BS 476: Part 21 Fire Resistance Tests
Summary of Data Obtained During a Test
on a Composite Slim Floor Beam

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SUMMARY

BS 467:PART 21 FIRE RESISTANCE TESTS

SUMMARY OF DATA OBTAINED DURING A TEST ON A COMPOSITE SLIM FLOOR BEAM

D.E. Wainman

During the five years 1989-1993 British Steel Technical carried out more than thirty standard fire resistance tests on hot rolled structural steel sections. Data arising from the tests are being summarised in a series of reports, each one dealing with either a different form of construction or a generic group of test assemblies.

This is the fifth report issued as part of that series. It contains a detailed description of the design, instrumentation and construction for a single test assembly, usually referred to as a 'composite slim floor beam', together with the data arising from it. The test was carried out at the Warrington Fire Research Centre.

The serial size for the steel section used was 254 x 254 mm x 89 kg/m UC. The steel grade was BS 4360:Grade 43A (now BS EN 10025 S275). The section was loaded so as to develop a bending stress of 165 N/mm². (the maximum likely service stress for such a section), in the lower flange. The performance of the test assembly was judged against the load bearing capacity criterion outlined in Section 5 of BS 476:Part 21:1987. The fire resistance rating for the assembly was found to be 44 minutes.
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BS 476:PART 21 FIRE RESISTANCE TESTS

SUMMARY OF DATA OBTAINED DURING A TEST ON A COMPOSITE SLIM FLOOR BEAM

1. INTRODUCTION

Between 1989 and 1993 more than 30 full scale fire resistance tests were carried out on a wide range of structural assemblies. The major features of all the tests were summarised in an earlier Technical Note[1]. Data obtained during the tests are being presented in a series of reports, each of which is concerned with either a different form of construction or a generically similar group of test assemblies. The first report in the series was issued in 1993[2] and included material relating to eight flange plated slim floor beams. Subsequent reports have given details relating to:

- five web encased column assemblies[3],
- tests on connections between beams and columns[4] and
- a single test on an arched metal deck floor[5].

This is therefore the fifth report issued as part of that ongoing series. It contains a detailed description of the design, instrumentation and construction for a single test assembly, together with the data arising from it which are included in Appendix 1. The test assembly was a steel and concrete composite slim floor beam construction. The data are presented in a format which is generally consistent with that of the earlier publications. As before, no analysis of the data is included since this has 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, the one in this document being number 126. As in the previous compendia and reports the thermal data are reduced to summary values at various times throughout the duration of the test. It should be noted, however, that all the thermal data, usually recorded at one minute intervals, can be made available on a PC disk (see comments in Appendix 3). This may be obtained, on request, from British Steel, Swinden Technology Centre.

The work reported here forms 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. TEST ASSEMBLY WFCR 44174

The test assembly consisted of a 5 metre length of 254 x 254 mm x 89 kg/m universal column section which, initially, had Grade 30 normal weight concrete cast onto the lower flange. The concrete had a nominal depth of 160 mm and was finished flush with the toes of the flange. It was held in place by means of ten mild steel 'tangs' formed from 50 mm wide x 3 mm thick strip. These were tack welded, five per side, at 800 mm centres, to the inside faces of the lower flange. The concrete was left to cure for approximately four weeks.

Richard Lees Grade Z28 'SUPER HOLORIB' profiled steel decking (400 mm wide x 1.2 mm thick), was positioned on top of the cast concrete blocks and buttressed up to the web. The decking, which ran the complete length of the beam, was attached to the concrete using shot fired HILTI fixings at 300 mm centres. Grade 30 light-weight concrete was cast onto the steel decking to provide a floor section which was nominally 840 mm wide x 120 mm thick.
The light-weight concrete contained LYTAG aggregate at a nominal 1/2 mm sieve size. It was cast in accordance with a specification given by BOSAL / LYTAG and to BS 8110:Parts 1 and 2:1985, 'The Structural use of Concrete'. A layer of A142 steel reinforcing mesh was also incorporated into the floor slab. The soffit of the beam was left unprotected as was the under-side of the decking.

Dimensional details for the Richard Lees 'SUPER HCLORIB' decking are given in Fig. 1. A transverse section through the assembly showing the arrangement of the various components is given in Fig. 2. The dimensions of the mild steel laths are given in Fig. 3. The steel section used in the construction of the test assembly was manufactured by British Steel and supplied to the requirements of BS 4380:Grade 43A (now BS EN 10025:5275). Details of its chemical composition and mechanical properties are included in Data Sheet No. 126A in Appendix 1.

The normal weight concrete supporting the metal decking was cast during December 1988. The light weight concrete for the floor section was cast during January 1989 and was allowed to cure naturally until four weeks prior to the test. The complete assembly was then placed in an atmosphere controlled by a de-humidifier until the test date. Samples of both types of concrete were taken at the time of their casting. The densities and moisture contents, measured on the day of the test, were reported as being:

For the normal weight concrete:
- Density: 2200 kg/m³
- Moisture Content: 3.9% w/w

For the light weight concrete:
- Density: 1850 kg/m³
- Moisture Content: 4.7% w/w

The compressive, (crushing), strengths measured 28 days after casting were reported to be 30 N/mm² for both types of concrete.

3. DIMENSIONS AND SECTION PROPERTIES

The nominal dimensions and section properties, as specified in BS4:Part 1:1983 for the steel beam used in the construction of the test assembly are included in Data Sheet No. 126A. The actual dimensions of the section are also given, together with the calculated section properties.

4. INSTRUMENTATION

The test assembly was instrumented such that the temperature attained by the steel section could be recorded throughout the duration of the heating period. For this purpose twenty-two 3 mm diameter mineral insulated 'K' type thermocouples, (Ni-Cr / Ni-Al), with insulated hot junctions and Inconel 600 sheaths were used. The thermocouples were embedded to the mid-thickness position in the steel section. The thermocouple positions are as shown in Fig. 4, (longitudinal arrangement), and Fig. 5, (transverse arrangement).

Thermocouples of the same type were installed by WFRS for monitoring the temperature of the furnace atmosphere. These were situated at eight positions within the furnace, being evenly distributed on each side of the assembly, level with the soffit of the beam and 100 mm away from it.
Provision was also made for monitoring the vertical deflection of the assembly throughout the test. These measurements were made at the geometric centre of the upper, (concrete), surface using a displacement transducer connected to the WFRC data logging facility. The deflection values recorded are included in Data Sheet No. 1268 in Appendix 1.

5. ASSEMBLY

The test assembly was positioned so as to form part of the roof of the floor furnace at WFRC. It was simply supported on a refractory lined steel loading frame so as to give a total effective span between the roller supports of 4500 mm. This frame was supported on the outer walls of the gas fired furnace so that the length of beam actually exposed to the heating conditions of the test was 4000 mm.

6. LOADING

A total imposed load of 30.79 tonnes was applied to the steel section by means of four hydraulic rams positioned along the centre line of the web and at points corresponding to $y/4$, $y/2$, $3y/4$, and $y$ of the supported span. The applied load, together with the self weight of the system, was intended to develop a bending stress of 165 N/mm² in the lower flange of the steel section. This is the maximum allowable bending stress for a BS 4360:Grade 43A steel section according to the design rules in BS 449:Part 2, 1969. The applied load was kept constant for the first 52 minutes of the test, at which time it was removed.

The load to be applied to the test assembly was initially calculated on the basis of the nominal dimensions and section properties for the steel member concerned. These calculations were subsequently repeated to take account of the actual dimensions and mechanical properties of the section. Calculations relating to the applied load level are given in Appendix 2. A comparison of the calculation data to BS 5950:Part 1:1985 is also included.

7. FAILURE CRITERIA

The performance of the test assembly was judged against the load bearing capacity criterion outlined in Section 5 of BS 476:Part 21:1987. The maximum allowable deflection and the maximum allowable rate of deflection for the test assembly, as specified by the standard, were calculated to be 225 mm, (span / 20), and 8.79 mm/min, (span / 9000 x D), respectively, where $D$ = 256 mm, the measured depth of the section. The allowable rate of deflection criterion is not applicable until the deflection exceeds span / 30, i.e. 150 mm.

The maximum allowable rate of deflection criterion was exceeded after 41 minutes. A mid-span deflection of 147 mm was attained after 44 minutes at which time the rate of deflection was increasing steadily at 11 mm/min. Heating of the assembly continued until a deflection of 226 mm was attained after 52 minutes. The load was removed but heating of the assembly continued for a further 18 minutes in order to obtain additional thermal data.

In accordance with the failure criteria outlined above the load bearing capacity of the beam was stated to be 44 minutes.

8. CONCLUSIONS

1. Data arising from a standard fire resistance test carried out on a composite slim floor beam have been collected and reported. Details of the test assembly are given, together with a summary of the material properties, structural calculations, and the thermal data recorded.
2. The performance of the test assembly was judged against the load bearing capacity criterion outlined in Section 5 of BS 476:Part 21:1987. The fire resistance rating for the assembly was found to be 44 minutes.

D.E. Wainman
Investigator

D.M. Martin
Manager
Product Design & Engineering

REFERENCES


C.D.
FIG. 1  DIMENSIONAL DETAILS FOR THE RICHARD LEES 'SUPER HOLOРИB' PROFILED STEEL DECKING
FIG. 2
SCHEMATIC ARRANGEMENT OF COMPONENTS - TEST NO. WFRC 44174 (TRANSVERSE SECTION)
(BASED ON ACTUAL DIMENSIONS)
FIG. 5  THERMOCOUPLING POSITIONS IN THE STEELWORK - TRANSVERSE ARRANGEMENT IN DIRECTION OF ARROW 'X' IN FIG. 4
APPENDIX 1

DATA SHEET NO. 126
## COMPOSITE SLIM FLOOR BEAM

### DIMENSIONS AND PROPERTIES

<table>
<thead>
<tr>
<th>Section Serial Size and Type (mm)</th>
<th>Dimensions and Properties</th>
<th>Mass per Metre (kg)</th>
<th>Depth of Section (mm)</th>
<th>Width of Section (mm)</th>
<th>Thickness</th>
<th>Elastic Modulus</th>
<th>Plastic Modulus</th>
<th>Moment of Inertia</th>
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<tr>
<td>254 X 254</td>
<td>Nominal</td>
<td>89</td>
<td>260.4</td>
<td>255.9</td>
<td>10.5</td>
<td>17.3</td>
<td>1099</td>
<td>378.9</td>
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<tr>
<td>Column</td>
<td>Actual</td>
<td>90.9</td>
<td>258</td>
<td>260</td>
<td>10.8</td>
<td>17.4</td>
<td>1097</td>
<td>392.3</td>
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</table>

### CHEMICAL COMPOSITION (PRODUCT ANALYSIS - Wt. %)

<table>
<thead>
<tr>
<th>Section</th>
<th>Steel Quality</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>B</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>V</th>
<th>Cu</th>
<th>Nb</th>
<th>Al</th>
<th>N</th>
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<tr>
<td>Column</td>
<td>Grade 43A</td>
<td>0.15</td>
<td>0.28</td>
<td>0.90</td>
<td>0.009</td>
<td>0.019</td>
<td>&lt;0.02</td>
<td>&lt;0.005</td>
<td>&lt;0.02</td>
<td>&lt;0.005</td>
<td>0.04</td>
<td>&lt;0.005</td>
<td>0.025</td>
<td>0.0038</td>
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### ROOM TEMPERATURE TENSILE PROPERTIES

<table>
<thead>
<tr>
<th>Position</th>
<th>LYS (N/mm²)</th>
<th>UTS (N/mm²)</th>
<th>Elongation (%)</th>
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<tbody>
<tr>
<td>Flange</td>
<td>267</td>
<td>456</td>
<td>39</td>
</tr>
</tbody>
</table>

### TEST CONDITIONS

- Initial ambient temperature = 20°C.
- Based on an initial ambient temperature of 20°C.
- No data recorded.

---

A1/2
### THERMOCOUPLE LOCATION

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>TEMPERATURE Deg C AFTER VARIOUS TIMES (MINUTES)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Upper Range</td>
<td></td>
</tr>
<tr>
<td>F3</td>
<td>16</td>
</tr>
<tr>
<td>F5</td>
<td>17</td>
</tr>
<tr>
<td>F6</td>
<td>17</td>
</tr>
<tr>
<td>Mean</td>
<td>17</td>
</tr>
<tr>
<td>Upper Web</td>
<td></td>
</tr>
<tr>
<td>W5</td>
<td>18</td>
</tr>
<tr>
<td>W6</td>
<td>18</td>
</tr>
<tr>
<td>W7</td>
<td>10</td>
</tr>
<tr>
<td>W8</td>
<td>16</td>
</tr>
<tr>
<td>Mean</td>
<td>18</td>
</tr>
<tr>
<td>Lower Web</td>
<td></td>
</tr>
<tr>
<td>W1</td>
<td>18</td>
</tr>
<tr>
<td>W2</td>
<td>19</td>
</tr>
<tr>
<td>W3</td>
<td>19</td>
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<td>W4</td>
<td>19</td>
</tr>
<tr>
<td>Mean</td>
<td>19</td>
</tr>
<tr>
<td>Lower Range</td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>37</td>
</tr>
<tr>
<td>F2</td>
<td>56</td>
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<tr>
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<td>56</td>
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<td>F5</td>
<td>56</td>
</tr>
<tr>
<td>F6</td>
<td>57</td>
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<tr>
<td>Mean</td>
<td>55</td>
</tr>
</tbody>
</table>

#### Deflection (mm)

A13

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**TEST CENTRE**: Werrington Research **DATA NUMBER**: 126B

**TEST DATE**: 28th April 1999 **RESULTS**

| Time to L/20 | 44 minutes |
| Time to L/5000 d | 41 minutes |
| Time to L/200 | 52 minutes |
| Load Bearing Capacity | 44 minutes |
| Fire Resistance | 44 minutes |

**Mean Furnace Gas**

- (a) 467 595 767 778 747 769 783 800 317 631 654 786 846 942 922 933 466 692 797 878
- (b) 502 603 683 705 739 766 789 806 826 842 865 886 899 912 924 932 454 667 948

**Standard Curve**

- (a) 5 10 17 25 35 45 53 61 68 75 87 110 147 206 226

---

**A13**
APPENDIX 2

LOAD CALCULATION SUMMARY SHEETS

A2.1 TEST NO. WFRC 44174 ON 26 APRIL 1989
A2.2 CALCULATIONS BASED ON BS449:PART 2:1969
A2.3 CALCULATIONS BASED ON BS5950:PART 1:1985
A2.4 COMPARISON OF LOADINGS
A2.1 TEST NO. WFRC 44174 ON 26 APRIL 1989

A2.1.1 Geometry

Figure 2 gives the relevant details

A2.1.2 Material Properties

(a) Steel

Universal Column - 254 x 254 mm x 89 kg/m
Steel Grade - BS 4360 Grade 43A

(b) Summary of Nominal and Actual Dimensions and Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Nominal</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth of Section</td>
<td></td>
<td></td>
</tr>
<tr>
<td>h (mm)</td>
<td>260.4</td>
<td>256</td>
</tr>
<tr>
<td>Breadth of Section</td>
<td>255.9</td>
<td>260</td>
</tr>
<tr>
<td>Thickness of Flange</td>
<td>17.3</td>
<td>17.4</td>
</tr>
<tr>
<td>Thickness of Web</td>
<td>10.5</td>
<td>10.8</td>
</tr>
<tr>
<td>Area of Section</td>
<td>A (mm²)</td>
<td>11 400</td>
</tr>
<tr>
<td>Mass</td>
<td>m (kg/m)</td>
<td>89</td>
</tr>
<tr>
<td>Weight</td>
<td>m (N/m)</td>
<td>873</td>
</tr>
<tr>
<td>Distance of Neutral Axis from Base of Beam</td>
<td>y (mm)</td>
<td>130.2</td>
</tr>
<tr>
<td>Effective Span of Beam</td>
<td>L (mm)</td>
<td>4 500</td>
</tr>
<tr>
<td>Moment of Inertia (x-x)</td>
<td>I (cm⁴)</td>
<td>14 307</td>
</tr>
<tr>
<td>Elastic Modulus (x-x)</td>
<td>Z (cm³)</td>
<td>1 099</td>
</tr>
<tr>
<td>Plastic Modulus (x-x)</td>
<td>S (cm³)</td>
<td>1 228</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
<td>E (kN/mm²)</td>
<td>205</td>
</tr>
<tr>
<td>Design Strength (11)</td>
<td>p (N/mm²)</td>
<td>265</td>
</tr>
</tbody>
</table>

(1) Flange thickness >16 mm, ≤40 mm

(c) Concrete

The density and moisture content of the two types of concrete were measured on the day of the test. The following results were obtained:

For the normal-weight concrete:

Maximum moisture content : 3.0% w/w
Density : 2200 kg/m³

For the light-weight concrete:

Maximum moisture content : 4.7% w/w
Density : 1650 kg/m³
The characteristic strength of both types of concrete was accepted as being 30 N/mm² based on the results from the 28 day cube strength tests. The density of normal weight concrete is typically 2400 kg/m³.

A2.2 CALCULATIONS BASED ON BS449: PART 2:1969

A2.2.1 Calculations Using Nominal Dimensions and Properties

Maximum allowable bending stress, Table 2, (for steel with a minimum yield stress of 275 N/mm²):

\[ f_{\text{max}} = 165 \text{ N/mm}^2 \]

Percentage of allowable bending stress required during the test is 100%.

Therefore, bending stress required is 165 N/mm²

\[ f = 165 \text{ N/mm}^2 \]

The required bending moment is given by \( (f l) / y \).

\[ f l / y = \frac{wL^2}{8} \]

Therefore, \( w \), the load per metre run, (in N/m), is given by:

\[ w = \frac{811}{yL^2} \]

\[ = \frac{8 \times 165 \times 14307 \times 10^{-7}}{130.2 \times 4500 \times 4500} \]

\[ = 71.629 \text{ N/m} \]

For the normal weight concrete slabs on each side of the beam:

Depth = 160 mm

Width = (255.9 - 10.5) / 2 mm

122.7 mm

Total area of cross section = 2 x 160 x 122.7 mm²

39 264 mm²

Density of concrete is 2200 kg/m³

Therefore the normal-weight concrete load per metre run is given by:

\[ w_{\text{nwc}} = 39 264 \times 2200 \times 10^4 \text{ kg/m} \]

\[ = 86.38 \text{ kg/m} \]

\[ = 847.39 \text{ N/m} \]

A2/3
For the light-weight concrete slab,

Depth = 120 mm

Width = 840 mm

Total area of cross section = 120 x 840 mm² = 100 800 mm²

Density of concrete is 1850 kg/m³

Therefore the light-weight concrete load per metre run is given by:

\[ w_{LWC} = 100 \, 800 \times 1850 \times 10^4 \, \text{kg/m} \]

\[ = 186.48 \, \text{kg/m} \]

\[ = 1829.37 \, \text{N/m} \]

The total concrete load per metre run is given by:

\[ w_{cone} = 847.39 + 1829.37 \, \text{N/m} \]

\[ = 2676.8 \, \text{N/m} \]

(say, 2677 N/m)

Total Self Weight of Beam and Concrete Slabs, (Dead Load).

\[ w_1 = 873 + 2677 \, \text{N/m} \]

\[ = 3550 \, \text{N/m} \]

Total load to produce required bending stress

\[ w_2 = 71 \, 629 - 3550 \, \text{N/m} \]

\[ = 68 \, 079 \, \text{N/m} \]

Therefore total imposed load

\[ W = 68 \, 079 \times 4.5 \, \text{N} \]

\[ = 306 \, 356 \, \text{N} \]

\[ = 306.36 \, \text{kN} \]

Using four point loads at \( \frac{1}{6} \), \( \frac{2}{6} \), \( \frac{3}{6} \) and \( \frac{4}{6} \) of the supported span, equivalent to W/4.
Point Loads Required are:

\[ P = 306.36 / 4 \text{ kN} \quad \text{(i.e. 31.22 kg / 4 kg)} \]

\[ = 76.59 \text{ kN} \quad \text{(i.e. 7867 kg)} \]

7.61 tonnes

The total load actually applied was 30.79 tonnes.

A2.2.2 Retrospective Calculations Using Actual Dimensions and Properties

The required bending moment is given by \( f \ell \) / \( y \)

\[ \frac{f \ell}{y} = \frac{wL^2}{8} \]

Therefore, \( w \), the load per metre run, (in N/m), is given by

\[ w = \frac{8 f \ell}{y L^2} \]

\[ = \frac{8 \times 1 \times 14035 \times 10^3}{128 \times 4500 \times 4500} \text{ N/m} \]

\[ = 67.122.2 \text{ N/m} \quad \text{(A2/1)} \]

Since the load actually applied was 30.79 tonnes

\[ W = 30790 \text{ kg} \]

\[ = 302,080 \text{ N} \]

and therefore the total load generating the bending stress is

\[ w_y = 302,050 / 4.5 \text{ N/m} \]

\[ = 67.122.2 \text{ N/m} \]

For the normal weight concrete slabs on each side of the beam.

Depth = 159 mm

Width = \((280 - 10.8) / 2\)

= 124.6 mm

Total area of cross section = \(2 \times 159 \times 124.6 \text{ mm}^2\)

= 39,623 mm²

Density of concrete is 2200 kg/m³

A2/5
Therefore the normal weight concrete load per metre run is given by:

\[ w_{nc} = 39,623 \times 2200 \times 10^4 \text{ kg/m} \]
\[ = 87.17 \text{ kg/m} \]
\[ = 855.14 \text{ N/m} \]

For the light-weight concrete slab:

Depth = 122 mm
Width = 840 mm
Total area of cross section = 122 x 640 mm²
\[ = 102,480 \text{ mm}^2 \]
Density of concrete is 1850 kg/m³

Therefore the light-weight concrete load per metre run is given by:

\[ w_{lw} = 102,480 \times 1850 \times 10^4 \text{ kg/m} \]
\[ = 189.59 \text{ kg/m} \]
\[ = 1859.86 \text{ N/m} \]

The total concrete load per metre run is given by:

\[ w_{tc} = 855.14 + 1859.86 \text{ N/m} \]
\[ = 2715 \text{ N/m} \]

The total self-weight of the Beam and Concrete Slabs is given by

\[ w_s = 891 + 2715 \text{ N/m} \]
\[ = 3606 \text{ N/m} \]

Therefore the load available to generate a bending moment is

\[ w = 67122.2 + 3606 \text{ N/m} \]
\[ = 70,728.2 \text{ N/m} \]
Substituting w in the earlier expression (A2/1) we have:

\[
70728.2 = \frac{8 \times 1 \times 14035 \times 10^7}{128 \times 4500 \times 4500} \text{N/mm}^2
\]

\[
\therefore \quad f = \frac{70728.2 \times 128 \times 4500 \times 4500}{8 \times 14035 \times 10^7} = 163.3 \text{N/mm}^2
\]

The retrospective calculation, based on actual dimensions and properties, suggests that the steel section was loaded to 99% of the maximum allowable bending stress (BS 449 Design Rules).

A2.3 CALCULATIONS BASED ON BS5950:PART 1:1985

A2.3.1 Initial Calculations Using Nominal Dimensions and Properties

(a) Moment Capacity of beam for a plastic or compact section, with assumed low shear load.

\[
M_i = p_i S \quad \text{but} \leq 1.2 p_i Z
\]

\[
= 265 \times 1228 \times 10^6 \text{kN m}
\]

\[
= 325,424 \text{kN m}
\]

Check whether \( p_i S \leq 1.2 p_i Z \)

\[
1.2 p_i Z = 1.2 \times 265 \times 1099 \times 10^3 \text{kN m}
\]

\[
= 349,488 \text{kN m}
\]

So \( p_i S \) is less than 1.2 \( p_i Z \)

(b) From A2.2.1, Self Weight of beam and Concrete Slabs, (dead load), is 3588 N/m

So \( w_i = 3588 \text{kN/m} \)

Moment produced by dead load is given by

\[
\text{Moment}_i = \frac{(w_i L)^2}{8} \text{kN m}
\]

\[
= \frac{3588 \times 4.5 \times 4.5}{8} \text{kN m}
\]

\[
= 9,082 \text{kN m}
\]

From A2.2.1, Total Imposed Load is 306 185 N.

So \( W = 306,185 \text{kN} \)
Assuming a uniformly distributed load, the moment produced by the imposed load is given by

\[
\text{Moment}_p = \frac{(WL)}{8} \text{ kN m}
\]
\[
= \frac{306.185 \times 4.5}{8} \text{ kNm}
\]
\[
= 172.229 \text{ kNm}
\]

Total Moment Applied, (dead + imposed loads)

\[
M_u = 9.082 + 172.229 \text{ kNm}
\]
\[
= 181.311 \text{ kNm}
\]

Since \(M_u\) also equals the applied moment at the fire limit state, \(M_f\), then the load ratio is

\[
\text{LR} = \frac{M_f}{M_u}
\]
\[
= \frac{181.311}{325.42}
\]
\[
= 0.557
\]

(c) Check Shear Force, \((F_v)\), does not exceed shear capacity, \((P_v)\)

Maximum Shear Force at the ends

\[
F_v = \frac{WL}{2}
\]
\[
= \frac{(71.629 \times 4.5)}{2} \text{ kN}
\]
\[
= 161.165 \text{ kN}
\]

Shear Capacity

\[
P_v = 0.6 \rho f A_v
\]

where \(A_v\) is the shear area.

For an I section \(A_v = h \times s\)

\[
P_v = 0.6 \times 265 \times 260.4 \times 10.5 \times 10^{-3} \text{ kN}
\]
\[
= 434.74 \text{ kN}
\]

Therefore since \(F_v < P_v\), the low shear load calculation, (a), is acceptable.

A2/8
A2.3.2 Calculations Using Actual Dimensions and Properties

(a) Moment Capacity of Beam for a plastic or compact section, with assumed low shear load:

\[ M_a = p_s S \quad \text{but } s \leq 1.2 p_s Z \]
\[ = 267 \times 1225 \times 10^{-3} \text{ kN m} \]
\[ = 327.34 \text{ kN m} \]

Check whether \( p_s S \leq 1.2 p_s Z \)

\[ 1.2 p_s Z = 1.2 \times 267 \times 1097 \times 10^{-3} \text{ kN m} \]
\[ = 351.46 \text{ kN m} \]

So \( p_s S \) is less than \( 1.2 p_s Z \).

(b) From A2.2.2, Self Weight of beam and concrete slabs, (dead load), is 3606 N/m.

So \( w_1 = 3606 \text{ kN/m} \)

Moment produced by dead load is given by

\[ \text{Moment}_1 = \frac{(w_1 L^2)}{8} \text{ kN m} \]
\[ = \frac{3606 \times 4.5 \times 4.5}{8} \text{ kN m} \]
\[ = 9.128 \text{ kN m} \]

From A2.2.2 Total imposed load is 392 050 N.

So \( W = 302.050 \text{ kN} \)

Assuming a uniformly distributed load, the moment produced by the imposed load is given by

\[ \text{Moment}_2 = \frac{(WL)}{8} \text{ kN m} \]
\[ = \frac{302.050 \times 4.5}{8} \text{ kN m} \]
\[ = 169.903 \text{ kN m} \]

Total Moment Applied, (dead + imposed loads)

\[ M_s = 9.128 + 169.903 \text{ kN m} \]
\[ = 179.031 \text{ kN m} \]
and therefore the load ratio given by

\[
LR = \frac{M}{M_c} = \frac{179.031}{327.34} = 0.547
\]

### A2.4 COMPARISON OF LOADINGS

#### A2.4.1 BS 449:Part 2:1969

Based on nominal dimensions and section properties it was calculated that in order to develop the maximum permissible bending stress of 165 N/mm² in the lower flange of the steel section an imposed load of 31.2 tonnes was required. However, in the test the load actually applied was 30.79 tonnes. Retrospective calculations using this load in conjunction with the actual section properties data indicates that the bending stress in the lower flange was very slightly lower than intended at 163.3 N/mm², or 99% of the maximum permitted value.

#### A2.4.2 BS 5950:Part 1:1985

Based on nominal values and the application of the previously calculated imposed loading of 31.2 tonnes the load ratio for the test assembly was found to be 0.557. When the lower actual loading value was used in conjunction with the actual section properties data the load ratio value reduced to 0.547.
APPENDIX 3

PC DISK VERSION OF DATA

As mentioned in the Introduction to this report the data recorded during the test are available on a PC disk. The following section gives a brief outline of the material available and its format. The reader may find it useful to additionally consult Reference A3.1.

The data are held on the disk 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 K, 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 file is identified by reference to the DATA SHEET NUMBER sequence, i.e. 126.DAT. This numbering system is consistent with that introduced in Reference A3.1. The thermal data recorded during the fire tests have been divided into 'SETS' which reflect the positions of the thermocouples in the steel section. Mean temperature values are included in the 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 the data file, README.126 which relates to data in file 126.DAT is shown in Table A3.1.

REFERENCE

### TABLE A3.1
**README FILE ASSOCIATED WITH DATA FILE 126.DAT**

Data file 126.DAT contains data recorded during the standard fire resistance test number WFRC 44174 which is described in report SL/PDE/R/S2442/4/96/C - "Summary of Data Obtained During a Test on a Composite Slim Floor Beam" and should be read in conjunction with that document.

There are 31 items of data which, together with their mean values, are grouped in sets as shown below.

<table>
<thead>
<tr>
<th>Set Number</th>
<th>Items in Columns</th>
</tr>
</thead>
<tbody>
<tr>
<td>SET001.DAT</td>
<td>TIME, F3, F5, F8, MEAN</td>
</tr>
<tr>
<td>SET002.DAT</td>
<td>TIME, W6, W8, W7, W8, MEAN</td>
</tr>
<tr>
<td>SET003.DAT</td>
<td>TIME, W1, W2, W3, W4, MEAN</td>
</tr>
<tr>
<td>SET004.DAT</td>
<td>TIME, F1, F2, F4, F6, F7, MEAN</td>
</tr>
<tr>
<td>SET005.DAT</td>
<td>TIME, A1, A2, A3, A4, A5, A6</td>
</tr>
<tr>
<td>SET006.DAT</td>
<td>TIME, ISO, AT1, AT2, AT3, AT4, AT5, AT6, MEAN ATM</td>
</tr>
<tr>
<td>SET007.DAT</td>
<td>TIME, DEFORMATION</td>
</tr>
</tbody>
</table>

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