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BS476: Part 8 Indicative Fire Tests on Slim Floor Assemblies

British Steel Corporation

Research Organisation

BS476:PART 8 INDICATIVE FIRE TESTS ON SLIM FLOOR ASSEMBLIES

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SYNOPSIS

Two BS476:Part 8 indicative fire tests have been carried out to measure the local heating rates of the steel in slim floor assemblies incorporating 254 x 254 mm column sections and 200 mm thick concrete slabs. The results suggested that a 1 h fire resistance time should be achieved with the 132 kg/m and 167 kg/m universal columns used as fully loaded floor beams but that the ability of the lighter 107 kg/m section to satisfy the same fire rating was questionable.

KEY WORDS

3. Fire Resistance
4. Concrete
5. Floors
6. +BS 476
7. Fire Tests
8. Lab Reports

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BS476:PART 8 INDICATIVE FIRE TESTS ON SLIM FLOOR ASSEMBLIES

1. INTRODUCTION

The most common form of floor construction in steel framed buildings consists of precast concrete slabs resting on the top flange of a universal beam. Few fully loaded, bare steel beams in sizes of commercial interest achieve a fire resistance time in excess of ½ h when tested to BS476:Part 8 in the simply supported condition. However, research has shown that by combining steel frame members within other elements of structure it is possible to attain a fire resistance of 1 h without the added cost of fire protection. Such a design procedure is incorporated in the draft BS5950:Part 8 for the shelf angle beam. An added advantage is that the depth of the floor membrane is reduced by placing the precast concrete slabs on steel angles bolted to the web of the beam.

The floor depth in a steel framed multistorey building influences the costs of cladding and service ducting. Slim floors with minimum beam downstand allow minimum cladding area and maximum freedom for service runs in any direction with the result of minimum cladding material cost and minimum service fixing time. Current designs of slim floor utilised a column section as the floor beam to support the precast concrete slabs on the inside of the bottom flange. The assembly provides partial protection to the steelwork with the attendant benefits of improved fire resistance.

Any mathematical analysis of the performance of a slim floor design in a fire environment consists of two discrete parts, calculation of the thermal response followed by a structural assessment. The accuracy with which a structural analysis can be performed depends on the accuracy of the temperature distributions calculated during the first stage. In the absence of sufficient thermal data to enable an accurate structural analysis to be carried out, the present report describes two indicative BS476:Part 8 fire tests in which the steel heating rates of slim floor assemblies were measured. The first experiment, carried out in the 1 m cube furnace at the Warrington Research Centre comprised a 254 x 254 mm x 132 kg/m universal column section and 200 mm thick precast concrete floor slabs. The second test, comprised a composite steel section made from three different weights of the 254 x 254 mm universal column serial size to form a 5 m beam which supported 200 mm thick concrete slabs.

2. EXPERIMENTAL PROCEDURE

The steel members used in the test comprised BS4360:Grade 43A columns of the following serial sizes:-

(a) For the 1 m cube furnace:

1.4 m length of 254 x 254 mm x 132 kg/m universal column.

(b) For the composite beam:

1.85 m length of 254 x 254 mm x 107 kg/m universal column.
1.85 m length of 254 x 254 mm x 132 kg/m universal column.
1.33 m length of 254 x 254 mm x 167 kg/m universal column.

Both ends of the 167 kg/m section and one end of each of the remaining sections were prepared for welding by grinding small chamfers on the flanges. The three sections were manually butt welded together to form the composite beam of Fig. 1 which was approximately 6.0 m in length. The sections were welded with the inner flange surfaces flush.

Chromel/alumel Type K 3 mm diameter thermocouples with insulated hot junctions were attached to the sections at the positions shown in Fig. 2 for the test in the cube furnace and in Fig. 3 for the composite beam.

The concrete slabs were specially cast to a Grade 30 strength and were 550 mm wide x 200 mm thick and 1550 mm long. Two slabs were used with the short section, one on

each side of the web, and these had been fired in an earlier test. Sixteen slabs were placed on the inner surface of the lower flange of the composite beam, eight on each side of the web. For both indicative tests the slabs were positioned to give a 75 mm bearing length, which left a gap of approximately 50 mm between the web and the end of the slab. The cavity was filled with sand to simulate the screed that is used in site practice. As no load was applied to the assembly the contact between the concrete and the steel flange was not as good as encountered in a complete BS476:Part 8 test. The floor beam is shown during assembly in Fig. 4(a) and during the fire test in Fig. 4(b).

3. EXPERIMENTAL RESULTS

3.1 Cube Furnace Test - 3rd April 1985

The average furnace gas and steel temperatures recorded during the test are given in Table 1. The test was prolonged for 120 min and for the majority of the time the furnace temperature was approximately 50°C higher than that required by the standard curve. The position of the burners was 300 mm below the exposed flange of the column. As the concrete slabs had been used in a previous fire test, evaporation of moisture only occurred after 50 min showing that the concrete was comparatively dry.

The steel temperature in the lower flange of the section reached 769°C after 1 h, 243°C at the ¼ web position, 148°C at the ¾ web position and 64°C on the upper flange. The temperature profiles are also shown in Fig. 5.

3.2 Composite Beam Behaviour - 20th November 1985

The furnace gas temperature recorded during the test are given in Table 2. The heating rate closely followed the standard curve for the first 20 min and thereafter dropped by approximately 40°C below the curve for the remainder of the test, as shown in Fig. 6.

The steel temperatures recorded during the test are given in Tables 3 to 5 for the three indicative slim floor designs. The temperature profiles are also shown in Figs. 7 to 9 for the slim floor assemblies incorporating the respective 254 x 254 mm column weights of 107, 132 and 167 kg/m. After 1 h, the steel temperatures in the lower flange were 700°C, 680°C and 692°C with increasing section weight respectively, the upper flange temperatures ranged from 45 to 90°C.

4. DISCUSSION

In the two indicative fire tests on the slim floor assembly incorporating the 254 x 254 mm x 132 kg/m columns the steel heating rates were different. The comparison is shown in Fig. 10; after 1 h into the BS476:Part 8 test the difference in the lower flange temperature between the two columns was 90°C. On the basis of the standard ISO curve the furnace temperature was approximately 50°C higher in the first test and 40°C lower in the second test. Under standard heating conditions the lower flange temperature after 1 h would therefore be approximately 725°C.

The calculated rise in temperature of the lower and upper flanges of this section using the finite element model is superimposed on the experimental curves of Fig. 10 and show good agreement with the average values recorded. The use of the FASBUS II program to calculate the deflection behaviour of the 132 kg/m section predicted a fire resistance of 66½ min at L/30 at which time the lower flange temperature would be 750°C. In a preliminary BS476:Part 8 fire test on a nominally fully loaded, slim floor assembly which used a 254 x 254 mm x 73 kg/m column the fire resistance corresponding to a deflection of L/30 was 44 min at which time the lower flange temperature was 757°C.

The heating rates of the 167 and 132 kg/m sections were similar and on the basis of the above comparison both of these slim floor assemblies should exceed 1 h fire resistance. The 107 kg/m section exhibited the fastest heating rate of those incorporated in the composite beam and an analysis of its structural behaviour using the FASBUS II model indicated that its ability to achieve a 1 h fire resistance would be doubtful.

5. CONCLUSIONS

Two indicative BS476:Part 8 fire tests have been carried out to measure the steel heating rates in slim floor assemblies comprising 254 x 254 mm column sections and 200 mm concrete slabs. For one test a composite beam was fabricated from lengths of column weighing 107, 132 and 167 kg/m. In the other test a 132 kg/m section was heated in a 1 m cube furnace.

A mathematical prediction of the temperature rise of the 254 x 254 mm x 132 kg/m section in the BS476:Part 8 test gave good agreement with the average temperatures observed. A fire resistance of 66½ min was also predicted for the deflection criterion of L/30 at which time the lower flange temperature would be approximately 750°C.

The indicative tests suggested that fully loaded slim floors incorporating the 132 and 167 kg/m sections should achieve a fire resistance of 1 h.

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TABLE 1 FURNACE AND STEEL TEMPERATURES RECORDED IN THE INDICATIVE CUBE FURNACE ON A SLIM FLOOR ASSEMBLY USING A 254 x 254 mm x 132 kg/m UNIVERSAL COLUMN

Time, min	Steel Temperature					Furnace Temperature	
	Lower Flange	Flange/Web Junction	¼ Web	¾ Web	Upper Flange	Furnace Atmosphere	Standard
0	21	21	21	21	21		
4	82	47	29	22	21	608	545
6	108	65	36	22	21	653	604
8	138	85	46	24	21	675	646
12	202	133	72	30	21	726	706
16	283	191	105	41	22	775	749
18	321	220	122	48	23	811	767
21	377	264	146	58	24	839	790
24	430	305	160	67	26	856	809
27	479	343	176	75	29	895	827
30	521	381	196	82	31	907	843
36	588	450	237	96	38	924	870
40	626	487	262	104	41	934	886
45	667	528	292	113	47	957	903
48	694	552	307	120	50	971	913
55	740	600	325	138	58	990	933
60	769	628	342	148	64	1003	946
65	794	651	367	157	69	1017	958
70	820	669	379	167	76	1019	969
75	843	685	386	175	82	1026	980
80	866	703	401	182	87	1032	989
85	887	724	422	190	92	1043	998
90	907	746	443	197	98	1047	1007
95	926	771	467	204	103	1054	1015
100	941	794	487	212	107	1056	1023
105	956	815	505	219	112	1063	1030
110	968	833	521	226	116	1068	1037
115	979	849	535	232	121	1071	1044
120	989	864	547	239	125	1076	1050

TABLE 2 FURNACE ATMOSPHERE TEMPERATURES RECORDED IN INDICATIVE FIRE TEST ON A COMPOSITE STEEL BEAM

TIME (min)	TEMPERATURE (C) ATMOSPHERE				
	2	3	4	5	6
0.0	13	13	13	13	12
1.0	350	369	361	361	335
2.0	444	448	459	411	421
3.0	510	521	527	488	483
4.0	529	547	558	510	515
5.0	587	599	615	570	574
6.0	597	607	634	587	591
7.0	622	636	654	613	617
8.0	631	635	664	621	633
9.0	640	655	676	633	640
10.0	660	671	700	653	667
11.0	696	698	733	695	687
12.0	701	711	743	708	702
13.0	711	718	749	703	712
14.0	715	720	747	723	712
15.0	716	728	752	725	712
16.0	726	736	764	725	720
17.0	731	741	766	729	725
18.0	727	740	759	732	731
19.0	749	755	780	753	750
20.0	749	757	789	752	749
21.0	753	765	791	757	756
22.0	761	765	795	763	756
23.0	767	771	801	764	765
24.0	770	776	804	772	763
25.0	774	780	807	775	772
26.0	777	784	808	768	783
27.0	776	787	808	781	774
28.0	785	793	817	785	786
29.0	786	795	822	783	786
30.0	792	795	820	795	785
31.0	795	793	828	795	794
32.0	799	803	830	797	800
33.0	804	804	835	805	797
34.0	809	814	838	806	806
35.0	808	811	840	812	804
36.0	815	816	844	814	815
37.0	817	819	849	818	816
38.0	823	825	851	818	819
39.0	824	829	854	827	830
40.0	827	830	859	830	824
41.0	836	834	865	836	838
42.0	838	839	868	838	834
43.0	843	843	874	844	839
44.0	845	847	876	843	848
45.0	847	851	878	849	843
46.0	856	859	886	850	852
47.0	854	857	887	848	854
48.0	855	863	890	862	857
49.0	863	868	891	864	863
50.0	863	868	897	869	863
51.0	870	872	900	867	868
52.0	873	877	901	871	871
53.0	873	881	903	877	878
54.0	881	884	911	879	880
55.0	885	888	915	882	880
56.0	887	889	917	882	879
57.0	892	893	920	885	892
58.0	891	897	923	885	893
59.0	899	901	924	893	894
73.0	937	944	966	934	937
74.0	938	949	967	936	935
75.0	945	950	975	940	950

TABLE 3 STEEL TEMPERATURES RECORDED IN A 254 x 254 mm x 107 kg/m COLUMN SECTION USED IN A SLIM FLOOR CONSTRUCTION

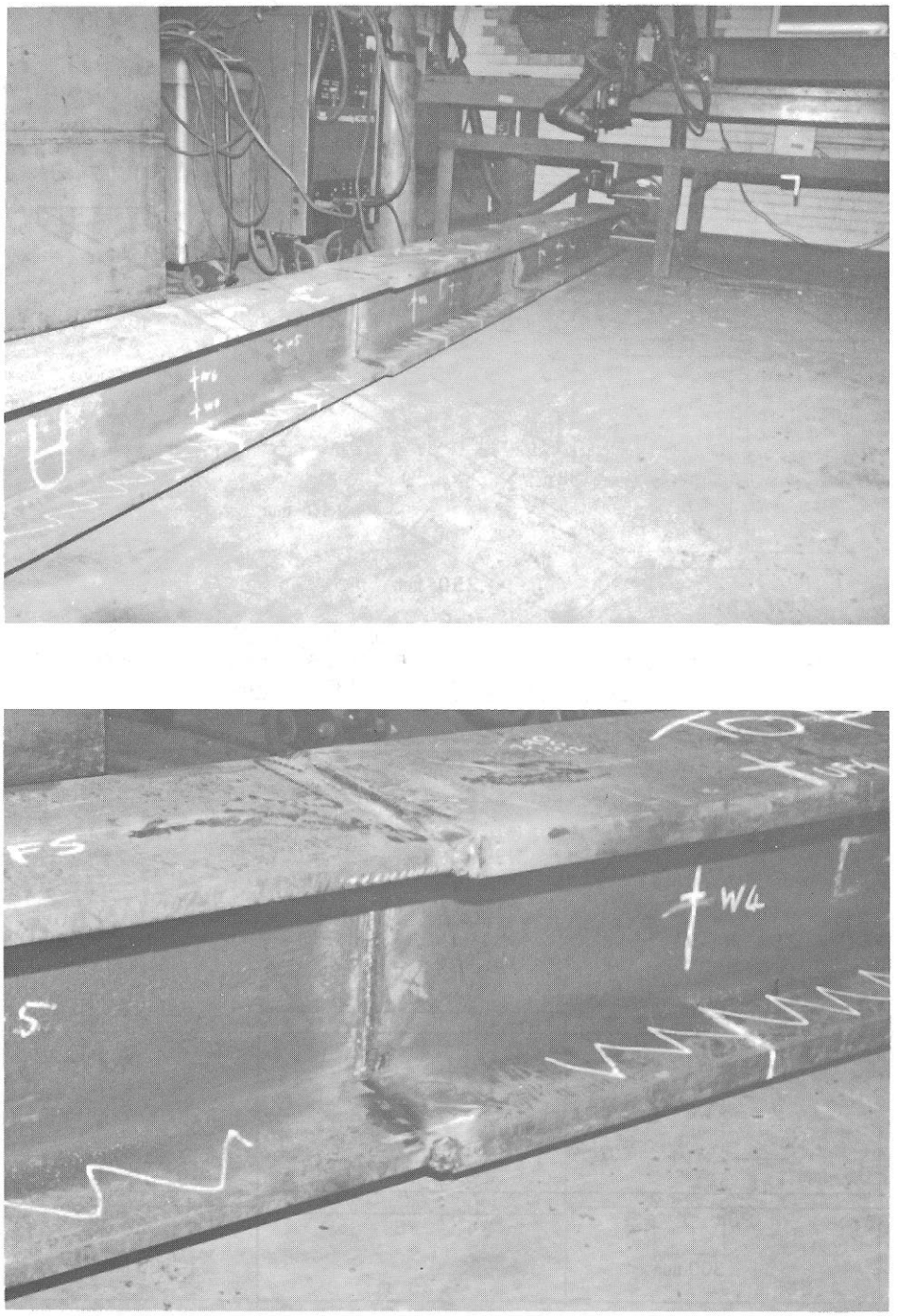
TIME	TEMPERATURE (C)						
	LOWER		WEB			UPPER	
(min)	flange	flange	mid	1/4	3/4	flange	flange
0.0	11	10	11	11	10	10	10
1.0	45	32	10	11	10	9	9
2.0	64	49	10	12	10	9	9
3.0	92	66	12	16	11	11	11
4.0	101	79	13	21	12	12	11
5.0	122	93	12	24	10	9	10
6.0	164	122	13	29	10	9	10
7.0	182	141	15	35	11	10	10
8.0	198	156	17	42	12	10	10
9.0	208	168	19	50	13	12	11
10.0	220	182	22	60	14	13	12
11.0	239	192	24	88	14	12	11
12.0	249	197	30	98	13	10	10
13.0	266	204	49	101	15	10	10
14.0	283	208	65	102	18	10	10
15.0	296	217	72	104	22	13	11
16.0	308	230	77	105	25	14	12
17.0	322	244	80	105	27	14	12
18.0	332	256	82	106	28	12	11
19.0	355	277	87	110	31	15	13
20.0	368	294	89	113	33	16	14
21.0	379	309	91	117	35	17	14
22.0	396	326	94	122	38	18	14
23.0	412	341	97	126	41	19	15
24.0	423	355	100	131	44	20	16
25.0	436	367	101	137	48	22	17
26.0	449	381	102	142	52	24	18
27.0	461	394	103	147	57	26	19
28.0	474	405	103	152	60	28	20
29.0	487	419	103	158	64	30	21
30.0	478	427	103	162	67	30	22
31.0	484	439	103	167	70	33	23
32.0	492	450	103	172	74	36	25
33.0	499	461	105	177	77	39	28
34.0	512	472	106	184	80	41	30
35.0	523	481	107	190	83	44	33
36.0	533	490	108	196	87	47	36
37.0	544	503	109	201	90	49	38
38.0	552	512	111	206	93	51	42
39.0	612	519	113	212	96	53	46
40.0	555	529	113	216	97	54	48
41.0	624	538	116	222	100	57	53
42.0	571	548	116	226	100	58	55
43.0	638	555	118	233	103	61	60
44.0	587	566	118	236	102	63	62
45.0	597	575	119	242	103	66	66
46.0	659	580	121	248	104	70	70
47.0	614	590	121	252	103	71	72
48.0	669	596	124	259	104	74	76
49.0	668	603	126	265	105	77	79
50.0	675	610	127	271	104	80	81
51.0	645	621	128	276	103	80	81
52.0	658	628	130	282	103	83	83
53.0	697	631	134	290	105	86	85
54.0	702	639	137	297	106	88	87
55.0	706	646	139	303	106	88	87
56.0	683	659	141	308	105	87	86
57.0	692	666	144	315	105	88	87
58.0	697	672	147	322	106	89	88
59.0	704	680	151	329	107	90	88
73.0	781	755	197	414	126	96	92
74.0	787	760	202	422	129	96	93
75.0	795	767	206	431	131	97	94

TABLE 4 STEEL TEMPERATURES RECORDED IN A 254 x 254 mm x 132 kg/m COLUMN SECTION USED IN A SLIM FLOOR CONSTRUCTION

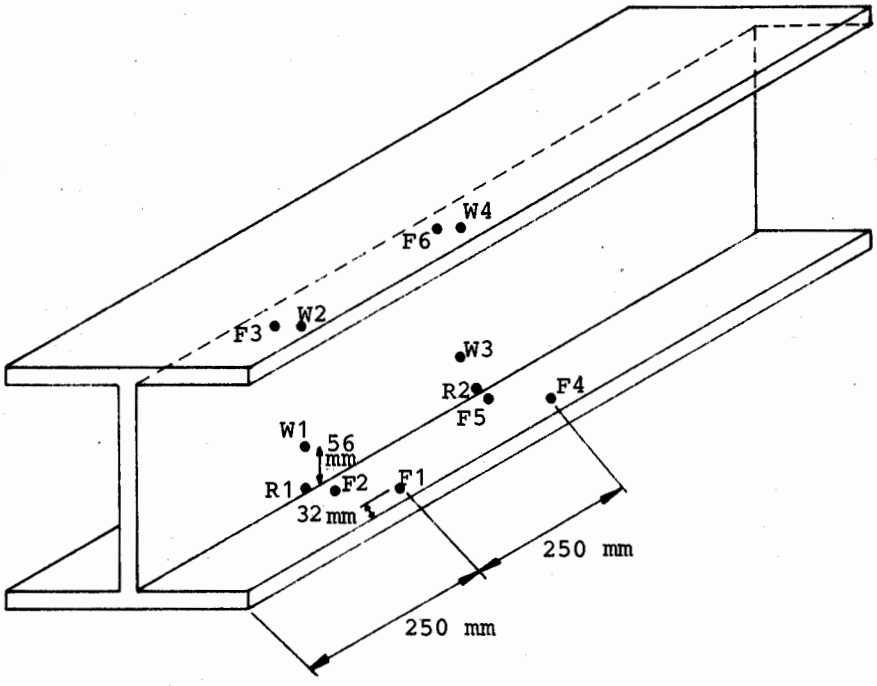
TIME	TEMPERATURE (C)							
	LOWER		WEB				UPPER	
(min)	flange	flange	mid	mid	1/4	3/4	flange	flange
0.0	10	9	9	9	11	9	9	9
1.0	21	35	9	9	11	9	8	8
2.0	30	38	9	9	13	9	9	8
3.0	43	49	11	10	16	10	10	9
4.0	54	60	12	11	20	11	10	10
5.0	67	72	11	10	22	9	8	8
6.0	78	88	12	11	26	9	9	8
7.0	93	120	13	12	31	10	9	8
8.0	107	135	15	13	37	10	10	8
9.0	120	148	17	16	43	11	11	9
10.0	136	165	20	18	50	12	10	10
11.0	147	177	22	19	56	12	10	10
12.0	155	185	22	20	62	11	8	8
13.0	164	193	25	22	82	12	9	8
14.0	173	205	29	25	96	13	10	9
15.0	183	219	35	29	101	14	11	9
16.0	194	233	44	32	104	16	11	10
17.0	205	247	64	34	105	18	10	10
18.0	216	259	72	35	105	18	9	9
19.0	233	277	78	39	108	22	11	10
20.0	247	290	81	42	110	24	11	11
21.0	261	303	84	45	111	26	11	11
22.0	275	317	87	48	115	27	11	11
23.0	290	330	90	51	118	29	12	11
24.0	303	343	92	54	122	31	12	11
25.0	317	356	94	58	128	33	13	12
26.0	330	367	96	61	133	35	13	12
27.0	344	380	97	64	139	37	13	12
28.0	357	394	98	68	145	38	14	13
29.0	371	405	99	71	151	40	14	13
30.0	383	417	98	74	156	41	14	13
31.0	396	429	99	77	162	42	15	13
32.0	409	441	100	82	169	44	16	14
33.0	421	453	100	87	176	46	17	15
34.0	433	465	101	91	183	47	17	16
35.0	445	476	102	95	190	49	18	16
36.0	457	487	102	97	196	50	19	17
37.0	469	498	102	100	203	51	19	18
38.0	479	507	103	101	210	53	20	19
39.0	491	518	104	103	218	55	22	20
40.0	499	526	104	104	224	56	21	21
41.0	512	539	107	107	232	58	23	23
42.0	519	546	106	107	237	59	22	22
43.0	531	557	109	110	245	62	25	25
44.0	538	564	109	111	251	62	23	24
45.0	547	573	111	113	258	64	24	26
46.0	559	583	115	116	266	68	27	28
47.0	565	590	116	117	271	70	26	28
48.0	576	601	120	120	279	77	29	30
49.0	583	608	124	122	286	83	30	32
50.0	592	616	127	124	293	87	31	33
51.0	598	623	129	124	298	89	30	33
52.0	608	633	132	126	304	92	32	34
53.0	618	642	137	130	311	95	35	37
54.0	623	648	140	132	318	97	37	39
55.0	630	655	143	134	324	97	38	40
56.0	635	661	145	134	328	97	38	40
57.0	646	671	148	137	334	98	41	41
58.0	653	678	151	139	340	99	43	43
59.0	661	686	155	141	345	100	45	45
73.0	737	762	198	174	417	114	85	68
74.0	741	766	202	178	424	116	90	72
75.0	746	772	206	181	430	117	93	75

TABLE 5 STEEL TEMPERATURES RECORDED IN A 254 x 254 mm x 167 kg/m COLUMN SECTION USED IN A SLIM FLOOR CONSTRUCTION

TIME (min)	TEMPERATURE (C)							
	LOWER		WEB				UPPER	
	flange	flange	mid	mid	1/4	3/4	flange	flange
0.0	10	10	10	10	10	10	11	10
1.0	26	25	9	10	11	9	8	9
2.0	34	36	10	10	13	9	8	10
3.0	47	52	11	11	16	10	9	10
4.0	58	64	12	12	20	11	10	11
5.0	70	77	11	11	21	9	8	10
6.0	82	88	12	13	26	10	8	10
7.0	100	105	14	14	31	10	8	10
8.0	116	120	16	16	37	11	9	10
9.0	130	135	18	18	43	12	10	11
10.0	143	150	21	21	50	13	10	11
11.0	157	167	23	23	56	14	10	11
12.0	169	179	24	23	62	13	8	10
13.0	183	196	27	26	71	14	9	10
14.0	197	211	31	30	90	15	9	10
15.0	210	224	35	34	98	17	10	11
16.0	223	238	39	38	103	19	11	12
17.0	237	249	43	43	106	20	11	11
18.0	245	264	45	47	109	21	9	10
19.0	259	283	51	59	114	24	11	12
20.0	270	296	57	69	118	26	12	12
21.0	285	310	63	75	122	28	12	12
22.0	301	326	73	80	128	31	12	12
23.0	317	340	80	83	133	35	13	13
24.0	332	354	85	86	139	40	13	13
25.0	346	367	89	89	146	46	14	14
26.0	360	381	93	91	152	52	16	14
27.0	374	394	97	94	158	59	17	14
28.0	386	406	99	96	165	66	18	15
29.0	399	418	102	98	171	73	20	16
30.0	410	430	102	98	176	78	21	15
31.0	424	445	104	100	182	83	23	15
32.0	435	458	105	102	189	88	25	16
33.0	444	469	106	103	195	91	27	17
34.0	453	480	107	103	201	93	30	18
35.0	465	490	108	104	207	96	32	19
36.0	478	501	108	105	214	97	35	20
37.0	490	512	109	106	220	99	38	21
38.0	501	521	110	107	225	99	42	23
39.0	514	530	111	108	232	101	45	25
40.0	516	537	111	107	236	100	48	27
41.0	533	549	113	109	243	102	52	31
42.0	535	555	112	108	248	101	54	32
43.0	554	566	114	110	255	102	58	36
44.0	553	573	114	109	259	101	60	37
45.0	561	581	115	110	265	102	62	40
46.0	582	592	118	112	272	103	66	44
47.0	579	598	118	112	277	102	67	46
48.0	600	608	120	115	284	103	71	50
49.0	598	611	122	117	290	104	73	54
50.0	604	618	124	119	296	104	75	57
51.0	607	629	125	120	301	102	76	59
52.0	628	640	127	122	307	102	78	62
53.0	645	641	130	125	315	104	81	66
54.0	638	645	134	128	321	104	83	70
55.0	644	650	136	130	327	104	85	73
56.0	641	668	138	131	332	103	85	75
57.0	665	678	140	133	339	103	87	78
58.0	675	685	144	136	345	104	89	82
59.0	680	692	147	138	352	104	90	85
73.0	752	757	203	186	431	126	97	97
74.0	757	762	210	191	439	129	97	98
75.0	763	768	217	197	446	133	98	99

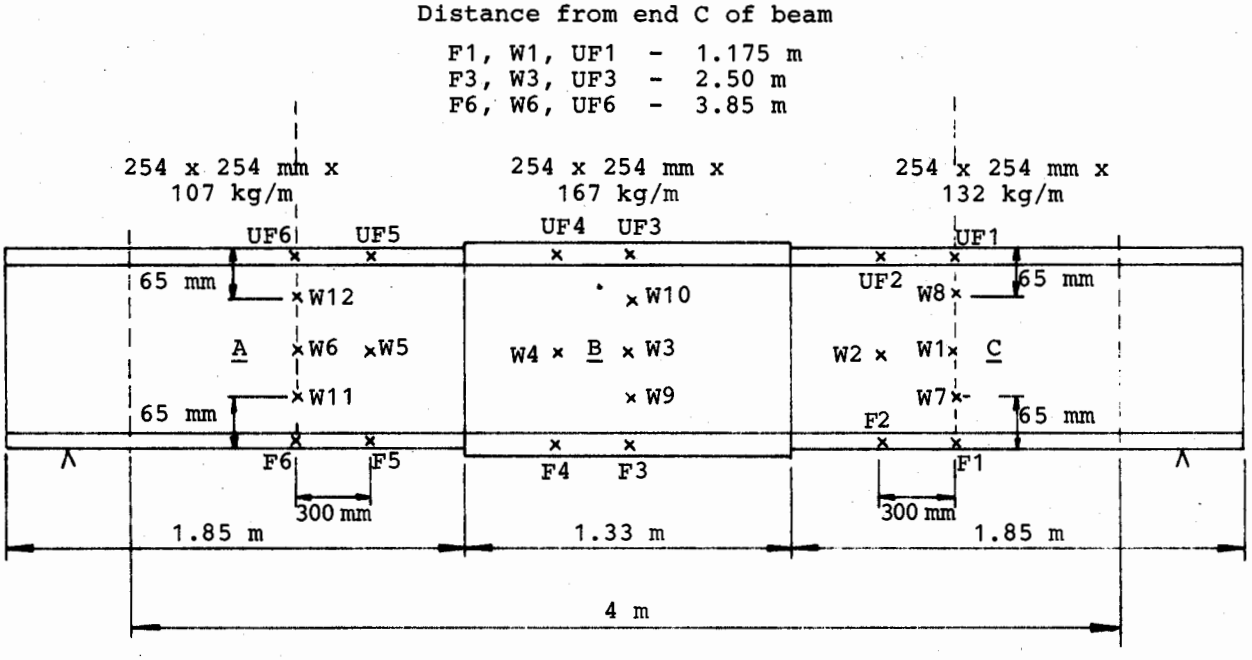


ASSEMBLY OF COMPOSITE BEAM FOR SLIM FLOOR TEST FIG. 1



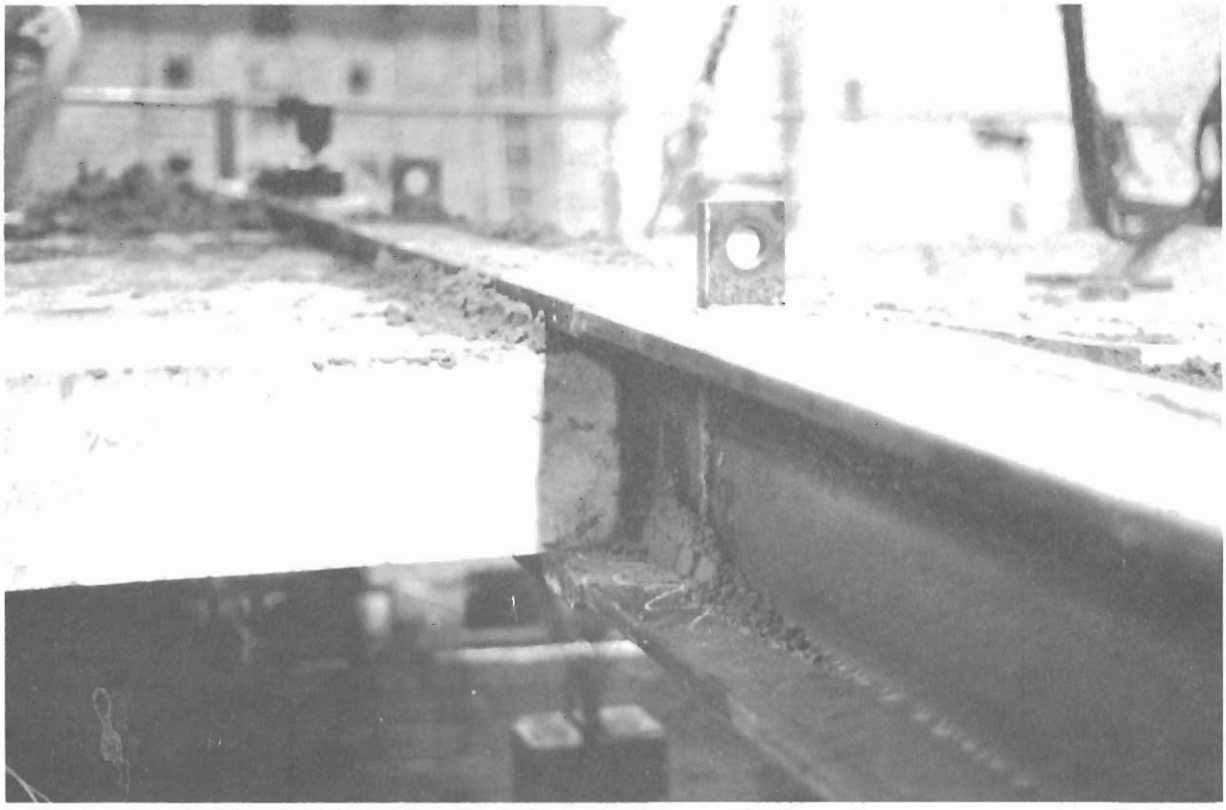
POSITION OF THERMOCOUPLES ON 254 x 254 mm x 132 kg/m COLUMN TESTED IN THE 1 m CUBE FURNACE

FIG. 2



POSITION OF THERMOCOUPLES ON COMPOSITE STEEL BEAM

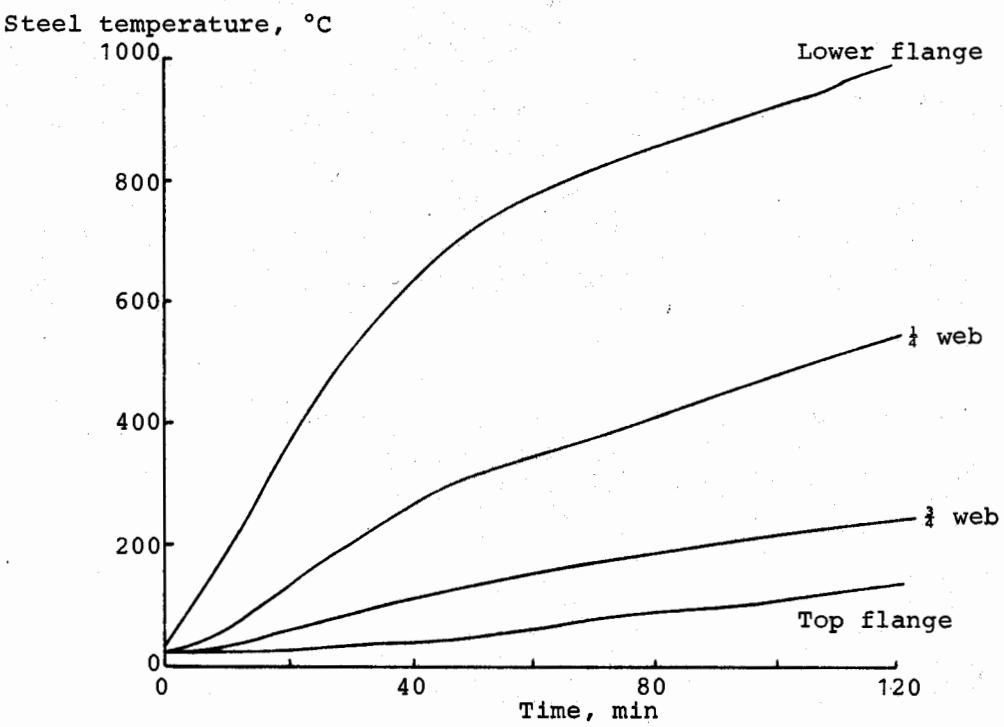
FIG. 3
(R2/4879)



(a)

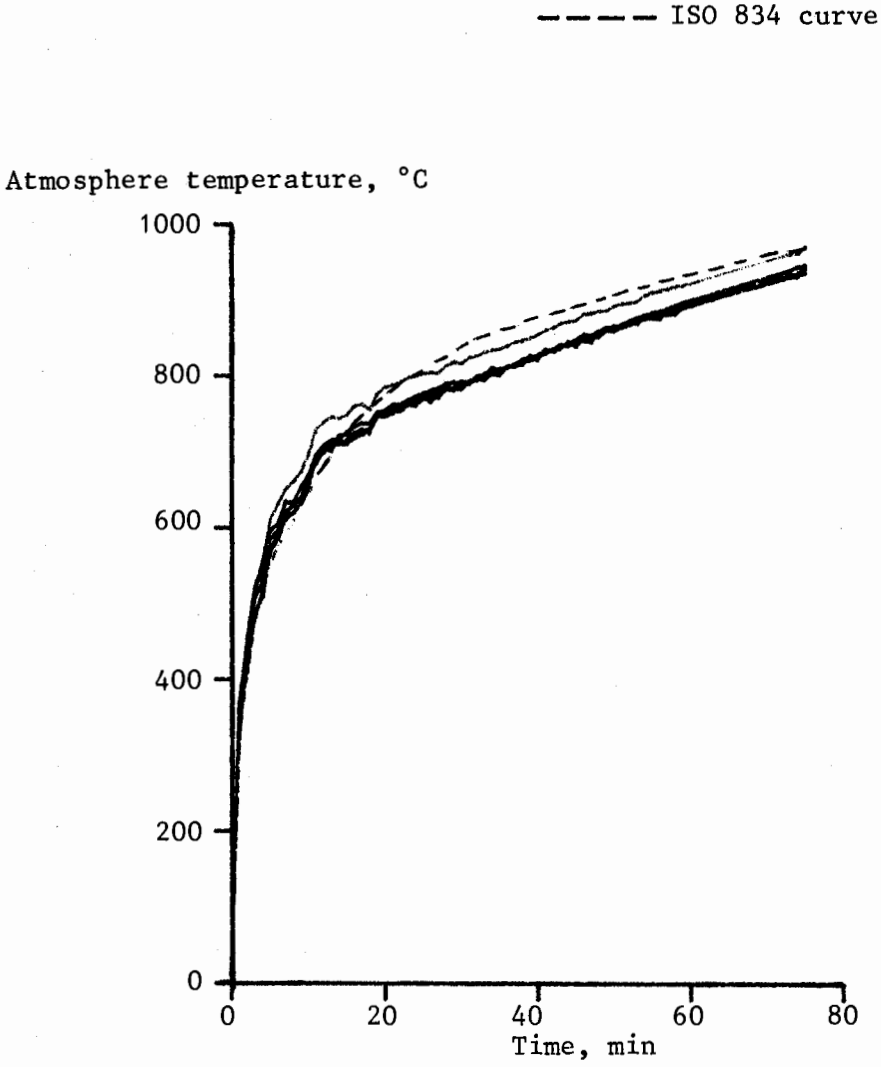
(b)

INDICATIVE FIRE TEST ON SLIM FLOOR COMPOSITE BEAM FIG. 4



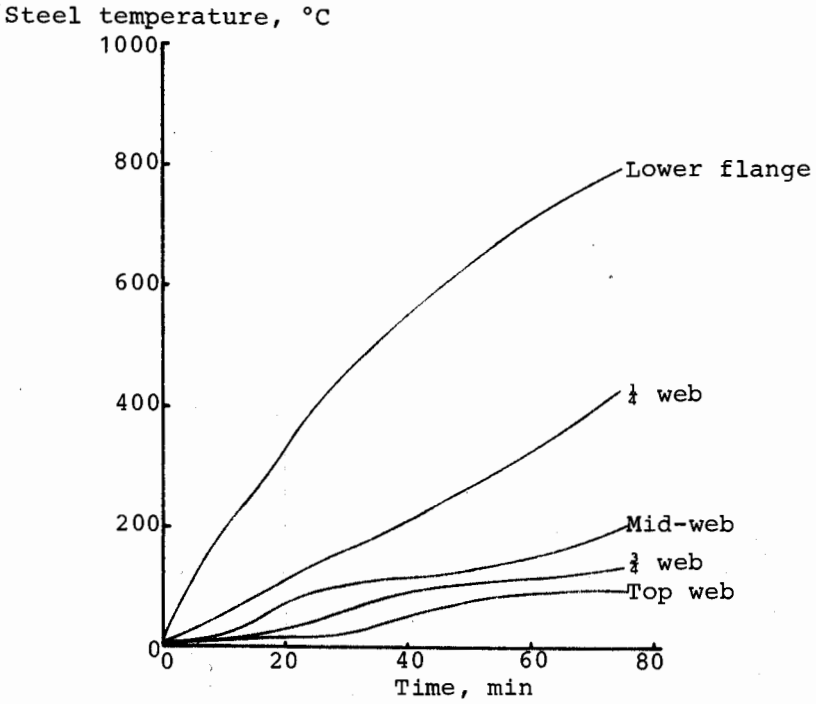
AVERAGE STEEL TEMPERATURES RECORDED IN A 254 x 254 mm x 132 kg/m UNIVERSAL COLUMN USED IN A SLIM FLOOR INDICATIVE TEST IN THE CUBE FURNACE

FIG. 5 (R2/4880)



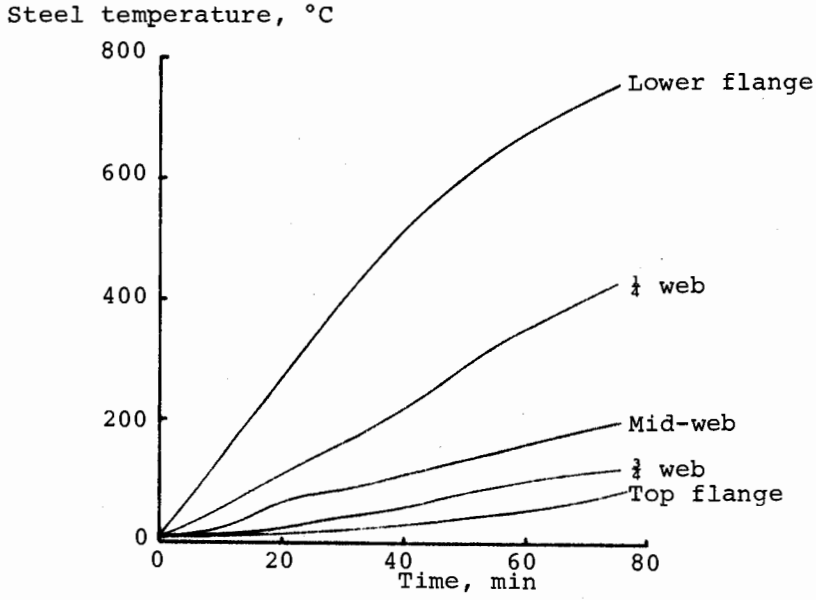
FURNACE ATMOSPHERE TEMPERATURES RECORDED DURING THE COMPOSITE BEAM TEST

FIG. 6



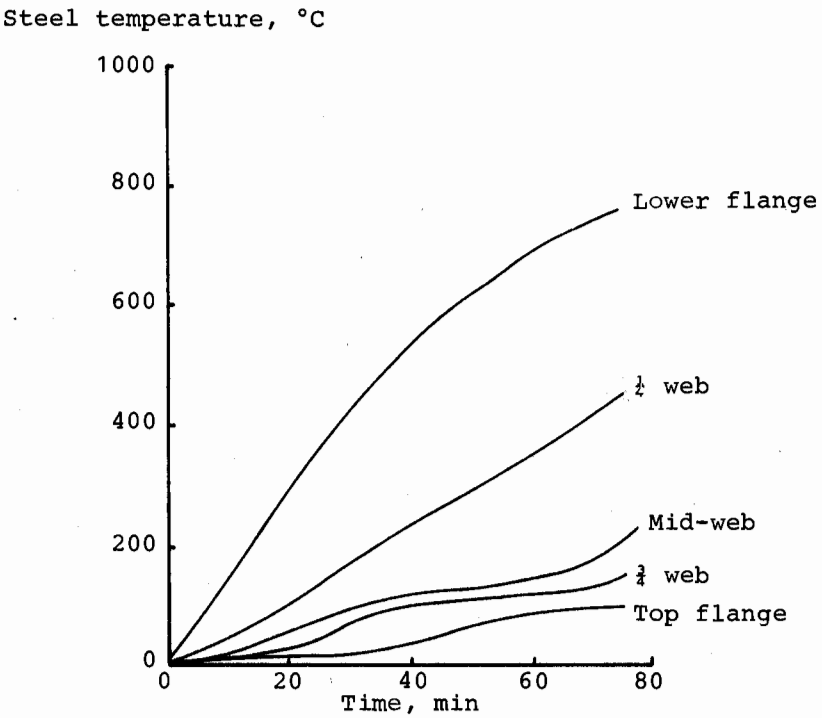
AVERAGE STEEL TEMPERATURES RECORDED IN A 254 x 254 mm x 107 kg/m UNIVERSAL COLUMN USED AS A SLIM FLOOR INDICATIVE TEST IN A COMPOSITE SECTION

FIG. 7



AVERAGE STEEL TEMPERATURES RECRODED IN A 254 x 254 mm x 132 kg/m UNIVERSAL COLUMN USED AS A SLIM FLOOR INDICATIVE TEST IN A COMPOSITE SECTION

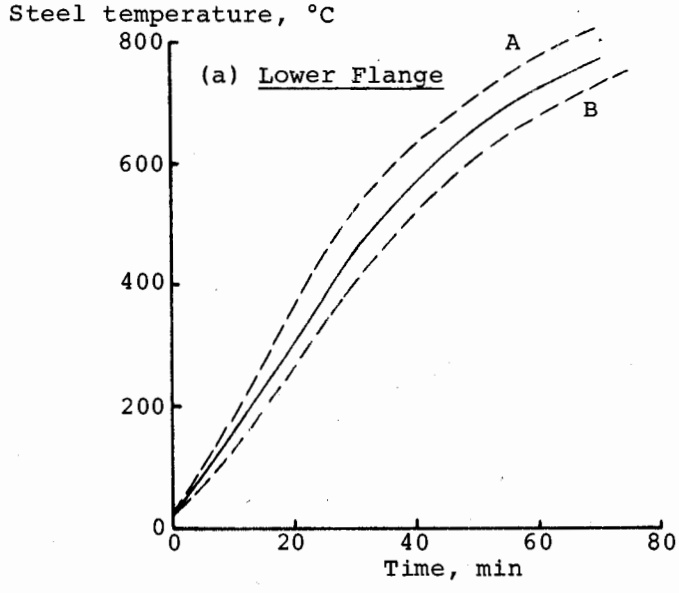
FIG. 8 (R2/4881)

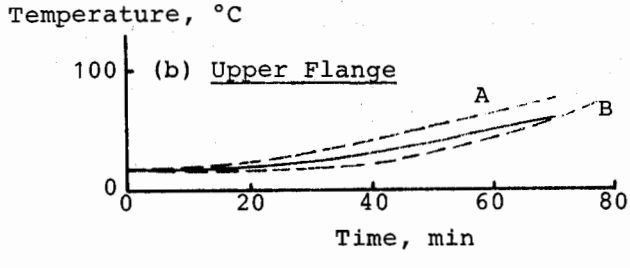


AVERAGE STEEL TEMPERATURES RECORDED IN A 254 x 254 mm x 167 kg/m UNIVERSAL COLUMN USED AS A SLIM FLOOR INDICATIVE TEST IN A COMPOSITE SECTION

FIG. 9 (R2/4882)

A - cube furnace test
B - beam furnace test





COMPARISON BETWEEN THE PREDICTED AND MEASURED STEEL TEMPERATURE IN A 254 x 254 mm x 132 kg/m COLUMN SECTION USED IN A SLIM FLOOR CONSTRUCTION

FIG. 10 (R2/4883)

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