LPCB®

Loss Prevention Standard

LPS 1107: Issue 1.2

Requirements, tests and methods of assessment of passive fire protection systems for structural steelwork

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CONTENTS **PAGE**

PARTICIPATING ORGANISATIONS

This standard was prepared by the Loss Prevention Certification Board with participation from the following organisations:

Association of Structural Fire Protection and Manufacturers	ASFPCM
Association of British Insurers	ABI
Lloyd's	
Association of County Councils	ACC
Confederation of British Industries	CBI
Property Services Agency	PSA

REVISION OF LOSS PREVENTION STANDARDS

Loss Prevention Standards will be revised by issue of revised editions or amendments. Details will be posted on our website at www.redbooklive.com

Technical or other changes which affect the requirements for the approval or certification of the product or service will result in a new issue. Minor or administrative changes (e.g. corrections of spelling and typographical errors, changes to address and copyright details, the addition of notes for clarification etc.) may be made as amendments. (See amendments table on page 30)

The issue number will be given in decimal format with the integer part giving the issue number and the fractional part giving the number of amendments (e.g. Issue 3.2 indicates that the document is at Issue 3 with 2 amendments).

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LPCB welcomes comments of a technical or editorial nature and these should be addressed to "the Technical Director" at enquiries@breglobal.co.uk.

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1 FOREWORD

This standard identifies the Loss Prevention Certification Board (LPCB) evaluation and testing practices for the certification and listing of suitable products. Certification is based on the following criteria.

i. Satisfactory product performance and construction in accordance with the requirements of the LPCB and the manufacturer's specifications.

ii. Verification of the establishment and maintenance of the manufacturer's quality management systems in accordance with BS 5750: Quality Systems

2. SCOPE

2.1 This document stipulates the performance criteria which apply to passive fire protection systems for structural steelwork.

2.2 The structural steelwork is assumed to be loaded to the maximum permissible bending stresses specified in British Standard BS 449 : Part 2 : 1969. The test procedures and heating regime of BS 476 : Part 8 : 1972, Part 20, 21 : 1987 are adopted where appropriate.

3. DEFINITIONS

3.1 Product

For the purposes of this document, the term "product" refers to the material used in a fire protection system to provide insulation to structural steel elements so increasing the inherent fire resistance of the elements.

3.2 Fire Protection System

For the purposes of this document, the term "fire protection system" refers to the product and the method of fixing or retaining the product around the structural steel element.

3.3 Stickability

For the purposes of this document, the term "stickability" refers to the ability of a fire protection system to remain fixed in position during the fire test.

3.4 Critical Temperature

For the purposes of this document, the term "critical temperature" refers to the temperature at which a structural element is assumed to fail to support the applied load. The critical temperature of an element varies with the magnitude of the applied load.

3.5 **Test Specimens**

For the purposes of this document, the term "test specimen" refers to the beams, columns and fire protection system which were used to evaluate the performance of a fire protection system.

3.6 **Passive Fire Protection Systems**

For the purposes of this document, the term "passive fire protection system" refers to board, blanket and spray/trowel applied systems other than intumescent coatings.

3.7 **Section Factor**

For the purposes of this document, the term "section factor" is defined as the ratio of the heated perimeter to section area.

3.8 **Heated Perimeter**

For the purposes of this document, the term "heated perimeter" of a section is defined as the inside perimeter of a fire protection system. For box protection systems the heated perimeter is the perimeter of the smallest rectangle that encloses the steel section.

4. REQUIREMENTS

4.1 **Test Arrangements**

All tests shall be arranged by the LPCB.

4.2 **Fire Resistance**

4.2.1 The relevant British Standard for testing structural steel elements protected by proprietary products is BS 476: Part 8: 1987, Part 20, 21: 1987. The performance of any product will be judged against this standard. All tests shall be carried out by a NAMAS accredited laboratory acceptable to the LPCB.

4.2.2 A limited number of tests (see Tables 1 and 2) on loaded beams and columns are required, supported by additional data obtained from unloaded sections and the results interpreted to give protection thicknesses for the full range of steel sections. See section 6 for further details.

4.2.3 Loaded beams and columns shall be loaded to their maximum permissible stresses in accordance with BS 449: Part 2: 1969.

4.2.4 For assessment purposes, a mean steel temperature at failure (critical temperature) of 550°C is assumed for beams and columns. The mean steel temperature is defined as:

(mean lower flange temperature + mean web temperature)/2.

4.2.5 Adequate stickability of the fire protection system shall be demonstrated at the maximum and minimum proposed thicknesses.

5. TEST PROCEDURES

5.1 General

5.1.1 Specification for Tests

Fire tests shall be performed on loaded sections in accordance with BS 476 : Part 8 : 1972, Part 20 and 21: 1987 as specified in para 4.2.1. Unloaded sections shall be subjected to the heating regime of BS 476: Part 8 (1972), Parts 20 and 22, 1987.

5.1.2 Measurement of Steel Cross-Section of Test Specimens

The steel section shall be measured with position as shown in Figure 1 at a minimum of two sections.

Steel thicknesses shall be measured to an accuracy $\pm$0.1mm and the depth and width of the sections shall be measured to an accuracy of within $\pm$0.5mm.

The mean values of the depth of section (D), width of section (B), flange thickness or

Wall thickness (T) and web thickness (t) shall be quoted, where applicable, in the test report.

The section factor for a specimen shall be calculated using the actual steel sizes and ignoring the root radii. For boxed protection systems, the section factor is calculated from the heated perimeter. See figure 2 for examples.

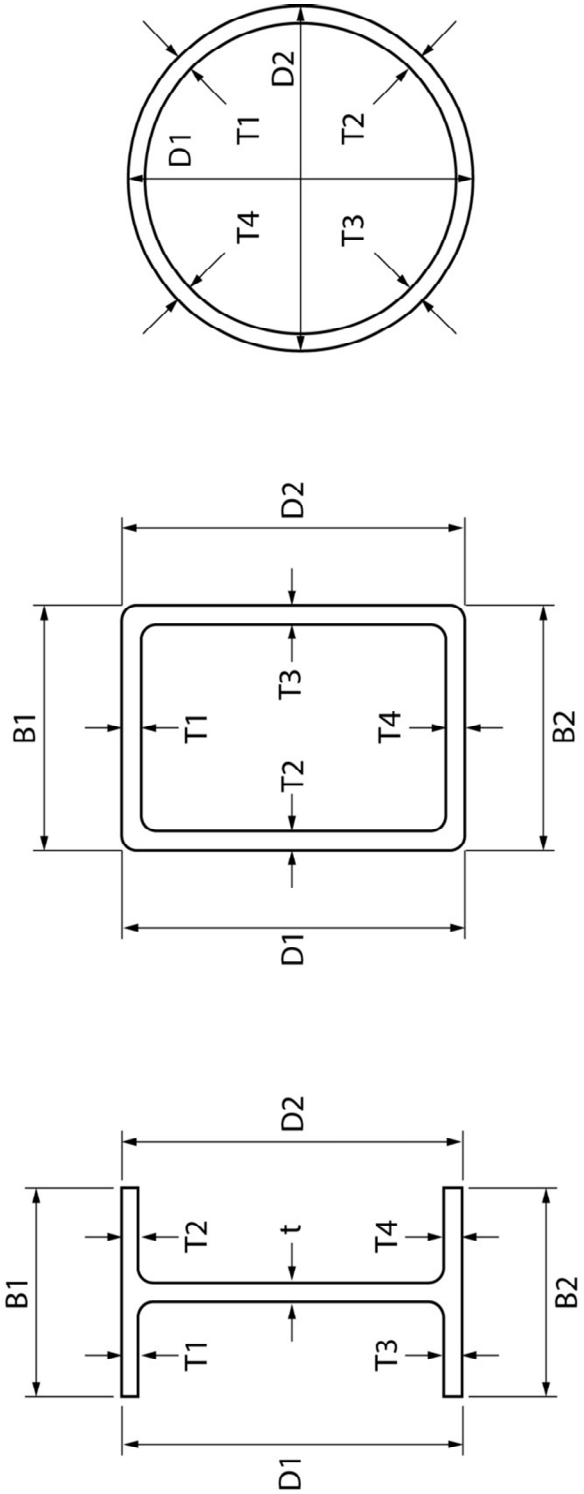


Figure 1: Steel measurement positions

Notes 1 Loose scale/rust should be removed at measurement positions
2 Measurements should be taken away from welds in structural hollow sections

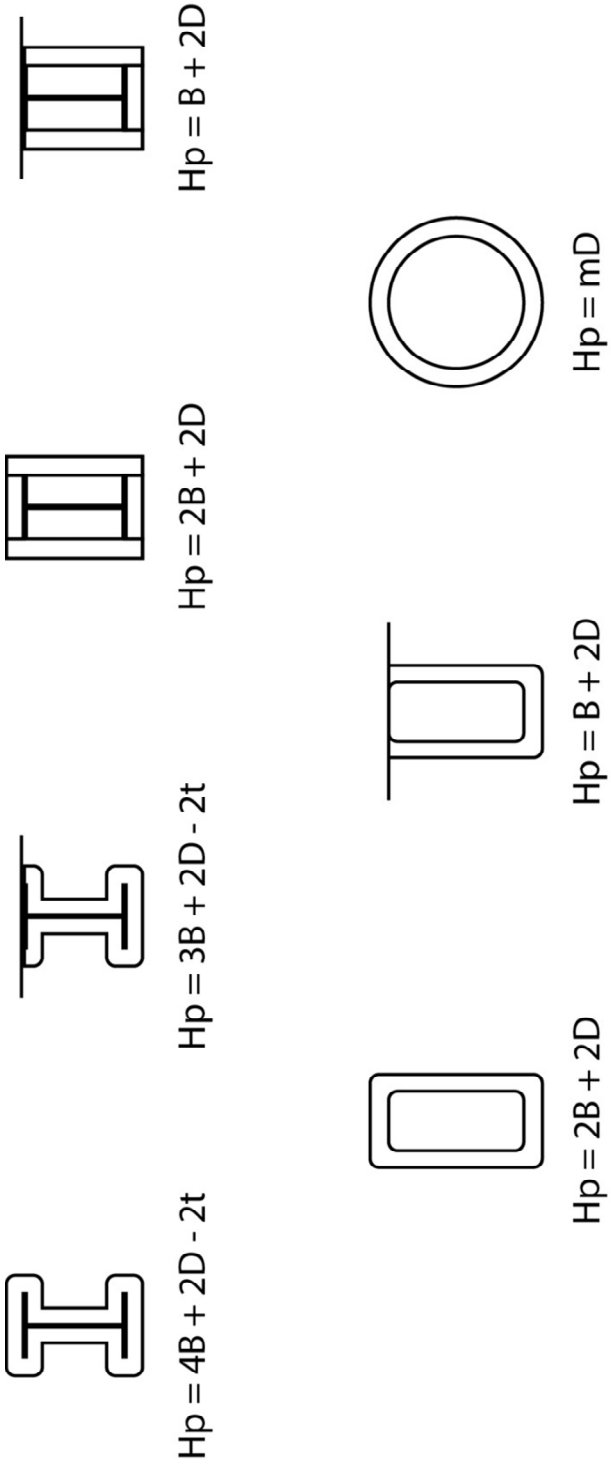


Figure 2: Examples of calculation of heated perimeter

See Figure 1 for definitions of D, B, T, and t

5.1.3 **Specimen Preparation and Application**

The steel preparation techniques shall be representative of practice.

The fire protection system shall be representative of that used in practice.

The specimens shall be in the same orientation as expected in practice during the application of the fire protection systems.

The protection thickness of spray materials applied to the test specimens shall not vary by more than ±15%. of the mean value.

The density of a product shall not vary by more than ±15% of the mean value.

5.1.4 **Conditioning of Test Specimens**

Specimens and sample, as defined below, shall be conditioned approximate to the state of strength, state of cure and moisture content that would be expected to occur in practice.

To ascertain if a product is fully conditioned for test, a representative sample at least 300mm x 300mm of maximum thickness shall be weighed regularly until its weight stabilizes before a specimen is tested.

If a specimen is force dried at temperatures above 30°C and relative humidities below 50%, the forced drying shall be terminated a minimum of 2 weeks before the specimens are tested. The specimen shall not be tested after this period until the weight of a representative sample has stabilized.

The moisture content of a representative sample of the product (if appropriate) shall be estimated by oven drying the sample between 100°C and 105°C. If a material is known to loose combined water below 100°C, it may be oven dried at lower temperatures before being oven dried at 100-105°C. Both values shall then be quoted in the test report.

5.2 **Test Procedures for Unloaded Sections**

5.2.1 **Size of Specimens**

Unloaded columns shall be a minimum of 1.0m high.

Unloaded beams shall be a minimum of 1.2m long.

5.2.2 **Instrumentation of Unloaded Specimens**

The temperature of the unloaded specimens shall be measured by chromel/alumel thermocouples. The thermocouples may be `peened' to hold them in position by drilling holes in the specimen slightly larger than the thermocouple and deep enough to accommodate the junction, and burring the edge of the hole. For structural hollow sections, the thermocouple junction shall be peened to steel plugs of the same thickness

as the section wall. The plug shall then be secured in a hole drilled in the section wall, and the thermocouple leads run through the inside of the section.

The thermocouple leads shall be run from the furnace without significantly affecting the fire protection system.

Five thermocouples shall be fitted to the unloaded columns (three on the flanges and two on the web of I-section columns). The positions of the thermocouples for I-section, rectangular and circular hollow section columns are shown in Figure 3. Additional thermocouples can be used.

Six thermocouples shall be fitted to the unloaded beams (four on the lower flange and two on the web on I-section and rectangular section beams are shown in Figure 4. Additional thermocouples can be used.

Additional thermocouples shall be applied if required by the LPCB to examine features of a specific fire protection system.

The temperature of the unloaded specimens shall be measured at intervals not exceeding 1 minute during the fire test.

5.2.3 **Application Techniques**

The fire protection shall be applied in accordance with section 5.1.3. Additional protection may be applied to the ends of the unloaded specimens to reduce end effects.

Unloaded columns shall be protected on four sides.

Unloaded beams shall be protected on three sides, the protection finishing flush with the top side of the upper flange (Figure 5).

5.2.4 **Location of Specimens in Furnace**

Unloaded columns shall be positioned in the furnace to ensure four-sided exposure. If the columns are placed on the floor on the furnace, the column bases shall be protected by sand or similar material to a maximum height of 150mm.

Unloaded beams shall be fitted to the roof of the furnace with a mineral fibre or ceramic fibre gasket fitted to the top flange of the beams (Figure 5).

5.2.5 **Observations**

The specimens shall be visually examined at regular intervals during the test. Note shall be made of the time at which cracks form or material becomes detached from a specimen.

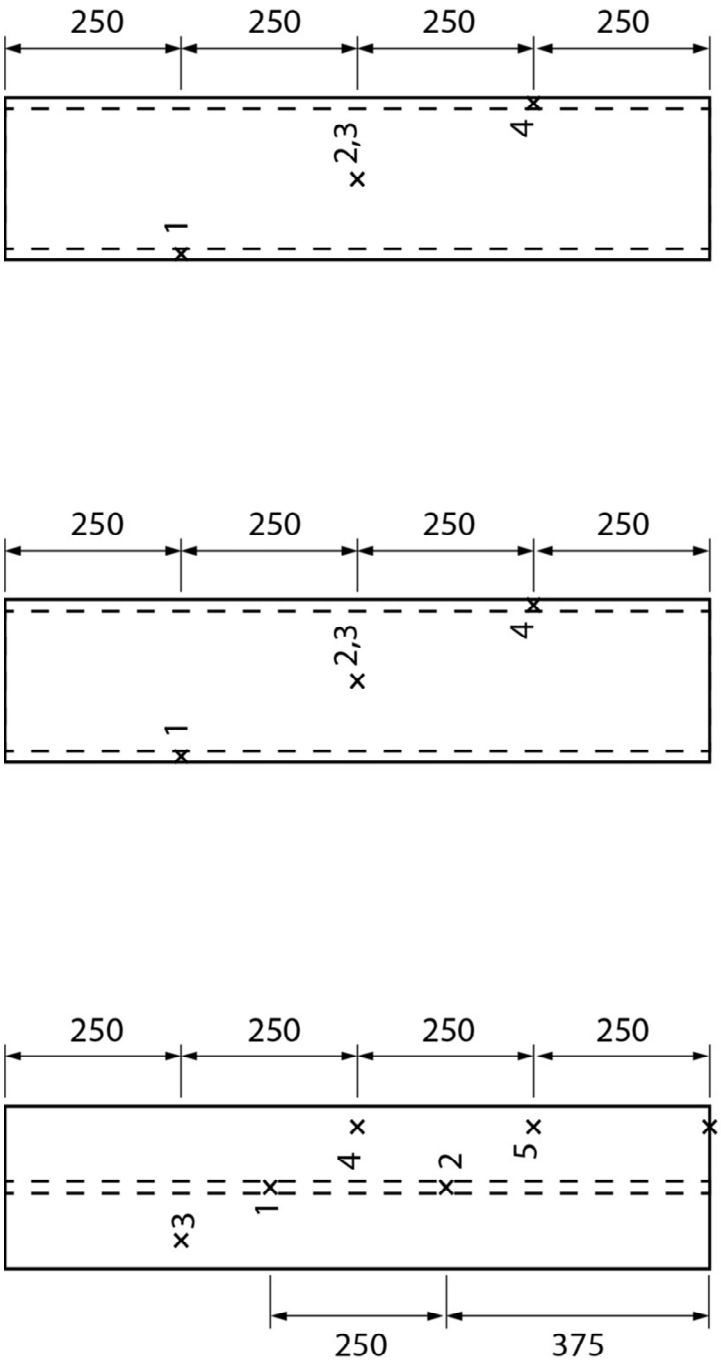


Figure 3: Position of thermocouples of unloaded columns

All dimensions in mm

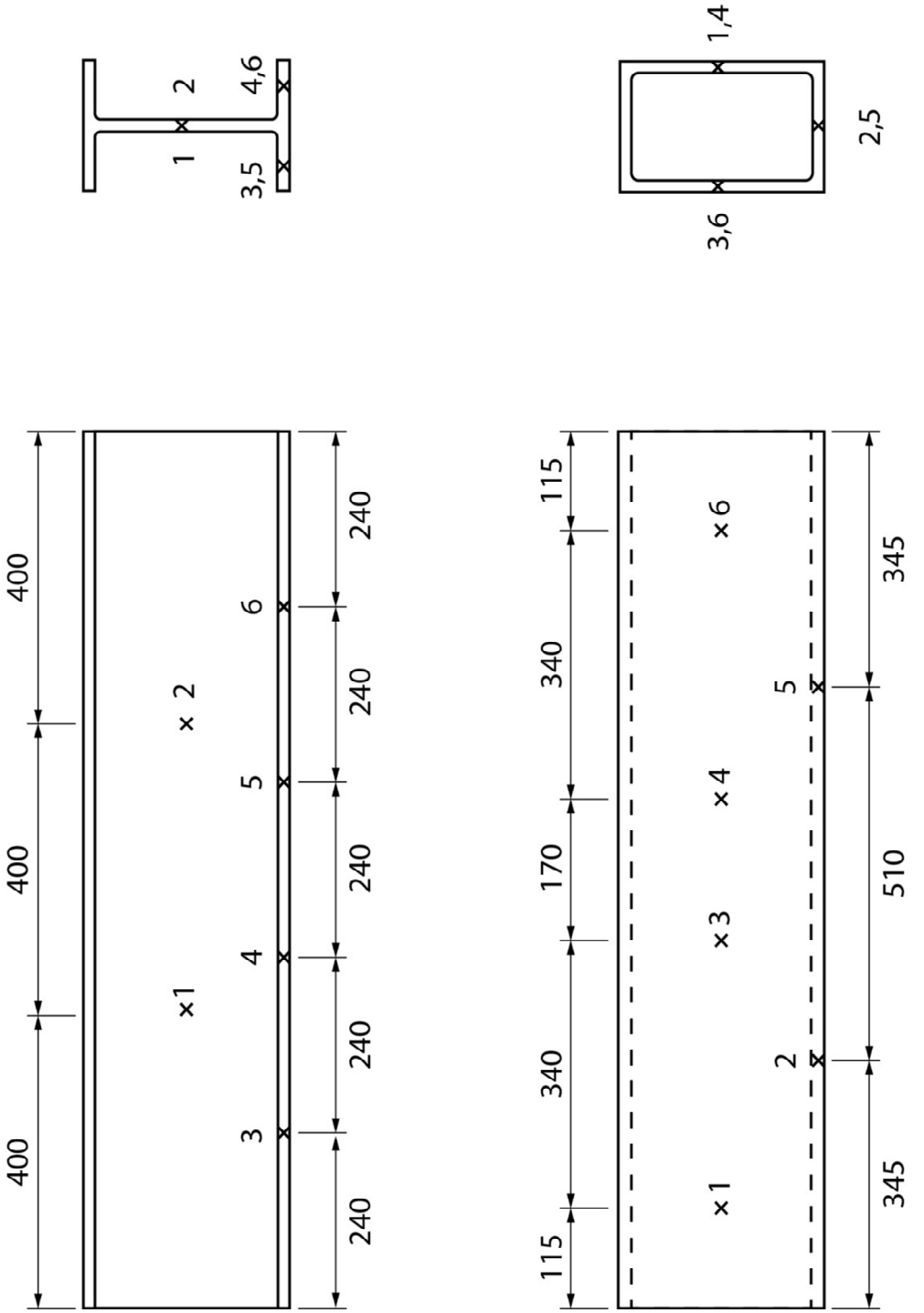


Figure 4: Position of thermocouples of unloaded beams

All dimensions in mm

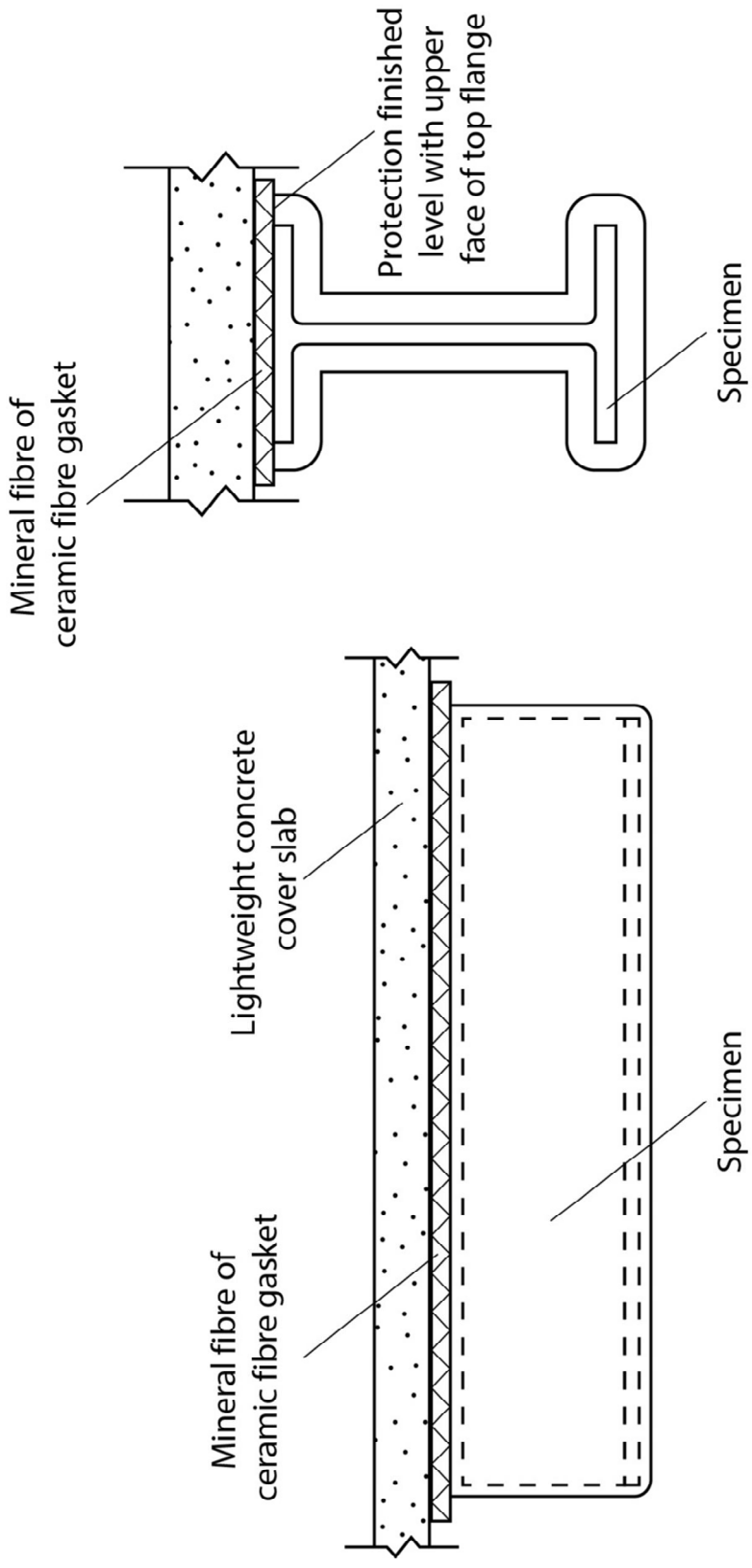


Figure 5: Method of mounting unloaded beams in furnace

5.2.6 **Termination of Test**

The test shall not be terminated until the mean web and mean flange temperatures of all the sections have exceeded 550°C.

The test may be continued beyond the 550°C limit to obtain additional information.

5.3 **Test Procedures for Unloaded Sections**

5.3.1 **General**

The test procedures of BS 476: Part 8: 1972[1], Part 20, 21: 1987 shall be adopted for testing loaded specimens. The specimens shall be loaded to induce maximum permissible stresses in accordance with BS 449: Part 2: 1969 during the fire test.

Additional procedures, not specified in BS 476 : Part 8 : 1972[1], Part 20, 21 : 1987 are detailed in sections 5.3.2 - 5.3.5.

Beams shall normally be tested, simply supported with an exposed length of 4m. A concrete slab approximately 920mm x 130mm deep shall be cast on top of the beam which shall not contribute significantly to the strength or stiffness of the steel beam. A specification for a suitable concrete slab and method of attachment to a steel beam is given in Appendix 1.

Columns shall normally be tested with an exposed length of approximately 3.1m. The columns shall be axially loaded and the column ends shall be effectively restrained against rotation.

Typical details showing a suitable method of supporting a column during a fire test are given in Appendix 2.

5.3.2 **Instrumentation of Loaded Specimens.**

In addition to the requirements of BS 476 : Part 8 : 1972, Part 20, 21: 1987 the temperature of the loaded specimens shall be measured by thermocouples attached to the specimen as described in sections of 5.2.2.

Nine thermocouples shall be fitted to loaded I-section beams, five on the lower flange and four on the web in the positions shown in Figure 6. The position of thermocouples on rectangular hollow section beams are also shown in Figure 6.

Ten thermocouples shall be fitted to the loaded I-section columns, six on the flanges and four on the web in the positions shown in Figure 7. The position of thermocouples on rectangular hollow section and circular hollow section columns are also shown in Figure 7.

Additional thermocouples shall be applied if required by the LPCB to examine features specific to a fire protection system.

The temperature of the loaded specimens shall be measured at intervals not exceeding 1 minute during the test.

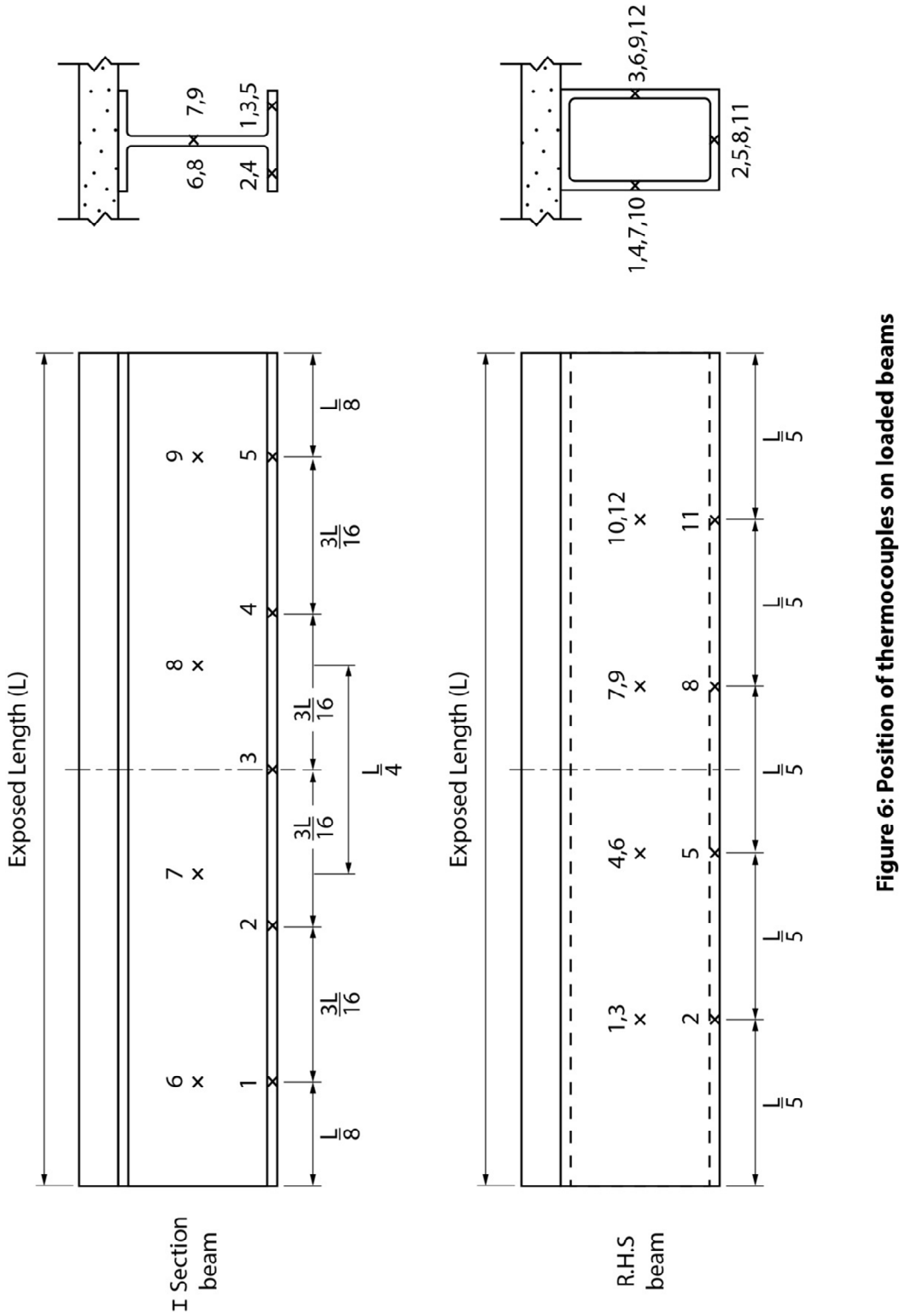


Figure 6: Position of thermocouples on loaded beams

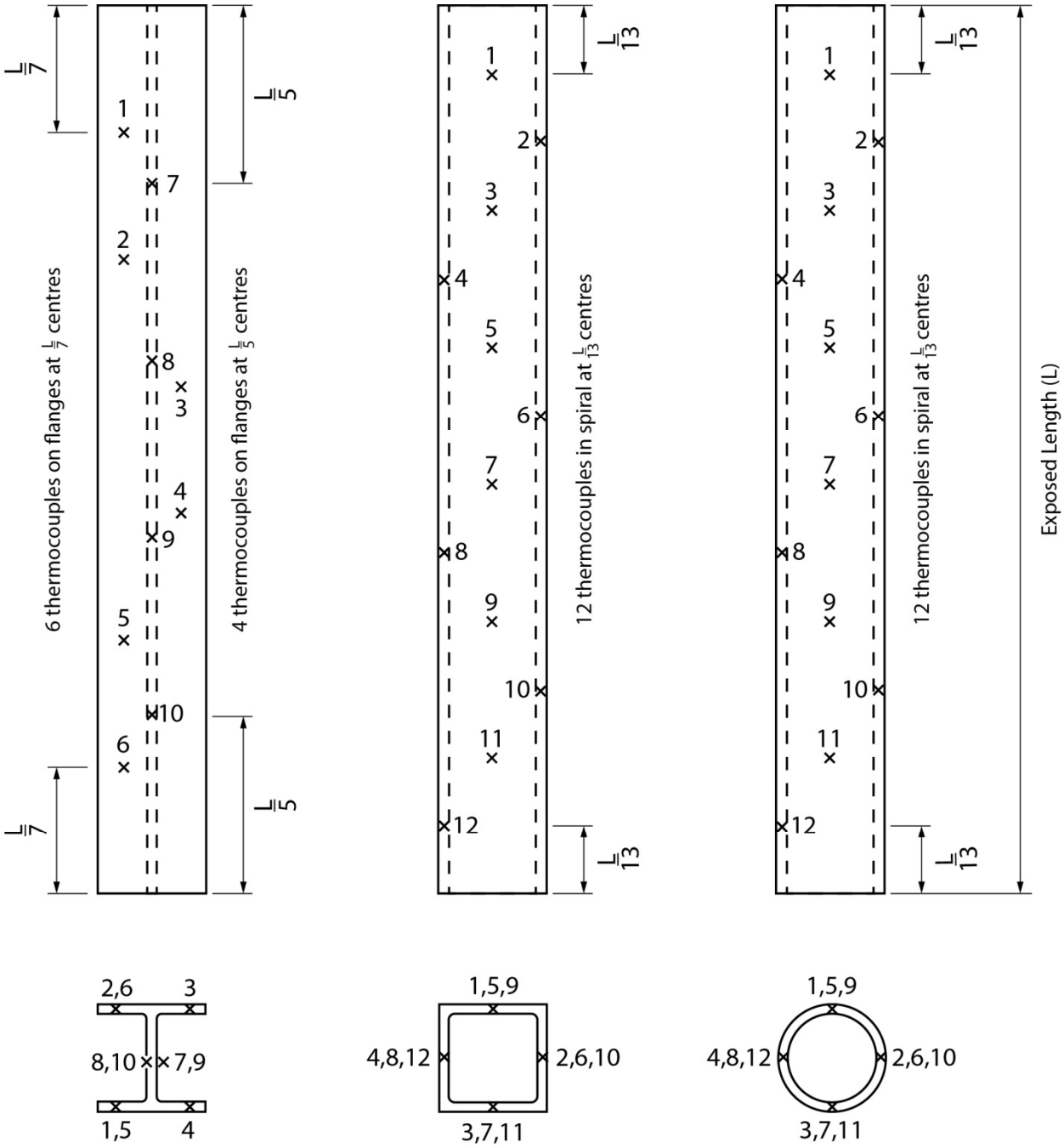


Figure 7: Position of thermocouples on loaded columns

5.3.3 **Application Techniques**

The fire protection shall be applied in accordance with section 5.1.3.

The loaded columns shall be protected on four sides.

The loaded beams shall be protected on three sides.

5.3.4 **Observations**

The specimens shall be visually examined at regular intervals during the test. Note shall be made of the time at which cracks form or the material becomes detached from the specimen.

5.3.5 **Termination of Test**

The test on a loaded beam shall not be terminated before the deflection has reached a value of L/35 where L is the clear span.

The test on a loaded column shall not be terminated before the rate of expansion of the column becomes negative.

Once the limits specified above have been reached, the test may be continued with the load reduced to gain additional information.

6. DESIGN OF TEST PROGRAMME

6.1 Assessment Procedures

6.1.1 **General**

To obtain an assessment establishing the relationship between protection thickness, section factor and fire resistance, the conditions in paragraph 6.2.2 shall be satisfied.

The test programme shall be designed and the assessment made by LPCB personnel.

6.2 Assessment Techniques

6.2.1 **General**

The techniques specified below are based on methods developed by the Fire Research Station, Borehamwood.

The assessment shall be based on insulation data obtained from unloaded sections, supported by tests on beams and columns.

A multiple linear regression method shall be used to interpolate the relationship between section factor, fire resistance and protection thickness assuming a critical steel temperature of 550°C.

6.2.2 **Selection of Test Specimens for Assessment of a Fire Protection System on I-Sections and Sections with Re-entrant Detail**

Table 1 specifies a test programme which shall normally be followed to provide an assessment for I-section beams and columns and similar sections with re-entrant details.

Table 1: Typical I-Section Programme

Type of Specimen	Designation	Thickness Ratio R
Loaded column	203 x 203 x 52	1.0
Loaded beams[1]	305 x 127 x 42 305 x 127 x 42	1.0 0.0
Unloaded beams[2]	305 x 102 x 25 305 x 102 x 25 356 x 171 x 67 356 x 171 x 67 254 x 146 x 43 254 x 146 x 31	0.2 0.8 0.5 0.8 0.4 0.5
Unloaded columns	254 x 254 x 132 152 x 152 x 30 254 x 254 x 89 203 x 203 x 52	0.3 0.0 0.2 1.0

Note 1: In some cases, for example, where it is considered that section depth could affect the stickability of a product, beams designated 406mm x 178mm x 60kg/m shall be used in preference to beams designated 35mm x 127mm x 42kg/m.

Note 2 : The thickness ratio R is defined by the following equation.

$$tt = R (tmax - tmin) + tmin \quad \text{..... Equation 1.}$$

Where tt is the target average fire protection thickness;
tmax is the maximum fire protection thickness,
tmin is the minimum fire protection thickness.

Where a fire protection system is intended to be used on deep webbed and/or wide flanged beams, an unloaded section having representative dimensions consistent with the testing facilities available shall be tested. Suitable specimen sizes are 610mm x 305mm x 149kg/m universal beams or 600mm x 300mm x 8mm plate girders. The data obtained from this section shall not be included in the regression analysis but shall be compared with the results of the regression analysis.

6.2.3 **Selection of Test Specimens for Assessment of a Fire Protection System Applied to Structural Hollow Sections and Sections Without a Re-Entrant Detail**

Where a fire protection system is intended to be used in sections without re-entrant details (e.g. structural hollow sections), further testing is required if in the opinion of the LPCB the change of section shape is considered to significantly affect the performance of the system.

For spray materials the use of wire mesh on sections without re-entrant details may be permitted at the discretion of the LPCB. Reference shall be made to Fire Protection for Structural Steel in Buildings[3] and Code of Practice for sprayed mineral insulation BS 8202: Part 1: 1987 for further information.

If an I-section assessment package has been successfully completed on a boxed fire protection system, the required protection thicknesses may be assumed to be the same for I-sections and structural hollow sections (SHS) having the same section factor.

For fire protection systems contoured to the steel section the following equation may be used to calculate a factored section factor from which the thickness of protection required for a SHS may be calculated from data obtained from I-sections.

for $Hp/A > 250$:

$$Hp/A^* = 1.25\ Hp/A \quad \text{..... Equation 2}$$

for $50 \leq HpA \leq 250$:

$$Hp/A^* = \left(1 + \frac{Hp/A}{1000}\right) Hp/A \quad \text{..... Equation 3}$$

where Hp/A* is the factored section factor which is used to calculate the required thickness of protection.

Hp/A is the section factor for the protected steel section encased with a boxed fire protection system.

Where specific test data relating to SHS is available, this shall be used in preference to the above method.

Table 2 specifies suitable loaded sections and unloaded sections which may be used to establish the behaviour of a fire protection system applied to structural hollow sections, assuming no data is available relating to other section shapes.

TABLE 2

Type of Specimen	Designation (mm)	Thickness Ratio R
Loaded columns	200 x 200 x 6.3 219ø x 10	1.0 1.0
Loaded beams	300 x 200 x 6.3 300 x 200 x 6.3	1.0 0.0
Unloaded beams	80 x 80 x 3.6 80 x 80 x 3.6 300 x 200 x 8.0 300 x 200 x 8.0 150 x 100 x 8.0 150 x 100 x 8.0	0.2 0.8 0.5 0.8 0.4 0.5
Unloaded columns	200 x 200 x 6.3 250 x 250 x 12.5 140 x 140 x 5.0 300 x 300 x 12.5	1.0 0.0 0.0 0.3

Note: See equation 1 for definition of thickness ratio R.

6.2.4 **Analysis of Test Results**

The following empirical equation is normally adopted to simulate the relationship between critical time, section factor and protection thickness.

FR = A1 + A2 t Hp/A + A3t ..... Equation 4

where; FR is the critical time to reach 550°C - mins,

t is the mean protection thickness - mm,

A/Hp is the reciprocal of the section factor - m,

A1, A2 and A3 are constants obtained from the test data.

The mean protection thicknesses are used in the analysis of data from unloaded sections.

The constants, A1, A2 and A3 in equation 3 shall be calculated by performing a multiple linear regression using the data from unloaded sections. The results will normally be accepted if the co-efficient of determination is greater than 0.95. A lower co-efficient of determination may be accepted by the LPCB, but values below 0.9 will normally be considered unacceptable.

If any unloaded specimens yield rogue results, these results may be disregarded, provided:

1. A satisfactory explanation of the reasons for the inconsistencies is given.

or

2. A minimum of eight unloaded sections are used in analysis which give a satisfactory spread of data in relation to the variables FR, tA/HP and T.

After the constants A1, A2 and A3 have been calculated with a satisfactory coefficient of determination, the fire resistance of the loaded sections shall be calculated. If the calculated fire resistance is more than that of a loaded section the reason for this discrepancy shall be identified. If, for example, the discrepancy was caused by material falling away or cracks or joints opening (i.e. inadequate stickability) the results may be rejected, a lower critical temperature adopted or safety factors applied to the predicted thicknesses at the discretion of the LPCB.

If subsequently an alternative application method is proposed which is shown to perform satisfactorily, the results on the unloaded sections may be considered acceptable.

The protection thickness may be calculated for a specified section factor and fire resistance period by rearranging equation 3 and substituting the values of A1, A2 and A3. Using this method, a table taking the following form shall be produced for the LPCB to approve.

The maximum and minimum fire protection thicknesses tested on loaded sections may be extrapolated by 10% for inclusion in Table 3. However, the minimum thicknesses shall not be less than 10mm unless specific loaded test data with fire protection thicknesses below 10mm is available.

The thicknesses specified in Table 3 shall be regarded as the minimum thickness to be applied on site.

Where BS 476 : Parts 4 and 7 results are available for the product, they shall be recorded on the bottom of Table 3.

TABLE 3

Section Factor Hp/A up to m^{-1}	30min	60min	90min	120min	180min	240min
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330						
BS 476 Result	Part 4			Part 7		

7. QUALITY REQUIREMENTS

The quality requirements for Passive Fire Protection Products are given in document LPS 1108 `Quality Schedule for the Certification of Passive and Active (Intumescents) Fire Protection Products for Structural Steelwork.'

8. POST INSTALLATION INSPECTION

The LPCB reserves the right to make random inspections of installed approved products. Any product found not to be in accordance with the specification agreed with the LPCB shall be reported to the Approvals Manager for disciplinary action.

9. COMPLAINTS

Complaints about LPCB approved products shall be investigated by the LPCB. Where complaints cannot be resolved to the satisfaction of the LPCB, approval shall be withdrawn.

APPENDIX 1 - SPECIFICATION FOR CONCRETE COVER SLAB

A1.1 General

The concrete cover slab shall not significantly affect the result of the fire test by contributing to the strength or stiffness of the test specimen. The following is a specification which is designed to minimise the effects.

A1.2 Specification for Concrete Cover Slabs

A1.2.1 Aggregate

The aggregate shall have a maximum size of 19mm. Prebatched aggregates may be used.

A1.2.2 Cement

Ordinary or Rapid Hardening Portland Cements may be used.

A1.2.3 Water/Cement Ratio

The water content shall be as low as practicable but shall not reduce the workability of the mix to unacceptable levels.

A1.2.4 Concrete Strength

The average 28 day strength of the concrete shall be approximately 20N/mm^2. Higher strengths are undesirable since these may affect the performance of the specimen.

A1.2.5 Reinforcement

The reinforcement shall be located at the mid-depth of the section. Breaks shall be provided at approximately the centre and quarter-span positions of the specimen. The amount of longitudinal reinforcement shall be minimised.

Figure 8 shows a suitable design of reinforcement.

A1.2.6 Steel/Concrete Ties

The concrete shall be secured to the top flange with ties designed to provide the minimum shear connection whilst holding the concrete in contact with the beam. A suitable design is shown in Figure 9.

A1.2.7 Reduction of Bond

To minimise composite action, the bond between the concrete and top flange of the steel beam shall be reduced by either coating the upper surface of the top flange with mould oil or applying a polythene film.

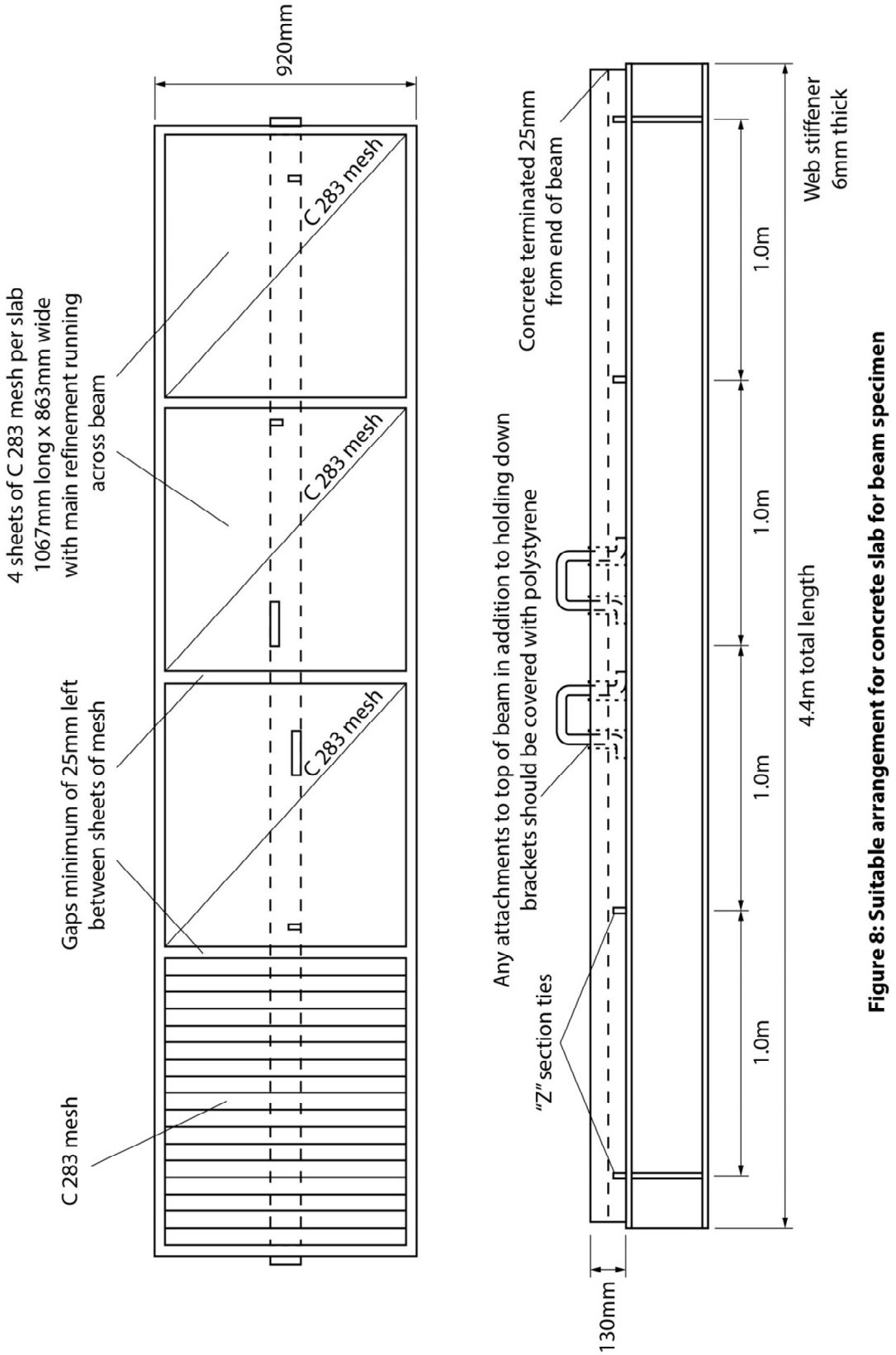


Figure 8: Suitable arrangement for concrete slab for beam specimen

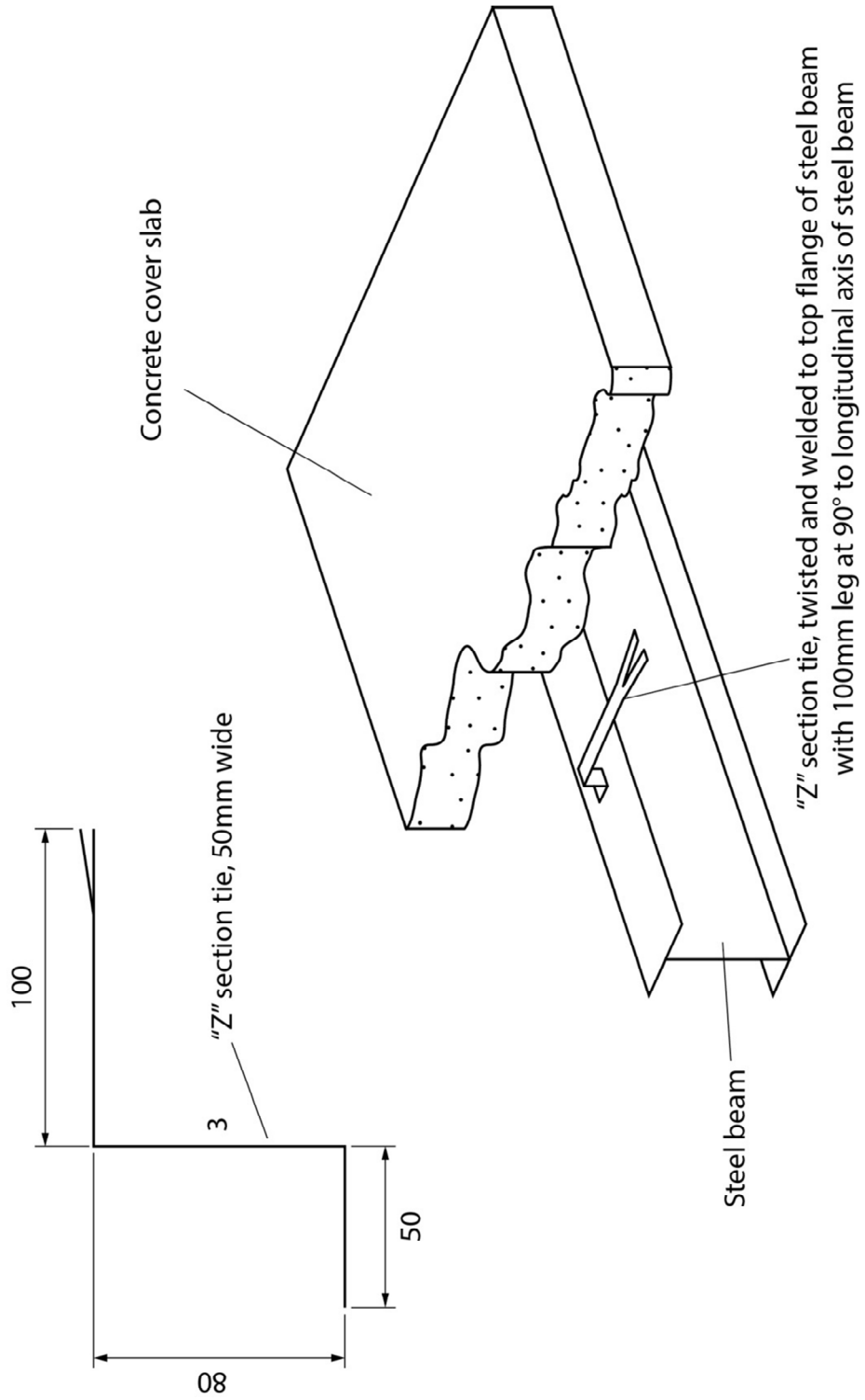
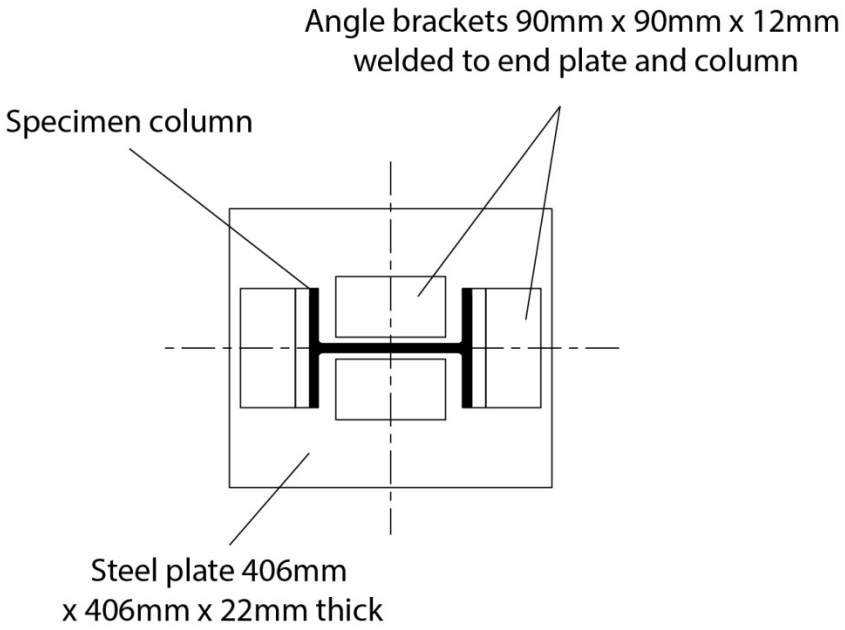


Figure 9: Steel tie detail
All dimensions in mm

APPENDIX 2 - DESIGN OF COLUMN ENDS TO PROVIDE FULL RESTRAINT IN BOTH DIRECTION AND ROTATION

A2. The design shown in Figure 10 has been shown to provide adequate restraint in both direction and rotation for full restraint to be assumed. The column shall be aligned vertically and a mortar bed fitted between the end plate and head cap to provide uniform axial loading.



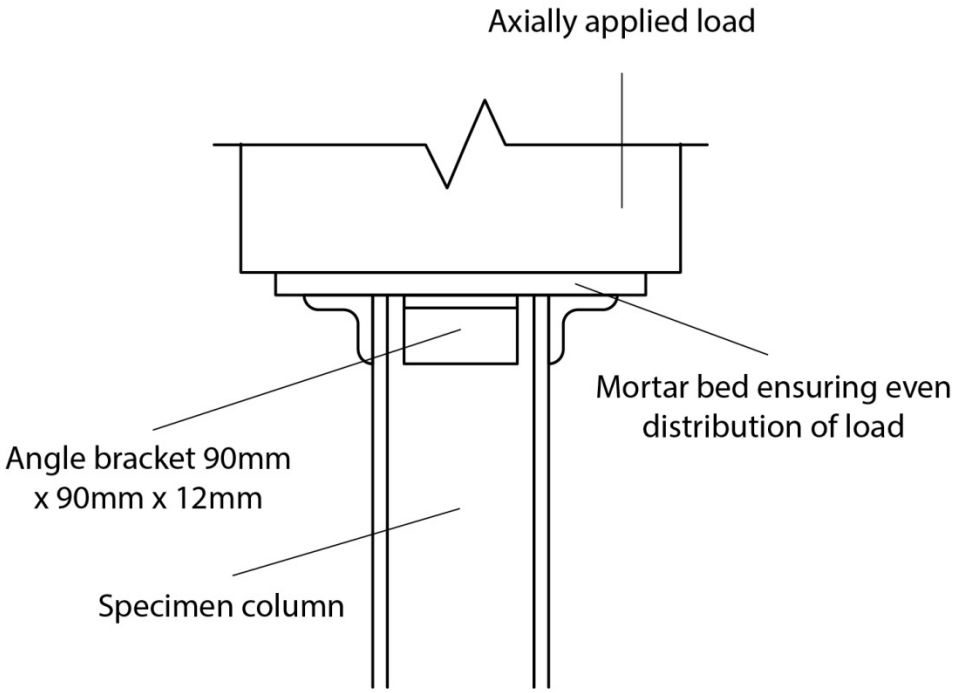


Figure 10: Typical detail of column ends showing suitable method to provide adequate restraint against rotation

PUBLICATIONS REFERRED TO

Title No.			LPCB Ref.*
1.	BS 449 : Part 2 : 1969	`The use of structural steel in buildings. Metric units.'	LPS 1109
2.	BS 476 : Part 4 : 1970	`Non-combustibility test for materials.' (1984)	
	BS 476 : Part 7 : 1971	`Surface spread of flame test for materials.'	
	BS 476 : Part 8 : 1972	`Fire Tests on building Materials and Structures. Test Methods and Criteria for the fire resistance of elements of building construction.'	
	BS 476 : Part 20 : 1987	`Method for the determination of the Fire Resistance of Elements of Construction (General Principles).'	LPS 1110
	BS 476 : Part 21 : 1987	`Method for the determination of Fire Resistance of Load Bearing Elements of Construction.'	LPS 1111
3.	`Fire Protection for Structural Steel in Buildings. Association of Structural Fire Protection Contractors and Manufacturers Ltd. and Constrado : 1983.'		LPS 1114
4.	BS 8202 : Part 1 : 1987	`Code of Practice for Sprayed Mineral Insulation.'	LPS 1115
5.	BS 5750 : Part 2 : 1987	`Quality Systems Specifications for manufacturers and Installation.'	LPS 1064
6.	LPS 1108	`Quality Schedule for the Certification of passive and active (intumescents) fire protection products for Structural Steelwork.'	LPS 1108

* NOTE : The LPCB Reference Number is included for internal use only.

Amendments Issued Since Publication

DOCUMENT NO.	AMENDMENT DETAILS	SIGNATURE	DATE
LPS 1107-1	Copyright and address change	CJA	05/10/01
LPS 1107-1	Further copyright change	CJA	29/07/02
LPS 1107-1.1	Further copyright changes	CJA	16/09/02
LPS 1107-1.2	1. New front cover 2. Title added to header 3. Contents page moved to Page 1 4. Revision of loss standards added on page 3 5. Notes added on Page 2 6. Formatting corrections and repagination 7. Figures redrawn 8. Update of copyright information	DC	Jan. 2014