332	3880 3798

CHEMICAL COMPOSITION (PRODUCT ANALYSIS - Wt. %)

Section	Steel Quality	C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu	Nb	Al	N
Column	Grade 43A	0.12	0.27	1.34	0.010	0.016	<0.02	<0.005	<0.02	<0.005	N/A	N/A	<0.005	0.0066

ROOM TEMPERATURE TENSILE PROPERTIES

Position	LYS N/mm^2	TS N/mm^2	Elongation %
Flange	298	465	33.0

NOTES

(N/A) Not analysed.

(a) Equals 60.93% of the maximum permissible load according to BS449:Part 2:1969.

(*) No data recorded.

Initial Ambient Temperature = 9°C

TEST CONDITIONS

	NOMINAL	ACTUAL
Column Length, mm	3400	3400
Column Exposed Length, mm	3100	3100
Column Effective Length, mm	2380	2380
Area of Cross Section, mm^2	9292.2	9084.8
Least Radius of Gyration, mm	64.62	64.66
Slenderness Ratio	36.83	36.81
BS449:Part 2:1969		
Allowable Stress, N/mm^2	140	140
Maximum Permissible Load, kN	1300.9	1271.9
Load Applied, kN	-	792.4 (a)
BS5950:Part 1:1985		
Design Strength, N/mm^2	275	298
Compressive Strength, N/mm^2	243.7	262.6
Load Capacity, kN	2264.5	2385.7
Load Ratio	0.574	0.332
Load Ratio Required	-	0.35

TEST CENTRE	: LPC-BOREHAMWOOD
TEST DATE	: 4th DECEMBER 1989
TEST NUMBER	: TE 7382

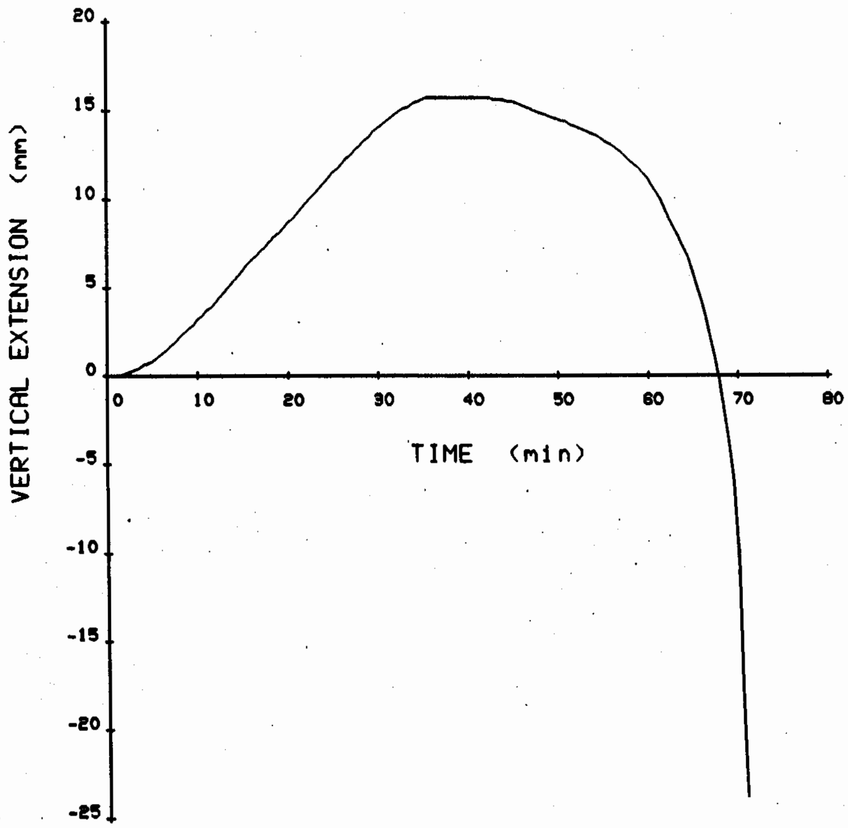
BS476 : PART 21 : 1987 ASSESSMENT	
LOAD BEARING CAPACITY	: 71 MINUTES
RELOAD TEST	: SATISFIED
FIRE RESISTANCE	: 71 MINUTES

DATA SHEET NUMBER **109B**

THERMOCOUPLE LOCATION		TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)																	
		3	6	9	12	15	18	21	24	27	30	35	40	45	50	55	60	65	71
Unexposed Flanges	F1	12	15	22	31	42	57	78	94	104	104	103	104	104	113	150	189	223	257
	F8	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Mean		12	15	22	31	42	57	78	94	104	104	103	104	104	113	150	189	223	257
Exposed Flanges	F3	54	96	146	202	254	305	354	407	457	502	575	638	691	731	762	798	831	871
	F11	63	129	193	246	299	348	402	450	501	544	614	672	721	754	782	813	841	871
Mean		59	113	170	224	277	327	378	429	479	523	595	655	706	743	772	806	836	871
	F2	50	99	158	211	263	316	377	431	481	525	594	657	708	747	778	814	843	872
	F6	75	159	234	278	328	378	438	494	543	584	648	706	751	780	811	841	871	903
	F7	62	151	216	269	316	361	409	465	511	552	616	675	720	751	777	803	831	860
	F9	70	110	174	220	272	315	373	423	468	511	582	644	694	734	764	794	824	849
	F10	80	130	187	251	294	333	380	429	473	517	582	641	690	730	761	789	821	851
	F14	48	114	202	250	310	368	421	465	518	560	619	674	725	756	787	817	846	874
Mean		64	127	195	247	297	345	400	451	499	542	607	666	715	750	780	810	839	868
	F4	62	106	155	209	258	304	352	402	449	491	563	626	676	718	750	778	810	848
	F12	72	142	204	250	299	341	391	434	483	520	587	644	692	728	760	787	816	847
Mean		67	124	180	230	279	323	372	418	466	506	575	635	684	723	755	783	813	848
Overall Mean		64	124	187	239	289	337	390	440	488	531	598	658	707	743	773	803	833	865
Flange/Web Junction	F5	54	91	135	186	228	267	313	359	401	443	513	576	627	669	704	736	760	797
	F13	58	117	186	231	276	317	363	407	452	492	558	615	663	700	732	760	783	814
Mean		56	104	161	209	252	292	338	383	427	468	536	596	645	685	718	748	772	806
Unexposed Web	W1	11	12	14	17	22	27	35	102	102	102	102	110	119	128	136	149	167	174
Exposed Web	W2	12	14	19	28	39	44	79	121	130	133	175	208	239	269	297	322	349	382
	W3	12	13	18	27	38	44	71	123	131	135	176	207	236	263	290	315	343	379
	W6	11	13	18	27	34	53	111	124	131	136	183	215	245	274	302	327	351	379
	W9	11	12	17	25	33	49	92	124	131	135	176	211	238	265	291	317	341	372
Mean		12	13	18	27	36	48	88	123	131	135	178	210	240	268	295	320	346	378
	W4	12	16	23	35	50	60	96	123	132	152	201	238	272	303	332	359	386	420
	W7	12	15	23	36	48	72	111	126	135	160	208	243	277	309	339	367	393	424
Mean		12	16	23	36	49	66	104	125	134	156	205	241	275	306	336	363	390	422
	W5	16	27	44	65	97	115	133	172	200	234	289	338	383	422	458	490	520	555
	W8	14	23	40	61	88	111	122	165	197	225	278	322	364	402	436	466	494	526
Mean		15	25	42	63	93	113	128	169	199	230	284	330	374	412	447	478	507	541
Shear Connectors	SC1	12	12	16	21	28	41	69	125	134	137	138	130	140	168	220	285	315	296
	SC2	14	20	31	45	58	50	84	124	134	141	138	145	180	221	273	317	326	520
Mean Furnace Gas		392	570	628	684	717	737	766	796	813	828	861	884	896	912	927	943	958	968
Standard Curve		502	603	663	705	739	766	789	809	826	842	865	885	902	918	932	945	957	971
Extension (mm)		0.3	1.2	2.7	4.2	6.0	7.6	9.2	10.9	12.5	14.0	15.6	15.7	15.5	14.5	13.4	11.2	5.9	-23.9
Concrete	C1	15	26	45	84	105	115	133	155	145	149	232	297	369	443	499	531	546	568
	C2	13	20	31	48	89	107	114	125	136	146	179	238	271	314	353	378	410	441
	C3	14	22	34	52	84	105	114	126	136	141	179	232	280	336	377	390	400	429
	C4	13	20	33	51	89	107	118	134	150	168	223	306	313	347	381	407	435	472
	C5	15	27	45	71	104	112	124	147	173	197	245	314	369	424	487	556	601	596
	C11	17	34	60	97	110	130	160	185	212	241	311	384	447	500	548	594	632	669
	C12	14	21	34	54	102	110	114	125	135	138	155	201	249	298	349	387	407	437
	C13	13	20	33	51	82	103	98	122	133	138	135	177	221	266	310	348	362	380
	C14	15	23	39	63	94	110	119	128	138	155	187	232	278	328	374	410	432	450
	C15	18	33	59	99	108	128	151	175	204	232	278	337	399	465	524	566	590	622
	C6	14	22	35	56	84	107	116	130	143	160	205	249	313	383	459	511	521	530
	C7	12	12	14	19	29	59	90	107	122	136	134	129	149	198	267	305	289	302
	C8	11	12	13	16	21	34	77	95	112	132	138	136	152	172	215	253	267	260
	C9	11	11	13	17	24	56	96	111	119	130	133	129	138	163	222	289	301	289
	C10	13	18	28	43	95	106	113	125	138	140	137	195	260	323	390	459	493	503
	C16	14	21	35	56	92	110	118	129	139	163	210	268	323	381	440	494	524	541
	C17	11	12	16	23	34	80	92	123	135	140	138	164	185	222	268	300	312	337
	C18	11	11	13	15	21	32	53	116	130	136	134	137	138	158	193	208	208	242
	C19	11	12	14	18	26	51	85	121	131	135	135	135	138	157	184	217	246	268
	C20	13	20	32	52	98	108	115	127	142	159	194	245	303	350	398	439	473	502

DATA SHEET NUMBER **109C**

COLUMN WITH CONCRETE INFILL BETWEEN FLANGES



DATA SHEET NUMBER	110A

COLUMN WITH CONCRETE INFILL BETWEEN FLANGES

DIMENSIONS AND PROPERTIES

Section Serial Size and Type mm	Dimensions and Properties	Mass per Metre kg	Depth of Section mm	Width of Section mm	Thickness		Elastic Modulus		Plastic Modulus		Moment of Inertia	
					Web mm	Flange mm	Axis x-x cm^3	Axis y-y cm^3	Axis x-x cm^3	Axis y-y cm^3	Axis x-x cm^4	Axis y-y cm^4
203 × 203 Column	Nominal Actual	60 60.4	209.6 211.1	205.2 206.2	9.3 9.6	14.2 14.2	582.4 591.6	199.5 201.4	653.6 664.6	303.5 306.7	6103 6245	2047 2077

CHEMICAL COMPOSITION (PRODUCT ANALYSIS - Wt. %)

Section	Steel Quality	C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu	Nb	Al	N
Column	Grade Fe510B	0.15	0.02	1.46	0.012	0.020	0.02	<0.005	0.02	0.07	<0.02	<0.005	<0.005	0.0046

ROOM TEMPERATURE TENSILE PROPERTIES

Position	LYS N/mm^2	TS N/mm^2	Elongation %
Flange	377	513	22.0

NOTES

(a) Equals 68.53% of the maximum permissible load according to BS449:Part 2:1969.

(*) No data recorded.

Initial Ambient Temperature = 10°C

TEST CONDITIONS

	NOMINAL	ACTUAL
Column Length, mm	3400	3400
Column Exposed Length, mm	3100	3100
Column Effective Length, mm	2380	2380
Area of Cross Section, mm^2	7602.2	7699.3
Least Radius of Gyration, mm	51.88	51.94
Slenderness Ratio	45.88	45.82
<u>BS449:Part 2:1969</u>		
Allowable Stress, N/mm^2	188	188
Maximum Permissible Load, kN	1429.2	1447.5
Load Applied, kN	-	976 (a)
<u>BS5950:Part 1:1985</u>		
Design Strength, N/mm^2	355	377
Compressive Strength, N/mm^2	286.3	301.9
Load Capacity, kN	2176.5	2324.4
Load Ratio	0.657	0.420
Load Ratio Required		0.45

TEST CENTRE	: LPC-BOREHAMWOOD
TEST DATE	: 13th DECEMBER 1990
TEST NUMBER	: TE 80470

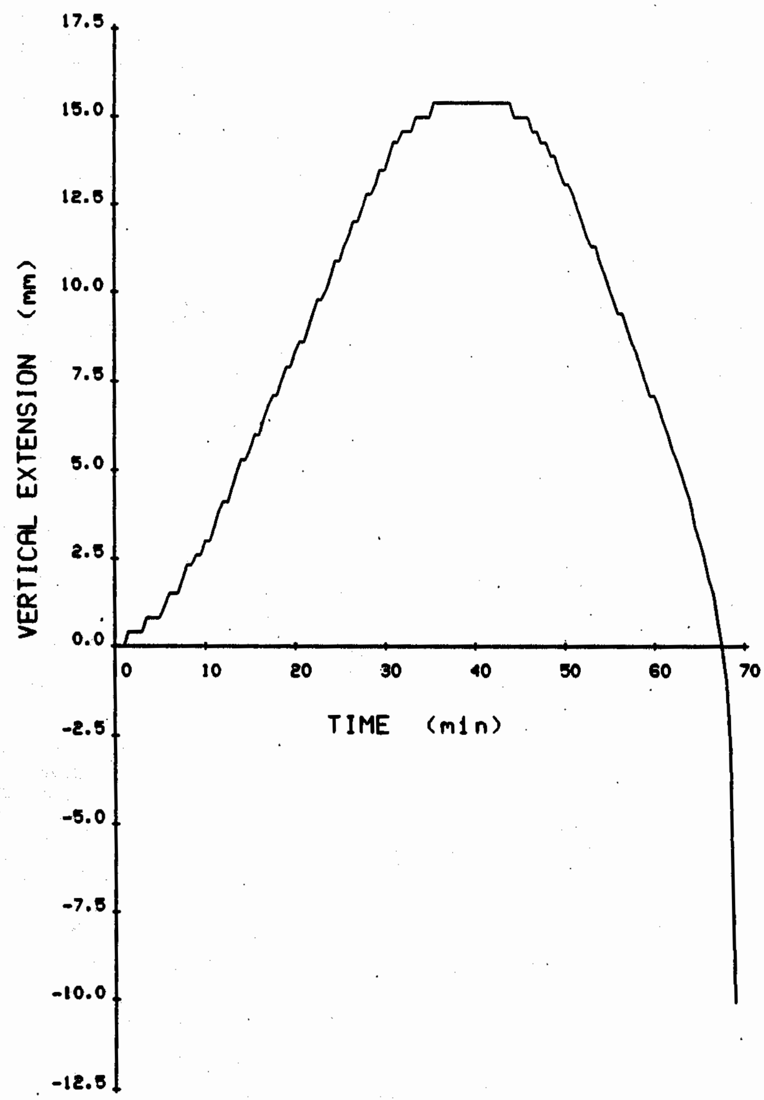
BS476 : PART 21 : 1987 ASSESSMENT	
LOAD BEARING CAPACITY	: 69 MINUTES
RELOAD TEST	: SATISFIED
FIRE RESISTANCE	: 69 MINUTES

DATA SHEET NUMBER **110B**

THERMOCOUPLE LOCATION		TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)																	
		3	6	9	12	15	18	21	24	27	30	35	40	45	50	55	60	65	69
Unexposed Flanges	F1	7	9	10	14	18	24	30	37	44	68	92	97	106	123	141	160	180	194
	F8	7	9	10	12	16	20	25	32	38	66	97	96	98	111	130	149	168	182
Mean		7	9	10	13	17	22	28	35	41	67	95	97	102	117	136	155	174	188
Exposed Flanges	F3	53	93	131	171	222	273	339	401	456	510	594	663	720	759	797	832	863	884
	F11	41	83	135	182	234	287	340	394	448	501	583	646	696	730	760	795	827	851
Mean		47	88	133	177	228	280	340	398	452	506	589	655	708	745	779	814	845	868
	F2	56	99	137	209	266	319	368	418	470	522	596	656	705	744	772	805	834	857
	F6	51	96	139	181	235	293	350	416	475	531	610	673	717	747	776	810	842	863
	F7	35	72	119	163	210	250	301	349	400	451	530	596	650	692	727	755	782	805
	F9	47	79	113	162	214	264	310	361	414	466	543	608	662	703	737	768	801	826
	F10	57	96	136	175	217	261	315	367	418	467	542	609	664	708	744	773	808	833
	F14	38	103	158	215	261	303	350	397	448	498	574	634	683	723	750	782	812	834
Mean		47	91	134	184	234	282	332	385	438	489	566	629	680	720	751	782	813	836
	F4	41	73	108	145	190	236	292	348	402	455	534	604	664	707	742	775	808	832
	F12	33	68	112	156	207	255	300	354	408	461	544	609	659	697	727	755	786	811
Mean		37	71	110	151	199	246	296	351	405	458	539	607	662	702	735	765	797	822
Overall Mean		45	86	129	176	226	274	327	381	434	486	565	630	682	721	753	785	816	840
Flange/Web Junction	F5	49	79	111	148	190	233	284	336	387	436	511	577	633	676	713	743	769	793
	F13	68	122	166	209	275	313	348	413	464	515	590	652	682	720	747	771	797	818
Mean		59	101	139	179	233	273	316	375	426	476	551	615	658	698	730	757	783	806
Unexposed Web	W1	7	7	7	7	9	11	13	16	25	87	88	86	85	84	82	95	118	135
Exposed Web	W2	9	15	25	37	54	80	110	143	150	189	240	278	313	347	380	413	445	470
	W3	8	14	22	36	48	68	107	141	148	157	222	262	297	334	371	407	444	474
	W6	8	12	23	36	54	81	113	143	149	171	205	240	275	313	351	389	426	461
	W9	7	11	23	34	53	74	98	144	150	171	228	270	308	344	379	414	446	471
Mean		8	13	23	36	52	76	107	143	149	172	224	263	298	335	370	406	440	469
	W4	9	17	28	43	58	82	127	143	152	180	243	290	329	367	404	441	477	506
	W7	8	15	29	48	71	101	127	145	154	204	258	305	347	383	418	450	481	503
Mean		9	16	29	46	65	92	127	144	153	192	251	298	338	375	411	446	479	505
	W5	14	28	46	68	98	127	144	168	206	244	314	369	416	459	499	536	568	600
	W8	14	26	49	83	111	127	141	183	223	269	334	389	438	478	515	548	576	601
Mean		14	27	48	76	105	127	143	176	215	257	324	379	427	469	507	542	572	601
Shear Connectors	SC1 Top	7	10	16	25	38	59	101	138	142	154	147	169	197	231	264	297	330	358
	SC2 Top	8	12	21	33	49	*	*	*	*	152	152	171	197	227	261	298	333	361
Mean		8	11	19	29	44	59	101	138	142	153	150	170	197	229	263	298	332	360
	SC1 Bottom	7	10	16	27	41	61	98	141	147	152	146	163	191	225	259	296	332	359
	SC2 Bottom	8	13	21	35	54	87	124	143	148	152	150	171	200	232	265	301	335	362
Mean		8	12	19	31	48	74	111	142	148	152	148	167	196	229	262	299	334	361
Overall Mean		8	11	19	30	46	67	106	140	145	153	149	169	196	229	262	298	333	360
Mean Furnace Gas		388	570	575	651	687	699	745	770	793	816	846	865	888	903	918	936	948	955
Standard Curve		502	603	663	705	739	766	789	809	826	842	865	885	902	918	932	945	957	966
Extension (mm)		0.4	1.5	2.6	4.1	5.6	7.1	8.6	10.5	12.0	13.5	15.0	15.4	15.0	13.1	10.1	7.1	3.0	-10.1
Concrete	C1	20	40	84	105	93	132	195	283	384	413	399	479	543	590	641	692	734	767
	C2	10	20	41	70	62	86	168	218	282	289	213	273	330	378	435	482	527	558
	C3	11	19	40	59	63	104	140	192	251	219	176	225	281	323	370	422	460	491
	C4	11	18	37	57	77	109	158	176	231	245	186	226	292	319	365	413	460	491
	C5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	C6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	C7	7	7	12	21	30	71	181	241	324	424	167	158	196	247	297	347	397	432
	C8	7	6	12	11	8	61	211	262	311	341	158	145	153	172	209	254	304	340
	C9	6	7	15	24	10	72	153	225	263	272	148	144	160	191	239	290	332	364
	C10	10	18	42	63	63	102	188	198	218	179	198	250	305	356	420	474	511	548

DATA SHEET NUMBER **110C**

COLUMN WITH CONCRETE INFILL BETWEEN FLANGES



DATA SHEET NUMBER	111A

COLUMN WITH CONCRETE INFILL BETWEEN FLANGES

DIMENSIONS AND PROPERTIES

Section Serial Size and Type mm	Dimensions and Properties	Mass per Metre kg	Depth of Section mm	Width of Section mm	Thickness		Elastic Modulus		Plastic Modulus		Moment of Inertia	
					Web mm	Flange mm	Axis x-x cm^3	Axis y-y cm^3	Axis x-x cm^3	Axis y-y cm^3	Axis x-x cm^4	Axis y-y cm^4
254 × 254 Column	Nominal Actual	73 71.9	254.0 256.5	254.0 254.5	8.6 8.5	14.2 13.9	895.5 892.1	305.5 300.3	989.6 984.8	463.2 455.3	11373 11441	3880 3821

CHEMICAL COMPOSITION (PRODUCT ANALYSIS - Wt. %)

Section	Steel Quality	C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu	Nb	Al	N
Column	Grade Fe430A	0.10	0.27	1.30	0.013	0.018	0.02	<0.005	0.02	<0.005	0.02	<0.005	<0.005	0.0060

ROOM TEMPERATURE TENSILE PROPERTIES

Position	LYS N/mm^2	TS N/mm^2	Elongation %
Flange	290	450	31.0

NOTES

(a) Equals 95.63% of the maximum permissible load according to BS449:Part 2:1969.

(*) No data recorded.

Initial Ambient Temperature = 14°C

TEST CONDITIONS

	NOMINAL	ACTUAL
Column Length, mm	3400	3400
Column Exposed Length, mm	3100	3100
Column Effective Length, mm	2380	2380
Area of Cross Section, mm^2	9292.2	9157.5
Least Radius of Gyration, mm	64.62	64.59
Slenderness Ratio	36.83	36.85
BS449:Part 2:1969		
Allowable Stress, N/mm^2	140	140
Maximum Permissible Load, kN	1300.9	1282.1
Load Applied, kN	-	1244 (a)
BS5950:Part 1:1985		
Design Strength, N/mm^2	275	290
Compressive Strength, N/mm^2	243.7	256.0
Load Capacity, kN	2264.5	2344.3
Load Ratio	0.574	0.531
Load Ratio Required	-	0.55

TEST CENTRE :	LPC-BOREHAMWOOD
TEST DATE :	23rd JANUARY 1991
TEST NUMBER :	TE 80471

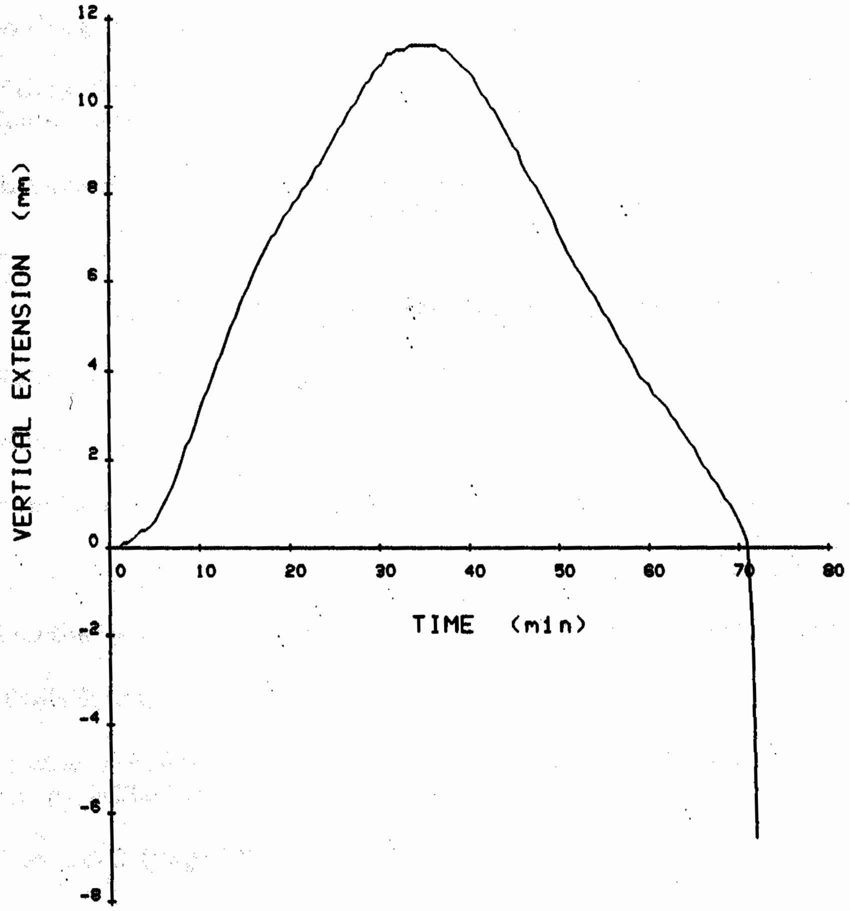
BS476 : PART 21 : 1987 ASSESSMENT	
LOAD BEARING CAPACITY	: 72 MINUTES
RELOAD TEST	: SATISFIED
FIRE RESISTANCE	: 72 MINUTES

DATA SHEET NUMBER **111B**

THERMOCOUPLE LOCATION		TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)																		
		3	6	9	12	15	18	21	24	27	30	35	40	45	50	55	60	65	70	72
Unexposed Flanges	F1	15	16	16	16	17	20	23	28	33	44	77	87	94	105	117	129	143	158	164
	F8	15	16	16	16	19	23	28	35	44	94	98	97	98	105	117	133	149	166	172
Mean		15	16	16	16	18	22	26	32	39	69	88	92	96	105	117	131	146	162	168
Exposed Flanges	F3	51	91	144	214	274	331	385	438	489	537	608	662	706	738	772	805	835	865	876
	F11	57	106	168	225	275	324	376	428	477	526	597	653	696	729	760	794	825	855	867
Mean		54	99	156	220	275	328	381	433	483	532	603	658	701	734	766	800	830	860	872
	F2	53	85	129	177	230	282	334	387	439	490	569	631	680	719	751	786	818	849	860
	F6	41	90	153	211	266	315	368	422	476	528	605	661	705	737	771	803	834	864	874
	F7	36	83	154	213	264	313	366	419	468	517	589	646	689	721	749	781	809	836	847
	F9	57	91	138	190	241	290	334	378	424	470	547	613	668	712	745	781	813	843	855
	F10	53	97	149	204	256	300	334	368	410	456	531	593	648	694	728	760	794	824	836
	F14	37	84	143	196	247	296	348	403	454	502	574	634	680	716	747	780	812	840	852
Mean		46	88	144	199	251	299	347	396	445	494	569	630	678	717	749	782	813	843	854
	F4	43	77	123	181	234	286	335	383	434	481	557	616	664	702	733	764	797	827	839
	F12	45	89	146	194	241	286	335	382	431	480	555	613	658	694	725	753	786	816	829
Mean		44	83	135	188	238	286	335	383	433	481	556	615	661	698	729	759	792	822	834
Overall Mean		47	89	145	201	253	302	352	401	450	499	573	632	679	716	748	781	812	842	854
Flange/Web Junction	F5	50	86	132	185	232	278	320	363	412	457	531	591	639	677	709	737	765	796	807
	F13	37	68	122	169	212	253	293	335	384	435	510	567	612	649	682	711	738	769	781
Mean		44	77	127	177	222	266	307	349	398	446	521	579	626	663	696	724	752	783	794
Unexposed Web	W1	17	17	18	19	20	23	25	29	35	50	92	105	106	107	107	106	109	118	125
Exposed Web	W2	15	17	22	29	41	47	60	102	130	131	128	180	206	232	254	275	296	318	327
	W3	16	16	21	30	38	58	101	129	131	133	169	211	240	265	289	311	333	355	370
	W6	15	15	19	27	40	53	82	127	132	134	174	200	227	248	266	284	308	338	361
	W9	15	15	15	20	27	38	88	113	121	125	124	128	137	150	166	184	204	231	243
Mean		15	16	19	27	37	49	83	118	129	131	149	180	203	224	244	264	285	311	325
	W4	16	16	20	27	45	74	107	123	127	130	127	137	157	190	219	248	277	307	324
	W7	15	16	20	27	45	62	92	126	130	131	139	150	199	226	248	273	302	336	426
Mean		16	16	20	27	45	68	100	125	129	131	133	144	178	208	234	261	290	322	375
	W5	17	25	39	62	103	117	127	135	143	192	238	285	331	368	400	431	459	486	502
	W8	17	25	42	70	97	115	126	134	156	210	272	316	355	389	420	449	476	500	506
Mean		17	25	41	66	100	116	127	135	150	201	255	301	343	379	410	440	468	493	504
Shear Connectors																				
SC1 Top		16	16	17	19	26	42	74	130	134	133	128	123	129	140	153	172	194	221	236
SC2 Top		16	16	17	23	36	62	110	128	132	132	127	123	129	140	153	170	192	219	232
Mean		16	16	17	21	31	52	92	129	133	133	128	123	129	140	153	171	193	220	234
SC1 Bottom		16	16	17	19	28	47	116	132	134	134	128	131	136	143	156	173	194	218	228
SC2 Bottom		16	16	17	23	40	78	127	134	135	134	128	123	127	135	148	164	183	204	210
Mean		16	16	17	21	34	63	122	133	135	134	128	127	132	139	152	169	189	211	219
Overall Mean		16	16	17	21	33	57	107	131	134	133	128	125	130	140	153	170	191	216	227
Mean Furnace Gas		409	599	670	706	722	747	773	797	816	831	854	877	891	907	922	936	951	963	969
Standard Curve		502	603	663	705	739	766	789	809	826	842	865	885	902	918	932	945	957	968	973
Extension (mm)		0.3	1.0	2.5	4.2	5.7	7.0	7.9	8.9	10.0	10.9	11.4	10.8	9.1	7.1	5.3	3.7	2.3	0.6	-6.6
Concrete	C1	17	29	48	78	108	130	133	149	184	222	284	346	392	442	494	541	581	623	641
	C2	15	23	35	56	87	106	119	128	136	147	181	227	260	304	351	383	415	454	473
	C3	16	23	37	57	84	118	127	134	136	143	177	216	245	289	324	355	388	424	450
	C4	15	22	34	54	80	107	123	132	136	149	178	216	244	277	309	345	386	426	452
	C5	17	29	50	80	105	116	125	145	172	199	254	*	*	*	*	*	*	*	*
	C6	17	25	39	66	92	109	123	131	140	158	208	257	305	355	404	454	*	*	*
	C7	15	15	17	21	30	52	74	93	109	122	145	183	*	*	*	*	*	*	*
	C8	15	15	15	17	22	32	56	77	100	118	131	132	134	147	164	187	216	250	266
	C9	15	15	15	19	26	40	62	85	112	129	130	131	133	145	165	197	238	280	298
	C10	15	20	31	49	69	82	98	116	132	136	151	195	236	281	327	377	426	472	490

DATA SHEET NUMBER **111C**

COLUMN WITH CONCRETE INFILL BETWEEN FLANGES



APPENDIX 2

LOAD CALCULATION SUMMARY SHEETS

A2.1 TEST NO. TE 7436 ON 7-NOV-1989

DATA:

Universal Column	-	305 × 305 mm × 240 kg/m
Steel Grade	-	BS4360 : Grade 43A

Column Length	L	=	3400 mm
Column Effective Length	ℓ	=	0.7 × L
		=	0.7 × 3400
		=	<u>2380 mm</u>

A2.1.1 Section Properties Based on Nominal Dimensions

Area of Cross Section	A	=	30543.6 mm^2
Least Radius of Gyration	r_{y-y}	=	81.36 mm

A2.1.2 Calculations Based on Nominal Dimensions

Slenderness Ratio	λ	=	ℓ / r_{y-y}
		=	2380 / 81.36
		=	<u>29.25</u>

From Table 17A, (Page 60), of BS449:Part 2:1969.

Allowable Stress, (p_c), for λ = 29.25 is 143 N/mm^2.

Maximum Permissible Load,	P	=	$p_c \times A$
		=	(143 × 30543.6) / 1000
		=	<u>4367.7 kN</u>

Calculate the load capacity of the section in accordance with BS5950:Part 1:1985.

From Table 6, (Page 15).

For a Grade 43A steel section with a flange thickness >16 mm but ≤40 mm the design strength, p_y, is 265 N/mm^2.

From Table 27C, (Page 63).

For a slenderness ratio of 29.25 the compressive strength, p_c, is 247 N/mm^2.

Load Capacity,	P_c	=	$A \times p_c$
		=	(30543.6 × 247) / 1000
		=	<u>7544.3 kN</u>

$$\text{Load Ratio} = \frac{\text{Applied Load at Limit State}}{\text{Load Capacity at 20°C}}$$

$$= \frac{4367.7}{7544.3}$$

$$= \underline{0.579}$$

A2.1.3 Section Properties Based on Actual Dimensions

Area of Cross Section, $A = 29666.0\ mm^2$
Least Radius of Gyration, $r_{y-y} = 79.90\ mm$

A2.1.4 Calculations Based on Actual Dimensions

Slenderness Ratio,

$$\lambda = \ell / r_{y-y} = 2380 / 79.90 = \underline{29.79}$$

From Table 17A, (Page 60), of BS449:Part 2:1969.

Allowable Stress, (p_c), for $\lambda = 29.79$ is 143 N/mm^2.

Maximum Permissible Load,

$$P = p_c \times A = (143 \times 29666.0) / 1000 = \underline{4242.2\ kN}$$

But the load actually applied was that calculated in A2.1.2, i.e. 4368 kN.

Calculate the load capacity of the section in accordance with BS5950:Part 1:1985.

Since no LYS values were recorded for the material, the design strength, p_y, has been assumed to be 265 N/mm^2, (Table 6, Page 15).

From Table 27C, (Page 63).

For a slenderness ratio of 29.79 the compressive strength, p_c, is 246 N/mm^2.

Load Capacity,

$$P_c = A \times p_c = (29666.0 \times 246) / 1000 = \underline{7297.8\ kN}$$

Load ratio, based on the actual load applied.

$$= \frac{4368}{7297.8} = \underline{0.599}$$

A2.2 TEST NO. TE 7381 ON 29-NOV-1989

DATA:

Universal Column	-	254 × 254 mm × 73 kg/m
Steel Grade	-	BS4360 : Grade 43A

Column Length $L = 3400$ mm

Column Effective Length $\ell = 0.7 \times L$
$= 0.7 \times 3400$
$= \underline{2380 \text{ mm}}$

A2.2.1 Section Properties Based on Nominal Dimensions

Area of Cross Section $A = 9292.2$ mm²

Least Radius of Gyration $r_{y\text{-}y} = 64.62$ mm

A2.2.2 Calculations Based on Nominal Dimensions

Slenderness Ratio $\lambda = \ell / r_{y\text{-}y}$
$= 2380 / 64.62$
$= \underline{36.83}$

From Table 17A, (Page 60), of BS449:Part 2:1969.

Allowable Stress, (p_c), for $\lambda = 36.83$ is 140 N/mm².

Maximum Permissible Load, $P = p_c \times A$
$= (140 \times 9292.2) / 1000$
$= \underline{1300.9 \text{ kN}}$

Calculate the load capacity of the section in accordance with BS5950:Part 1:1985.

From Table 6, (Page 15).

For a Grade 43A steel section with a flange thickness <16 mm the design strength, p_y, is 275 N/mm².

From Table 27C, (Page 63).

For a slenderness ratio of 36.83 the compressive strength, p_c, is 243.7 N/mm².

Load Capacity, $P_c = A \times p_c$
$= (9292.2 \times 243.7) / 1000$
$= \underline{2264.5 \text{ kN}}$

$$\text{Load Ratio} = \frac{\text{Applied Load at Limit State}}{\text{Load Capacity at 20°C}}$$

$$= \frac{1300.9}{2264.5}$$

$$= \underline{0.574}$$

The load ratio ratio required was 0.5.

Hence, applied load = Load capacity $\times$ load ratio
= 2264.5×0.5
= <u>1132.25 kN</u>

In terms of BS449 the applied load was equal to 87.04% of the maximum permissible load of 1300.9 kN.

A2.2.3 Section Properties Based on Actual Dimensions

Area of Cross Section, $A = 9084.8\ mm^2$
Least Radius of Gyration, $r_{y\text{-}y} = 64.66\ mm$

A2.2.4 Calculations Based on Actual Dimensions

Slenderness Ratio, $\lambda = \ell / r_{y\text{-}y}$
$= 2380 / 64.66$
$= \underline{36.81}$

From Table 17A, (Page 60), of BS449:Part 2:1969.

Allowable Stress, (p_c), for $\lambda = 36.81$ is 140 N/mm^2.

Maximum Permissible Load, $P = p_c \times A$
$= (140 \times 9084.8) / 1000$
$= \underline{1271.9\ kN}$

But the load actually applied was that given in A2.2.2, i.e. 1132 kN.

Calculate the load capacity of the section in accordance with BS5950:Part 1:1985.

The measured LYS for the material was 298 N/mm^2.

From Table 27C, (Page 63), - (2 way linear interpolation)

For a slenderness ratio of 36.81 and a design strength of 298 N/mm^2 the compressive strength, p_c, is 262.6 N/mm^2.

Load Capacity, $P_c = A \times p_c$
$= (9084.8 \times 262.6) / 1000$
$= \underline{2385.7\ kN}$

Load ratio, based on the actual load applied.

$$= \frac{1132}{2385.7}$$

$$= \underline{0.474}$$

A2.3 TEST NO. TE 7382 ON 4-DEC-1989

DATA:

Universal Column	-	254 × 254 mm × 73 kg/m
Steel Grade	-	BS4360 : Grade 43A

Column Length	L	=	3400 mm
Column Effective Length	ℓ	=	0.7 × L
		=	0.7 × 3400
		=	2380 mm

A2.3.1 Section Properties Based on Nominal Dimensions

From Appendix A2.2.

Area of Cross Section	A	=	9292.2 mm^2
Least Radius of Gyration	$r_{y\text{-}y}$	=	64.62 mm
Slenderness Ratio	λ	=	36.83
Maximum Permissible Load	P	=	1300.9 kN
Load Capacity	P_c	=	2264.5 kN
Load Ratio		=	0.574

A2.3.2 Calculations

The load ratio required was 0.35.

Hence, Applied Load	=	Load capacity × Load ratio
	=	2264.5 × 0.35
	=	792.4 kN

In terms of BS449 the applied load was equal to 60.93% of the maximum permissible load of 1300.9 kN.

A2.3.3 Section Properties Based on Actual Dimensions

Area of Cross Section,	A	=	9084.8 mm^2
Least Radius of Gyration,	$r_{y\text{-}y}$	=	64.66 mm

A2.3.4 Calculations Based on Actual Dimensions

Slenderness Ratio,	λ	=	$\ell / r_{y\text{-}y}$
		=	2380 / 64.66
		=	36.81

From Table 17A, (Page 60), of BS449:Part 2:1969.

Allowable Stress, (p_c), for $\lambda = 36.81$ is 140 N/mm^2.

Maximum Permissible Load,	P	=	$p_c \times A$
		=	(140 × 9084.8) / 1000
		=	1271.9 kN

But the load actually applied was that given in A2.3.2, i.e. 792.4 kN.

Calculate the load capacity of the section in accordance with BS5950:Part 1:1985.

The measured LYS for the material was 298 N/mm^2.

From Table 27C, (Page 63), - (2 way linear interpolation)

For a slenderness ratio of 36.81 and a design strength of 298 N/mm^2 the compressive strength, p_c, is 262.6 N/mm^2.

Load Capacity,

$$P_c = A \times p_c = (9084.8 \times 262.6) / 1000 = \underline{2385.7 \text{ kN}}$$

Load ratio, based on the actual load applied.

$$= \frac{792.4}{2385.7} = \underline{0.332}$$

A2.4 TEST NO. 80470 ON 13-DEC-1990

DATA:

Universal Column	-	203 × 203 mm × 60 kg/m
Steel Grade	-	BS EN 10025 : Grade Fe510B

Column Length	L	=	3400 mm
Column Effective Length	ℓ	=	0.7 × L
		=	0.7 × 3400
		=	2380 mm

A2.4.1 Section Properties Based on Nominal Dimensions

Area of Cross Section	A	=	7602.2 mm^2
Least Radius of Gyration	$r_{y\text{-}y}$	=	51.88 mm

A2.4.2 Calculations Based on Nominal Dimensions

Slenderness Ratio	λ	=	$\ell / r_{y\text{-}y}$
		=	2380 / 51.88
		=	45.88

From Table 17B, (Page 61), of BS449:Part 2:1969.

Allowable Stress, (p_c), for $\lambda = 45.88$ is 188 N/mm^2.

Maximum Permissible Load,	P	=	$p_c \times A$
		=	(188 × 7602.2) / 1000
		=	1429.2 kN

Calculate the load capacity of the section in accordance with BS5950:Part 1:1985.

From Table 6, (Page 15).

For a Grade Fe510B steel section with a flange thickness <16 mm the design strength, p_y, is 355 N/mm^2.

From Table 27C, (Page 63).

For a slenderness ratio of 45.88 the compressive strength, p_c, is 286.3 N/mm^2.

Load Capacity,	P_c	=	$A \times p_c$
		=	(7602.2 × 286.3) / 1000
		=	2176.5 kN

$$\text{Load Ratio} = \frac{\text{Applied Load at Limit State}}{\text{Load Capacity at 20°C}}$$

$$= \frac{1429.2}{2176.5}$$

$$= \underline{0.657}$$

The load ratio ratio required was 0.45.

Hence, applied load = Load capacity × load ratio
= 2176.5 × 0.45
= 979.4 kN

(The load actually applied was 976 kN.)

In terms of BS449 the applied load was equal to 68.53% of the maximum permissible load of 1429.2 kN.

A2.4.3 Section Properties Based on Actual Dimensions

Area of Cross Section, $A = 7699.3\ mm^2$
Least Radius of Gyration, $r_{y\text{-}y} = 51.94\ mm$

A2.4.4 Calculations Based on Actual Dimensions

Slenderness Ratio, $\lambda = \ell / r_{y\text{-}y}$
$= 2380 / 51.94$
$= \underline{45.82}$

From Table 17B, (Page 61), of BS449:Part 2:1969.

Allowable Stress, (p_c), for $\lambda = 45.82$ is $188\ N/mm^2$.

Maximum Permissible Load, $P = p_c \times A$
$= (188 \times 7699.3) / 1000$
$= \underline{1447.5\ kN}$

But the load actually applied was that given in A2.4.2, i.e. 976.0 kN.

Calculate the load capacity of the section in accordance with BS5950:Part 1:1985.

The measured LYS for the material was $377\ N/mm^2$.

From Table 27C, (Page 63), - (2 way linear interpolation)

For a slenderness ratio of 45.82 and a design strength of $377\ N/mm^2$ the compressive strength, p_c, is $301.9\ N/mm^2$.

Load Capacity, $P_c = A \times p_c$
$= (7699.3 \times 301.9) / 1000$
$= \underline{2324.4\ kN}$

Load ratio, based on the actual load applied.

$$= \frac{976.0}{2324.4}$$

$$= \underline{0.420}$$

A2.5 TEST NO. 80471 ON 23-JAN-1991

DATA:

Universal Column	-	254 × 254 mm × 73 kg/m
Steel Grade	-	BS EN 10025 : Grade Fe430A

Column Length	L	=	3400 mm
Column Effective Length	ℓ	=	0.7 × L
		=	0.7 × 3400
		=	<u>2380 mm</u>

A2.5.1 Section Properties Based on Nominal Dimensions

From Appendix A2.2.

Area of Cross Section	A	=	9292.2 mm^2
Least Radius of Gyration	$r_{y\text{-}y}$	=	64.62 mm
Slenderness Ratio	λ	=	36.83
Maximum Permissible Load	P	=	1300.9 kN
Load Capacity	P_c	=	2264.5 kN
Load Ratio		=	0.574

A2.5.2 Calculations

The load ratio ratio required was 0.55.

Hence, applied load	=	Load capacity × load ratio
	=	2264.5 × 0.55
	=	<u>1245.5 kN</u>

(The load actually applied was 1244 kN.)

In terms of BS449 the applied load was equal to 95.63% of the maximum permissible load of 1300.9 kN.

A2.5.3 Section Properties Based on Actual Dimensions

Area of Cross Section,	A	=	9157.5 mm^2
Least Radius of Gyration,	$r_{y\text{-}y}$	=	64.59 mm

A2.5.4 Calculations Based on Actual Dimensions

Slenderness Ratio,	λ	=	$\ell / r_{y\text{-}y}$
		=	2380 / 64.59
		=	<u>36.85</u>

From Table 17A, (Page 60), of BS449:Part 2:1969.

Allowable Stress, (p_c), for λ = 36.85 is 140 N/mm^2.

Maximum Permissible Load,	P	=	$p_c \times A$
		=	(140 × 9157.5) / 1000
		=	<u>1282.1 kN</u>

But the load actually applied was that given in A2.5.2, i.e. 1244 kN.

Calculate the load capacity of the section in accordance with BS5950:Part 1:1985.

The measured LYS for the material was 290 N/mm^2.

From Table 27C, (Page 63), - (2 way linear interpolation)

For a slenderness ratio of 36.85 and a design strength of 290 N/mm^2 the compressive strength, p_c, is 256.0 N/mm^2.

Load Capacity,

$$P_c = A \times p_c$$
$$= (9157.5 \times 256.0) / 1000$$
$$= \underline{2344.3 \text{ kN}}$$

Load ratio, based on the actual load applied.

$$= \frac{1244}{2344.3}$$

$$= \underline{0.531}$$

APPENDIX 3

PC DISK VERSION OF DATA

As mentioned in the Introduction to this report the data recorded during each of the five fire tests are available on PC disks. The following section gives a brief outline of the material available and its format. The reader may find it useful to additionally consult reference 1.

The data are held on the disks in the form of ASCII text files. This format has been chosen since the majority of commercial software packages can import files of this type. The format allows the data to be referenced either via the screen, (or printer), or read directly by PC based software. The data are initially being made available on 3½ inch DSDD, 720 KB, floppy disks, but other disk sizes and formats can be supplied on request. The data files have been designated 'read only' in order to safeguard the user from accidentally corrupting or erasing them.

The data files are identified by reference to the DATA SHEET NUMBER sequence, i.e. from 107.DAT to 111.DAT inclusive. This numbering system is consistent with that introduced in reference 1. Thus, for example, data from test number TE 7436 can be found in data file 107.DAT. For each individual fire test the thermal data have been sub-divided into 'SETS' which reflect the thermocouple positions in the steelwork, and other materials. Mean temperature values are also included in these data sub-sets where it is considered valid to do so. In order that the columns of data in any particular 'SET' can be related to the corresponding thermocouple positions a 'README' file is associated with each data file. By way of example, README.107, which relates to data in file 107.DAT, is shown in Fig. A3.1.

It may be seen by reference to the data presented in Appendix 1 that there have been occasions when no temperature data were recorded. Such occurrences are indicated in the printed tables by the use of an asterisk. Since the use of such a character could cause problems if the software is expecting a numeric input, it has been replaced with the value zero in the disk held data files. It is obviously important for the user to ensure that any data have been read correctly by the particular software or program being used.

REFERENCE

1. D.E. Wainman: 'Compendia of UK Standard Fire Test Data - Unprotected Structural Steel Nos. 1 and 2, PC Disk Version', Report SL/HED/R/S2298/1/92/C, British Steel Technical, Swinden Laboratories, 1992.

TABLE A3.1
README FILE ASSOCIATED WITH DATA FILE 107.DAT

Data file 107.DAT contains data recorded during the standard fire resistance test number TE 7436 which is described in report number SL/HED/R/S2442/1/94/C - "SUMMARY OF DATA OBTAINED DURING TESTS ON WEB ENCASED COLUMNS" and should be used in conjunction with that document.

There are 26 items of data which, together with their mean values, are grouped in sets as shown below.

SET NUMBER	ITEMS IN COLUMNS
SET001.DAT	TIME, F1, F2, F3, F4, MEAN, F5, F6, F7, F8, MEAN, O/ALL MEAN
SET002.DAT	TIME, F10, F9, MEAN
SET003.DAT	TIME, W1, W2, W5, W8, MEAN
SET004.DAT	TIME, W3, W6, MEAN, W4, W7, MEAN
SET005.DAT	TIME, ISO, AT1, AT2, AT3, AT4, AT5, AT6, MEAN.
SET006.DAT	TIME, DEFLECTION