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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/mm^2, (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.

KEYWORDS

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+BS 476
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+BS 5950
+BS 449

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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 numbered 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 WFRC 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 butted 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 12 mm sieve size. It was cast in accordance with a specification given by BORAL / 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 HOLORIB' 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 tangs 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 4360:Grade 43A (now BS EN 10025 S275). 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/m^3
- Moisture Content : 3.9% w/w

For the light weight concrete.

- Density : 1850 kg/m^3
- Moisture Content : 4.7% w/w

The compressive, (crushing), strengths measured 28 days after casting were reported to be 30 N/mm^2 for both types of concrete.

3. DIMENSIONS AND SECTION PROPERTIES

The nominal dimensions and section properties, as specified in BS4:Part 1:1980 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 were as shown in Fig. 4, (longitudinal arrangement), and Fig. 5, (transverse arrangement).

Thermocouples of the same type were installed by WFRC 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. 126B 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 $^1/_8$, $^3/_8$, $^5/_8$, and $^7/_8$, 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/mm^2 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^2 / 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.

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D.M. Martin
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C.D.

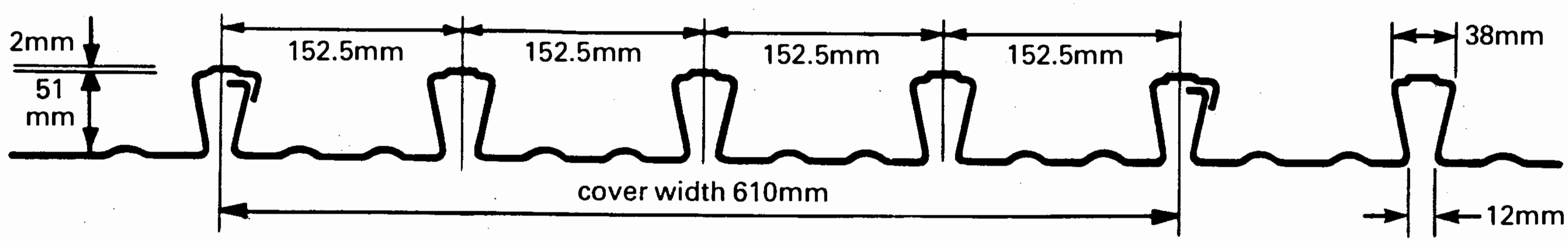
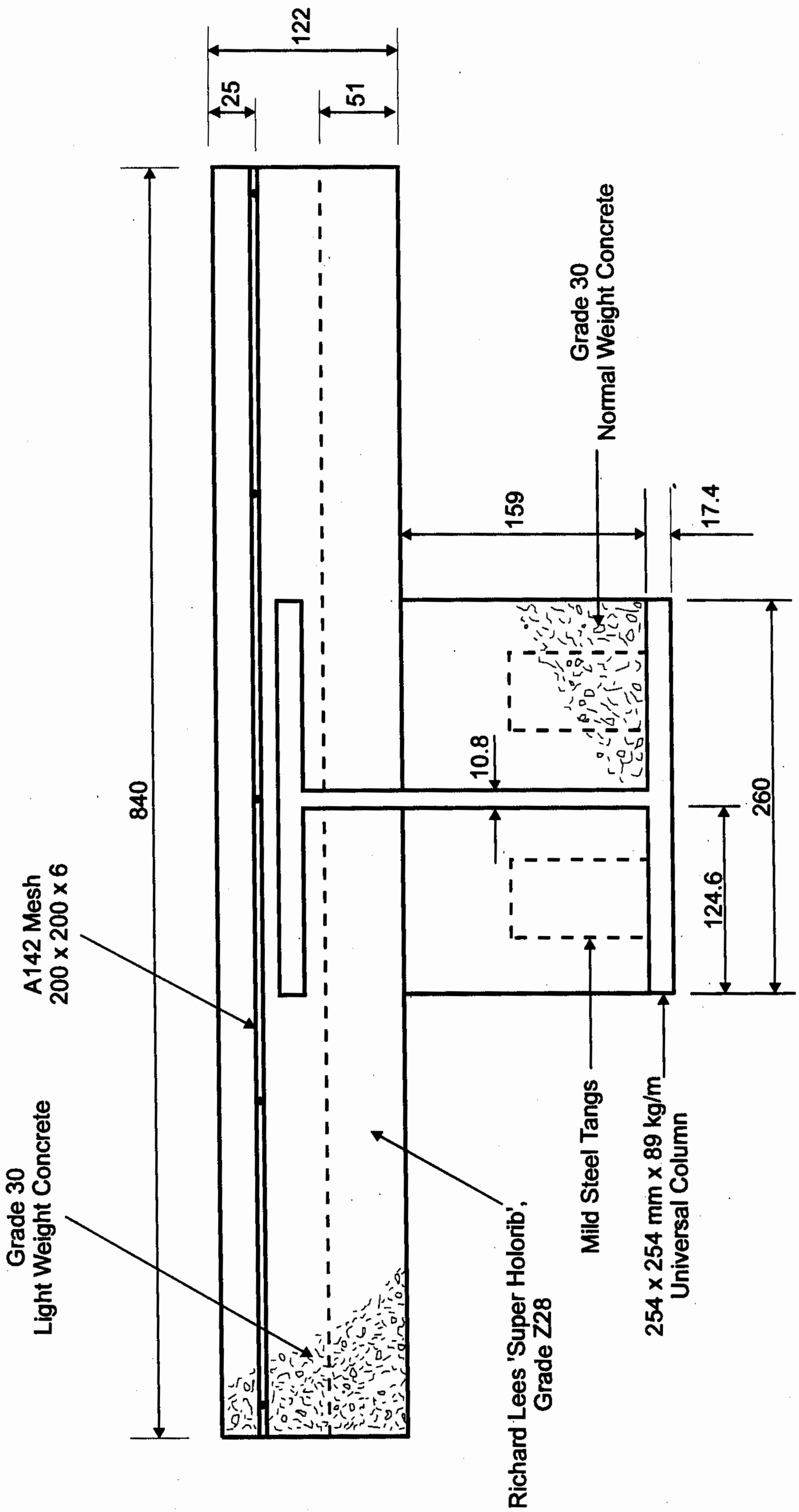


FIG. 1 DIMENSIONAL DETAILS FOR THE RICHARD LEES 'SUPER HOLORIB' PROFILED STEEL DECKING



(All Dimensions in mm)

FIG. 2 SCHEMATIC ARRANGEMENT OF COMPONENTS - TEST NO. WFRC 44174 (TRANSVERSE SECTION) (D0229C05)
(BASED ON ACTUAL DIMENSIONS)

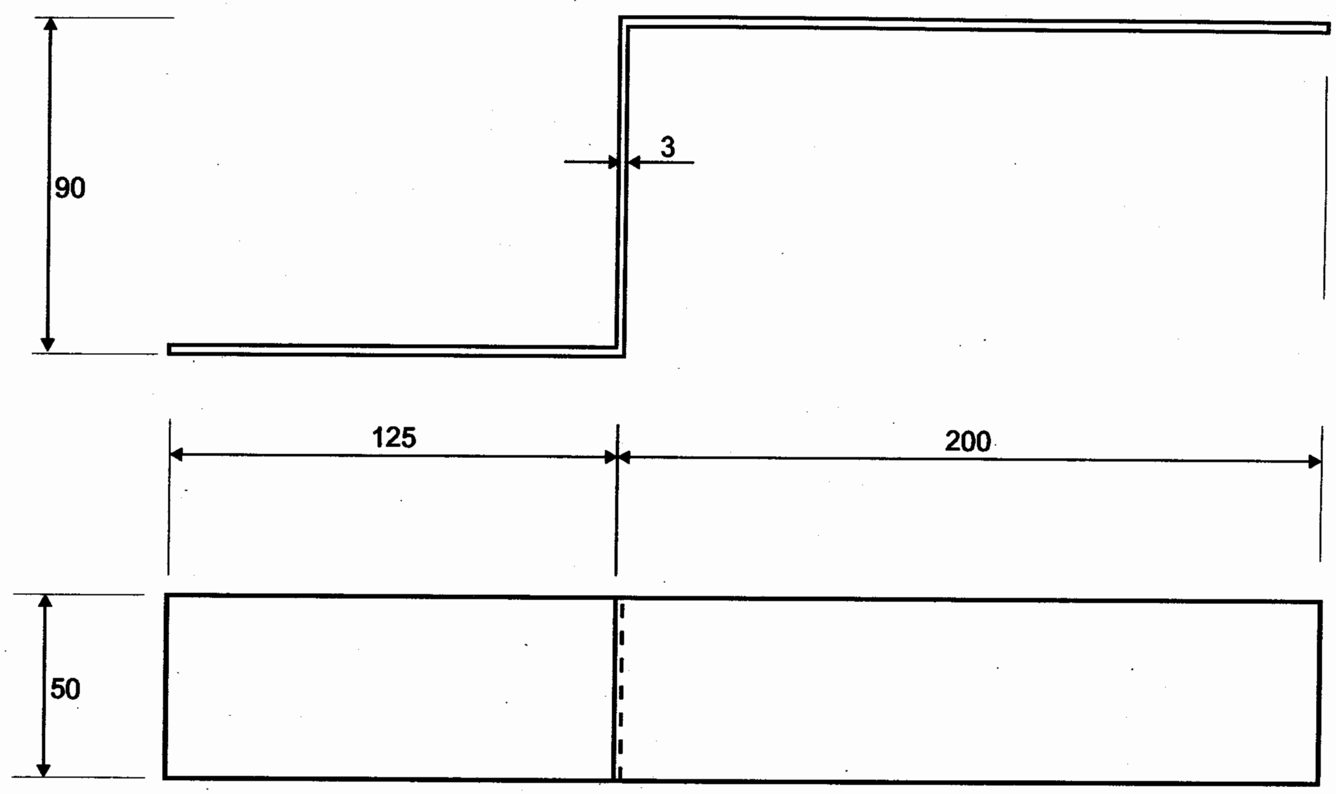
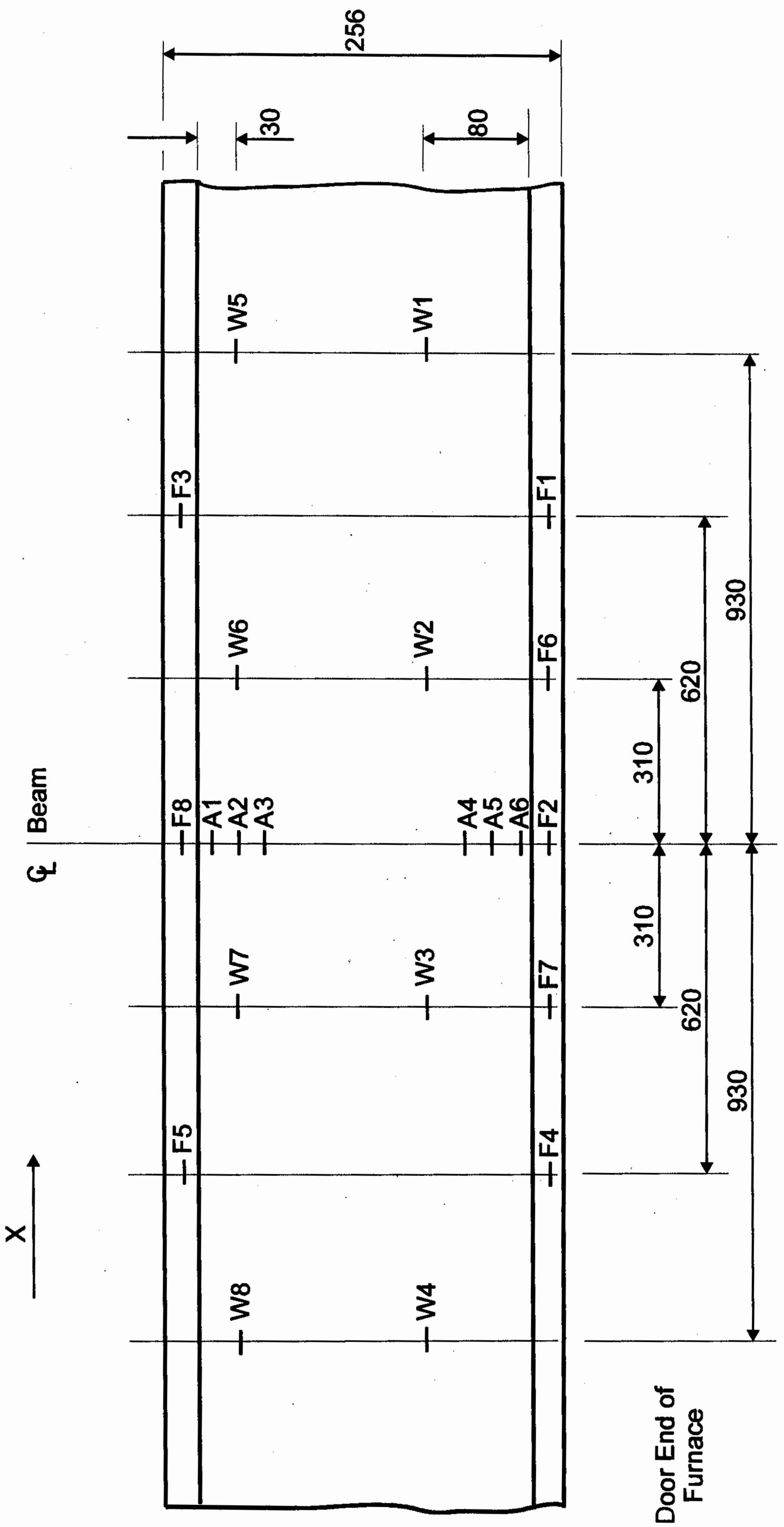


FIG. 3 DIMENSIONAL DETAILS FOR THE MILD STEEL TANGS (D0229C05)



(All Dimensions in mm)

FIG. 4 THERMOCOUPLE POSITIONS IN THE STEELWORK - LONGITUDINAL ARRANGEMENT (D0229C05)

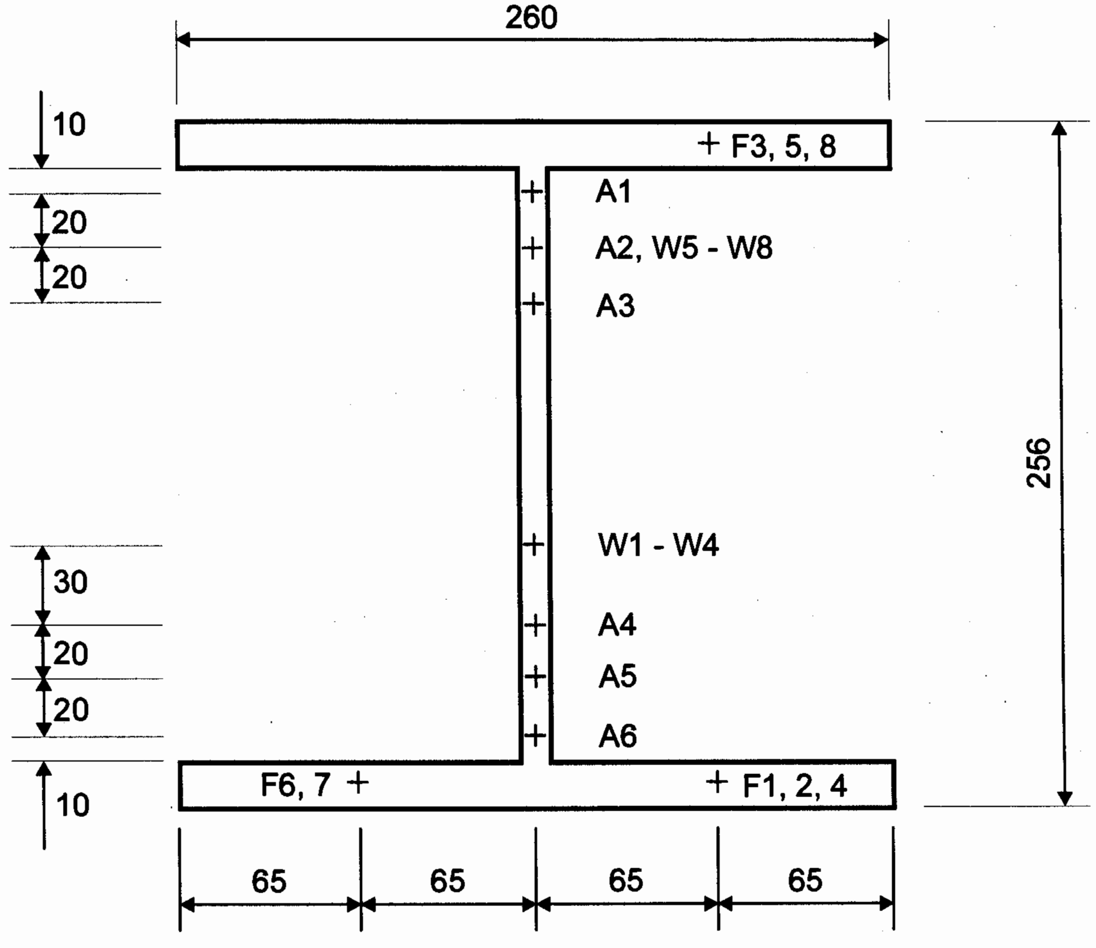


FIG. 5 **THERMOCOUPLE POSITIONS IN THE STEELWORK - TRANSVERSE ARRANGEMENT IN DIRECTION OF ARROW 'x' IN FIG. 4** **(D0229C06)**

APPENDIX 1

DATA SHEET NO. 126

DATA SHEET NUMBER	126A

COMPOSITE SLIM FLOOR BEAM

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 X 254 Column	Nominal Actual	89 90.9	260.4 256	255.9 260	10.5 10.8	17.3 17.4	1099 1097	378.9 392.3	1228 1226	575.4 595.7	14 307 14 035	4849 5100

CHEMICAL COMPOSITION (PRODUCT ANALYSIS - Wt. %)

Section	Steel Quality	C	Si	Mn	P	S	Cr	Mo	Ni	V	Cu	Nb	Al	N
Column	Grade 43A	0.15	0.28	0.90	0.009	0.019	<0.02	<0.005	<0.02	<0.005	0.04	<0.005	0.025	0.0038

ROOM TEMPERATURE TENSILE PROPERTIES

Position	LYS (N/mm^2)	UTS (N/mm^2)	Elongation (%)
Flange	267	456	39

TEST CONDITIONS

NOTES

(a) Initial ambient temperature = 20°C.

(b) Based on an initial ambient temperature of 20°C.

(*) No data recorded.

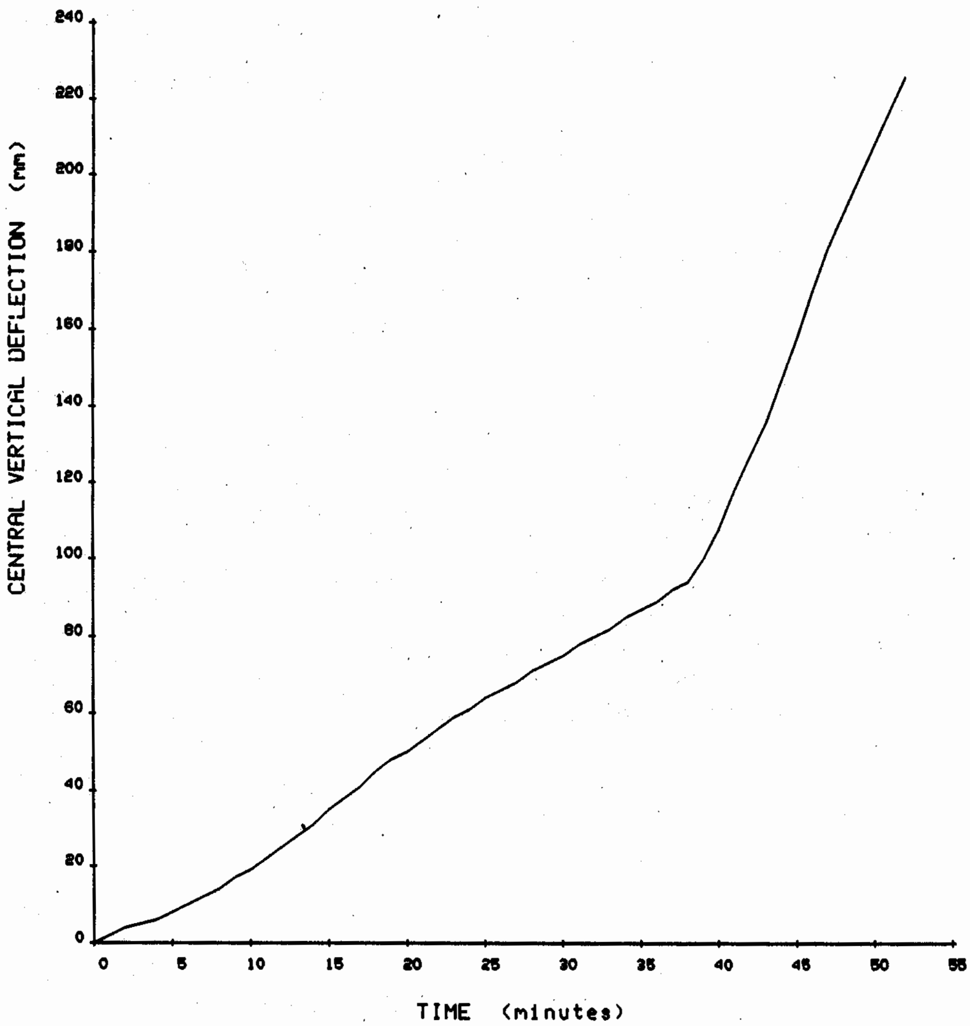
TEST CENTRE	: Warrington Research
TEST DATE	: 26th April 1989
TEST NUMBER	: WFRC 44174

BS476:PARTS 20 & 21: 1987 RESULTS	
Time to L/30	: 44 minutes
Time to $L^2/9000$ D	: 41 minutes
Time to L/20	: 52 minutes
Reload Test	: Not carried out
Load Bearing Capacity	: 44 minutes
Fire Resistance	: 44 minutes

DATA SHEET NUMBER **126B**

THERMOCOUPLE LOCATION		TEMPERATURE Deg. C AFTER VARIOUS TIMES (MINUTES)																		
		3	6	9	12	15	18	21	24	27	30	35	40	44	50	52	55	60	65	70
Upper Flange	F3	16	17	19	22	25	29	33	39	46	53	71	92	103	106	108	110	115	125	141
	F5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	F8	17	18	19	21	24	27	31	34	39	44	59	78	94	104	104	105	105	106	108
	Mean	17	18	19	22	25	28	32	37	43	49	65	85	99	105	106	108	110	116	125
Upper Web	W5	18	19	21	23	27	33	44	60	73	83	94	101	104	114	119	125	133	143	153
	W6	18	19	22	25	29	35	43	53	64	74	87	95	101	111	116	122	132	142	154
	W7	18	18	20	22	25	30	37	46	57	70	83	90	94	100	103	110	119	125	132
	W8	16	17	19	21	24	29	36	44	53	63	77	89	98	107	111	118	127	138	150
	Mean	18	18	21	23	26	32	40	51	62	73	85	94	99	108	112	119	128	137	147
Lower Web	W1	18	24	34	49	86	110	129	148	167	185	214	238	256	281	289	302	322	340	358
	W2	19	25	36	55	100	112	127	147	167	187	218	244	262	287	296	310	329	347	367
	W3	19	24	32	44	84	107	120	140	157	173	200	222	238	262	270	282	302	321	340
	W4	19	25	35	51	88	113	128	147	165	183	213	238	257	282	290	304	323	342	361
	Mean	19	25	34	50	90	111	126	146	164	182	211	236	253	278	286	300	319	338	357
Lower Flange	F1	57	105	163	229	299	369	431	488	537	582	646	695	726	761	774	795	825	856	885
	F2	56	105	166	234	305	372	434	474	519	570	639	692	724	764	778	798	830	863	892
	F4	52	97	149	212	276	336	394	446	495	541	608	664	697	717	726	738	771	807	846
	F6	55	104	159	223	290	354	414	469	518	563	627	677	711	751	765	787	817	850	880
	F7	53	99	157	221	289	349	411	468	518	564	627	679	715	755	769	790	821	854	884
	Mean	55	102	159	224	292	356	417	469	517	564	629	681	715	750	762	782	813	846	877
Web @ 10 mm from U/F	A1	17	17	18	21	24	28	32	39	46	54	70	87	98	104	104	105	110	113	117
Web @ 30 mm from U/F	A2	17	17	18	21	25	30	38	48	58	68	83	94	100	104	105	110	119	126	133
Web @ 50 mm from U/F	A3	17	17	19	22	26	33	45	59	73	86	97	102	104	108	113	122	133	142	150
Web @ 50 mm from L/F	A4	23	35	55	92	121	153	184	213	240	267	306	339	362	391	401	415	434	457	480
Web @ 30 mm from L/F	A5	29	48	78	117	157	197	236	273	307	339	388	428	456	492	503	518	541	565	590
Web @ 10 mm from L/F	A6	41	71	115	163	216	270	320	367	409	449	509	556	589	629	640	656	681	709	737
Mean Furnace Gas	(a)	467	595	677	718	747	769	783	800	817	831	854	876	892	915	922	933	946	962	979
Standard Curve	(b)	502	603	663	705	739	766	789	809	826	842	865	885	899	918	924	932	945	957	968
Deflection (mm)		5	10	17	25	35	45	53	61	68	75	87	108	147	208	226	-	-	-	-

DATA SHEET NUMBER	**126C**



APPENDIX 2

LOAD CALCULATION SUMMARY SHEETS

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

		Nominal	Actual
Depth of Section	h (mm)	260.4	256
Breadth of Section	b (mm)	255.9	260
Thickness of Flange	t (mm)	17.3	17.4
Thickness of Web	s (mm)	10.5	10.8
Area of Section	A (mm^2)	11 400	11 575
Mass	m (kg/m)	89	90.86
Weight	m (N/m)	873	891
Distance of Neutral Axis from Base of Beam	y (mm)	130.2	128
Effective Span of Beam	L (mm)	4 500	4 500
Moment of Inertia (x-x)	I (cm^4)	14 307	14 035
Elastic Modulus (x-x)	Z (cm^3)	1 099	1 097
Plastic Modulus (x-x)	S (cm^3)	1 228	1 226
Modulus of Elasticity	E (kN/mm^2)	205	205
Design Strength [(†)]	p_y (N/mm^2)	265	267
Classification	Class 1, Plastic (Table 7, BS5950)		

† 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 : 3.9% w/w
Density : 2200 kg/m^3

For the light-weight concrete:-

Maximum moisture content : 4.7% w/w
Density : 1850 kg/m^3

The characteristic strength of both types of concrete was accepted as being 30 N/mm^2 based on the results from the 28 day cube strength tests. The density of normal weight concrete is typically 2400 kg/m^3.

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/mm^2):

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

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

Therefore, bending stress required is 165 N/mm^2

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

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

$$\frac{f\,I}{y} = \frac{wL^2}{8}$$

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

$$w = \frac{8fI}{yL^2}$$

$$= \frac{8 \times 165 \times 14\,307 \times 10^7}{130.2 \times 4500 \times 4500} \text{ N/m}$$

$$= \underline{71\,629 \text{ N/m}}$$

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 mm^2

= 39 264 mm^2

Density of concrete is 2200 kg/m^3

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

$$w_{NWC} = 39\,264 \times 2200 \times 10^{-6} \text{ kg/m}$$

$$= 86.38 \text{ kg/m}$$

$$= \underline{847.39 \text{ N/m}}$$

For the light-weight concrete slab.

Depth	=	120 mm
Width	=	840 mm

Total area of cross section = $120 \times 840\ mm^2$

= <u>$100\,800\ mm^2$</u>

Density of concrete is $1850\ kg/m^3$

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

w_{LWC} = $100\,800 \times 1850 \times 10^{-6}$ kg/m

= 186.48 kg/m

= <u>1829.37 N/m</u>

The total concrete load per metre run is given by:

w_{conc} = 847.39 + 1829.37 N/m

= <u>2676.8 N/m</u>

(say, 2677 N/m)

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

w_1 = 873 + 2677 N/m

= <u>3550 N/m</u>

Total load to produce required bending stress

w_2 = 71 629 - 3550 N/m

= <u>68 079 N/m</u>

Therefore total imposed load

W = 68 079 x 4.5 N

= 306 356 N

= <u>306.36 kN</u>

Using four point loads at $^1/_8$, $^3/_8$, $^5/_8$ and $^7/_8$ of the supported span, equivalent to W/4.

Point Loads Required are:-

$$P = 306.36 / 4 \text{ kN} \quad \text{(i.e. 31 229 / 4 kg)}$$

$$= \underline{76.59 \text{ kN}} \quad \text{(i.e. 7807 kg)}$$

$$\underline{7.81 \text{ tonnes}}$$

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 I) / y

$$\frac{f\,I}{y} = \frac{w\,L^2}{8}$$

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

$$w = \frac{8\,f\,I}{y\,L^2}$$

$$= \frac{8 \times f \times 14\,035 \times 10^7}{128 \times 4500 \times 4500} \text{ N/m} \qquad \text{... (A2/1)}$$

Since the load actually applied was 30.79 tonnes

$$W = 30\,790 \text{ kg}$$

$$= \underline{302\,050 \text{ N}}$$

and therefore the total load generating the bending stress is

$$w_2 = 302\,050 / 4.5 \text{ N/m}$$

$$= \underline{67\,122.2 \text{ N/m}}$$

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

Depth = 159 mm

Width = (260 - 10.8) / 2

= 124.6 mm

Total area of cross section = 2 x 159 x 124.6 mm^2

= 39 623 mm^2

Density of concrete is 2200 kg/m^3

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

$$w_{NWC} = 39\,623 \times 2200 \times 10^{-6} \text{ kg/m}$$

$$= 87.17 \text{ kg/m}$$

$$= \underline{855.14 \text{ N/m}}$$

For the light-weight concrete slab.

Depth = 122 mm

Width = 840 mm

Total area of cross section = 122×840 mm^2

= $\underline{102\,480 \text{ mm}^2}$

Density of concrete is 1850 kg/m^3

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

$$w_{LWC} = 102\,480 \times 1850 \times 10^{-6} \text{ kg/m}$$

$$= 189.59 \text{ kg/m}$$

$$= \underline{1859.86 \text{ N/m}}$$

The total concrete load per metre run is given by:

$$w_{conc} = 855.14 + 1859.86 \text{ N/m}$$

$$= \underline{2715 \text{ N/m}}$$

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

$$w_1 = 891 + 2715 \text{ N/m}$$

$$= \underline{3606 \text{ N/m}}$$

Therefore the load available to generate a bending moment is

$$w = 67\,122.2 + 3606 \text{ N/m}$$

$$= \underline{70\,728.2 \text{ N/m}}$$

Substituting w in the earlier expression (A2/1) we have:

$$70\,728.2 = \frac{8 \times f \times 14\,035 \times 10^7}{128 \times 4500 \times 4500} \text{ N/mm}^2$$

$$\therefore \quad f = \frac{\underline{70\,728.2 \times 128 \times 4500 \times 4500}}{8 \times 14\,035 \times 10^7}$$

$$= \underline{163.3 \text{ N/mm}^2}$$

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.

$$M_c = p_y S \quad \text{but} \le 1.2\, p_y Z$$

$$= 265 \times 1228 \times 10^{-3} \text{ kN m}$$

$$= \underline{325.42 \text{ kN m}}$$

Check whether $p_y S \le 1.2\, p_y Z$

$$1.2\, p_y Z = 1.2 \times 265 \times 1099 \times 10^{-3} \text{ kN m}$$

$$= \underline{349.48 \text{ kN m}}$$

So $p_y S$ is less than $1.2\, p_y Z$

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

So $w_1 = \underline{3.588 \text{ kN/m}}$

Moment produced by dead load is given by

$$\text{Moment}_1 = (w_1 L^2) / 8 \text{ kN m}$$

$$= \frac{\underline{3.588 \times 4.5 \times 4.5}}{8} \text{ kN m}$$

$$= \underline{9.082 \text{ kN m}}$$

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

So $W = \underline{306.185 \text{ kN}}$

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

$$\text{Moment}_2 = (WL)/8 \text{ kN m}$$

$$= \frac{306.185 \times 4.5}{8} \text{ kN m}$$

$$= \underline{172.229 \text{ kN m}}$$

Total Moment Applied, (dead + imposed loads)

$$M_x = 9.082 + 172.229 \text{ kN m}$$

$$= \underline{181.311 \text{ kN m}}$$

Since M_x also equals the applied moment at the fire limit state, M_f, then the load ratio is

$$LR = M_f / M_c$$

$$= 181.311 / 325.42$$

$$= \underline{0.557}$$

(c) Check Shear Force, (F_V), does not exceed shear capacity, (P_V)

Maximum Shear Force at the ends

$$F_V = \frac{wL}{2}$$

$$= (71.629 \times 4.5) / 2 \text{ kN}$$

$$= \underline{161.165 \text{ kN}}$$

Shear Capacity

$$P_V = 0.6\, p_y\, A_v$$

where A_v is the shear area.

For an I section $A_v = h \times s$

$$\therefore \quad P_V = 0.6 \times 265 \times 260.4 \times 10.5 \times 10^{-3} \text{ kN}$$

$$= \underline{434.74 \text{ kN}}$$

Therefore since $F_V < P_V$ the low shear load calculation, (a), is acceptable.

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.

$M_c = p_y S$ but $\leq 1.2\, p_y Z$

$= 267 \times 1226 \times 10^{-3}$ kN m

$=$ <u>327.34 kN m</u>

Check whether $p_y S \leq 1.2\, p_y Z$

$1.2\, p_y Z = 1.2 \times 267 \times 1097 \times 10^{-3}$ kN m

$=$ <u>351.48 kN m</u>

So $p_y S$ is less than $1.2\, p_y Z$.

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

So $w_1 =$ <u>3.606 kN/m</u>

Moment produced by dead load is given by

$\text{Moment}_1 = (w_1 L^2) / 8$ kN m

$$= \frac{3.606 \times 4.5 \times 4.5}{8} \text{ kN m}$$

$=$ <u>9.128 kN m</u>

From A2.2.2 Total imposed load is 302 050 N.

So $W = 302.050$ kN

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

$\text{Moment}_2 = (WL) / 8$ kN m

$$= \frac{302.050 \times 4.5}{8} \text{ kN m}$$

$=$ <u>169.903 kN m</u>

Total Moment Applied, (dead + imposed loads)

$M_x = 9.128 + 169.903$ kN m

$=$ <u>179.031 kN m</u>

and therefore the load ratio given by

$$LR = M_f / M_c$$

$$= 179.031 / 327.34$$

$$= \underline{0.547}$$

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/mm^2 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/mm^2, 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 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 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 test 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

A3.1 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 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.

Set Number	Items in Columns
SET001.DAT	TIME, F3, F5, F8, MEAN
SET002.DAT	TIME, W5, W6, W7, W8, MEAN
SET003.DAT	TIME, W1, W2, W3, W4, MEAN
SET004.DAT	TIME, F1, F2, F4, F6, F7, MEAN
SET005.DAT	TIME, A1, A2, A3, A4, A5, A6
SET006.DAT	TIME, ISO, AT1, AT2, AT3, AT4, AT5, AT6, MEAN ATM
SET007.DAT	TIME, DEFLECTION