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Report No.	RS/R/S1199/3/86/B
Date	23 SEPTEMBER 1986
Classification	CONFIDENTIAL - RESTRICTED

The Fire Resistance of Four Shelf Angle Floor Constructions - BS476: Part 8 Fire Tests Carried out Between 24th May 1984 and 19th December 1984

British Steel Corporation

Research Organisation

RS/R/S1199/2/86/B

THE FIRE RESISTANCE OF FOUR SHELF ANGLE FLOOR CONSTRUCTIONS - BS476:PART 8 FIRE TESTS CARRIED OUT BETWEEN 24TH MAY 1984 AND 19TH DECEMBER 1984

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SYNOPSIS

The report summarises the results from BS476:Part 8 fire tests carried out on four separate shelf angle floor constructions based on the use of an unprotected 406 x 178 mm x 54 kg/m universal beam. A BS4360:Grade 43A beam was incorporated in three assemblies and a Grade 50B beam in the fourth. Precast concrete floor slabs, either 200 mm or 100 mm thick and 550 mm wide were supported on 125 x 75 x 12 mm angles bolted to the web of the beam. The steel beams were subjected to different applied loads, as based on BS449.

The fire resistance of each assembly was influenced by the extent of the partial protection afforded by the floor slabs and the load applied to the beam. Both the Grade 50B beam loaded to 43% of the maximum design value and the Grade 43A beam at 80% of the maximum load exceeded the 1 h fire rating with 200 mm thick concrete slabs. Neither of the Grade 43A beams with 100 mm thick slabs loaded respectively to 100% and 60% of the maximum design value were as satisfactory, but in the latter design a fire resistance of 74 min was obtained by prolonging the test to a deflection of L/20.

KEY WORDS

3. Fire Resistance
4. Floorings
5. Deflection
6. Testing
7. Shelf Angles
8. +BS 476
9. Lab Reports
10. Concrete

23rd September 1986

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1. INTRODUCTION

When a fire breaks out in an enclosure the temperature of any steel section within it will rise at a rate depending upon its Hp/A ratio. If the steel section is not fully exposed to the fire its Hp/A is effectively reduced resulting in a lower heating rate and an increase in the fire resistance time.

The concept of partial protection can be extended to shelf angle floor systems which are used in the design of multi-storey buildings to reduce the floor/ceiling void depth. Two BS476:Part 8 fire tests were carried out on unprotected BS4360:Grade 43A beams of serial size 406 x 178 mm x 54 kg/m and 305 x 165 mm x 40 kg/m respectively which were used as part of a fully loaded shelf angle floor construction[1,2]. These results suggested that the use of such a design might satisfy the requirements of the Building Regulations for '1 h' buildings. However, further testing was required to determine the behaviour of other similar floors and to provide suitable 'bench mark' observations for the derivation of a mathematical model able to predict the fire resistance of the appropriate range of beam sizes, floor depths and applied loadings used in this form of design.

The present report summarises the results from four BS476:Part 8 fire tests on shelf angle floor constructions, comprising 406 x 178 mm x 54 kg/m BS4360 Grade 43A beams, 125 x 75 x 12 mm BS4360 Grade 50B angles and 200 mm or 100 mm thick precast concrete floor slabs. The steel beams were subjected to different applied loads, based on BS449 and fire tested at the Warrington Research Centre between 24th May 1984 and 19th December 1984.

2. DETAILS OF CONSTRUCTION

2.1 Steel Supply

The steel sections used in each construction were obtained either from a local steel stockholder or from Lackenby Works and comprised:-

5 m	406 x 178 mm x 54 kg/m universal beam (BS4360)
2 x 5 m	125 x 75 x 12 mm angles (BS4360:Grade 50B)

Samples were taken from each of the sections for chemical analysis and mechanical testing. The compositions are given in Table 1 and the mechanical properties in Table 2. One beam was found to comply with BS4360 Grade 50B, the remaining beams were within the limits specified for BS4360 Grade 43A and the angles were within the compositional tolerances of BS4360:Grade 50B.

2.2 Fabrication of Sections

The angles were positioned on either side of the beam to leave a 210 or 110 mm gap between the upper flange of the beam and the 125 mm leg of the angle. The shorter leg of the angle was located within the gap. Holes were drilled at 600 mm centres along the mid axis of the 75 mm angle leg to accommodate M20 8.8 grade bolts. In the earlier test M20 4.6 grade bolts had been used, two of which failed at one end of the test arrangement located outside the furnace. A schematic illustration showing the test assembly is given in Fig. 1.

2.3 Concrete Slabs

The concrete slabs were similar to those used in earlier tests and were cast into 1550 x 550 x 200 mm thick blocks, or 1550 x 550 x 150 mm thick blocks with one end tapering to 100 mm thick over a distance of 300 mm. The concrete contained steel reinforcement as shown in Fig. 2 and complied with BS8110:Grade 30 compressive strength.

2.4 Instrumentation

A total of 32 mineral insulated thermocouples of the chromel/alumel type, each with insulated hot junctions and an Inconel sheath were used to monitor the heating rate of the steel during each test. The thermocouples were located at the positions shown in Fig. 3; in summary, five thermocouples were embedded in the lower flange of the beam, four thermocouples in the exposed part of the web, four were attached to the protected part of the web and four were attached to the upper flange of the beam. These thermocouples were located around the central part of the beam.

Nine thermocouples were embedded in the shelf angles, three on the exposed leg, three on the unexposed leg and three on the root of the angle.

Thermocouples were also installed after the construction was assembled to monitor furnace atmosphere temperatures at six positions along the beam adjacent to the lower flange.

2.5 Assembly

The beam with the angles attached was placed on the furnace in the standard position to give an effective length of 4.5 m between the roller supports. Each slab was then manoevred into position between the shelf angle and the upper flange to utilise a 75 mm load bearing length on the shelf angle. This left a gap of 50 mm between the end of the slab and the web of the beam. The other end of the slab rested on a wall which was built along the edges of the furnace level with the shelf angle. A 12 mm gap was left between the slab and wall at the ends of the beam, thus enabling the slabs to move freely with the beam as it deflected vertically. Ceramic fibre blanket material was used to cover the gaps at both ends.

Once the 16 slabs were in position the 50 mm gap between the slab end and web was completely filled in with dried sand. The upper flange of the beam was also covered with a 25 mm layer of sand in order to simulate the thermal characteristics of a floor screed which is used in site practice.

Photographs of the construction during assembly are shown in Figs. 4 and 5.

2.6 Loading

The load to the beam was applied through the concrete slabs and angles to simulate service conditions. Four hydraulic jacks were positioned on either side of the beam at a distance of 0.5 m from its centreline. Loads were applied to eight points onto the concrete slabs using 1 m lengths of 152 x 152 mm x 23 kg/m universal column as load spreaders. Details of the loading calculations used in each test are given in Appendix 1. A photograph of the completed construction is shown in Fig. 6.

Deflection measurements were taken at the centre of the beam by the Warrington Research Centre staff using their potentiometric system. Additional measurements were also taken from the central concrete slab using a theodilite system.

3. TEST RESULTS

It is convenient to consider the four tests separately and in the following order.

3.1 Grade 50B Beam - Test A

Loaded to a design stress of 100 N/mm² using 200 mm thick concrete floor slabs. This construction achieved a fire resistance period of 94 min, at which time the L/30 failure criterion in the BS476:Part 8 fire test was reached.

3.1.1 Deflection Measurements

The deflection measurements made on the beam at the centre of the construction in Test A are shown in Fig. 7. The rate of deflection was greater in the first 30 min of the test but thereafter remained almost constant until failure occurred.

3.1.2 Temperature Measurements

A summary of steel temperatures and furnace atmosphere temperatures at various stages during the test is presented in Table 3.

The furnace atmosphere heating curves are compared with the International temperature/time curve in Fig. 8 which shows that the heating rate was generally in accordance with the standard curve throughout the test.

Average heating curves recorded at different positions across the shelf angle beam are compared in Fig. 9. At failure there was little scatter between the temperatures measured on the lower flange which were within the range 985 to 999°C with a mean of 992°C. The final temperatures in the exposed web were within the range 964 to 981°C with a mean of 974°C; the corresponding temperature range in the unexposed part of the web was between 229 and 257°C with a mean of 243°C. The upper flange reached a mean temperature of 103°C. The final average temperatures of the exposed and unexposed angle flanges were 945 and 716°C respectively.

3.1.3 Observations

In order to check an equipment malfunction it became necessary to remove the load after 16 min into the test which was then reapplied within 60 s. The concrete slabs developed a stepwise pattern as the beam deflected and several units exhibited vertical and shear edge cracks at the end of the test. The angles deformed in a uniform manner.

All the bolts remained intact after the reload test.

3.2 Grade 43A Beam - Test B

Loaded to a design stress of 132 N/mm^2 using 200 mm thick concrete slabs. This construction achieved a fire resistance time of 70 min at a deflection of L/30.

3.2.1 Deflection Measurements

The deflection measurements made on the beam at the centre of the construction in Test B are shown in Fig. 10.

3.2.2 Temperature Measurements

A summary of steel temperatures and furnace atmosphere temperatures at various stages during the test is presented in Table 4.

The furnace atmosphere heating curves are compared with the International temperature/time curve in Fig. 11, which shows that the heating rate was generally in accordance with the standard curve throughout the test.

Average heating curves recorded at different positions across the shelf angle beam are compared in Fig. 12. At failure there was little scatter between the temperatures measured on the lower flange which were within the range 910 to 922°C with a mean of 914°C. The final temperatures in the exposed web were within the range 878 to 898°C with a mean of 890°C; the corresponding temperature range in the unexposed part of the web was between 173 and 219°C with a mean of 191°C. The upper flange reached a mean temperature of 94°C. The final average temperatures of the exposed and unexposed angle flanges were 839 and 613°C respectively.

3.2.3 Observations

The shelf angle floor assembly satisfied the reload test. Nothing unusual occurred during the test.

3.3 Grade 43A Beam - Test C

Loaded to a design stress of 100 N/mm^2 using 100 mm thick concrete slabs. This construction achieved a fire resistance time of 43 min at a deflection of L/30 and 74 min at a deflection of L/20.

3.3.1 Deflection Measurements

The deflection measurements made on the beam at the centre of the construction in Test C are shown in Fig. 13. The rate of deflection increased to a maximum of 4 mm/min and decreased to 2 mm/min after 45 min.

3.3.2 Temperature Measurements

A summary of steel temperatures and furnace atmosphere temperatures at various stages during the test is presented in Table 5.

The furnace atmosphere heating curves are compared with the International temperature/time curve in Fig. 14, which shows that the heating rate was generally in accordance with the standard curve throughout the test.

Average heating curves recorded at different positions across the shelf angle beam are compared in Fig. 15. At failure there was little scatter between the temperatures measured on the lower flange, which were within the range 907 to 921°C with a mean of 915°C. The final temperatures in the exposed web were within the range 889 to 909°C with a mean of 900°C; the corresponding temperature range in the unexposed part of the web was between 287 and 340°C with a mean of 317°C. The upper flange reached a mean temperature of 222°C. The final average temperatures of the exposed and unexposed angle flanges were 804 and 616°C respectively.

3.3.3 Observations

The 100 mm thick concrete slabs were used for the first time in a BS476:Part 8 fire test on a shelf angle assembly and behaved in a similar manner to the thicker blocks. After the test, some of the slabs exhibited cracking (Fig. 16(a)). The deflection of both the beam and angle was uniform (Fig. 16(b)). The assembly satisfied the reload test and all the bolts remained intact.

3.4 Grade 43A Beam - Test D

Loaded to a design stress of 165 N/mm² using 100 mm thick concrete slabs. This construction achieved a fire resistance time of 29 min at a deflection of L/30. Copies of the letters received from the WRC confirming the general results from each test are given in Appendix 2.

3.4.1 Deflection Measurements

The deflection measurements made on the beam at the centre of the construction in Test D are shown in Fig. 17.

3.4.2 Temperature Measurements

A summary of steel temperatures and furnace atmosphere temperatures at various stages during the test is presented in Table 6.

The furnace atmosphere heating curves are compared with the International temperature/time curve in Fig. 18 which shows that the heating rate was generally in accordance with the standard curve throughout the test.

Average heating curves recorded at different positions across the shelf angle beam are compared in Fig. 19. At failure there was little scatter between the temperatures measured on the lower flange, which were within the range 724 to 738°C with a mean of 733°C. The final temperatures in the exposed web were within the range 707 to 724°C with a mean of 715°C; the corresponding temperature range in the unexposed part of the web was between 152 and 180°C with a mean temperature of 167°C. The upper flange reached a mean temperature of 97°C. The final average temperatures of the exposed and unexposed angle flanges were 571 and 368°C respectively.

3.4.3 Observations

Six minutes after the start of the test white fumes were emitted from the concrete slabs and these were present throughout the test. On completion of the experiment the majority of the slabs contained either shear or vertical edge cracks which were located in the tapered portion of the slab and originated from the vicinity of the flange tip.

4. DISCUSSION

The serial size of beam used in these experiments has never been subjected to a BS476:Part 8 fire test in the unprotected form. However, a study of the changing temperature distributions measured across other unprotected steel members tested in this way suggests that a fire resistance for the 406 x 178 mm x 54 kg/m beam of 19 min would be expected when loaded to maximum design load (BS449). If the temperature profiles are used as input data to the FASBUS II finite element programme which calculates the changes in stress and deflection a fire resistance of 23 min is predicted for a BS4360:Grade 43A section and 21 min for a Grade 50B section.

However, during a fire beneath a shelf angle floor beam the concrete floor keeps the temperatures of the top flange and the upper parts of the web to modest levels. The net result is that as the bottom flange gets hotter and gradually loses some of its load bearing capacity the neutral axis shifts upwards and tensile loads begin to be taken up by the shelf angles. Hence, the time to failure under load is longer than for bare unprotected beams having the floor slabs resting on the top flanges. Clearly, the use of different precast concrete floor slab thicknesses provide more or less protection to the web of the beam. In an earlier test in which the BS4360:Grade 43A beam in a shelf angle floor construction incorporating 200 mm thick concrete slabs was loaded to the maximum design value a fire resistance time of 67½ min was observed[1]. The use of 100 mm thick slabs in the present exercise reduced the fire resistance time to 29 min.

Previous work on unprotected steel beams showed that the fire resistance was improved by reducing the stress in the centre of the tensile flange of the beam. A similar effect occurred in the shelf angle floor tests. For example, with a floor thickness of 100 mm the fire resistance time increased by 14 min as a consequence of reducing the applied load by 40%.

The shelf angle floor design offers the scope for achieving a 1 h fire resistance without recourse to passive protection. If the benefits offered by this form of construction are to be recognised in the high percentage of building designs requiring such fire resistance it is necessary to evaluate the behaviour of all potential systems. The current study has provided valuable benchmark data for use in the development of a mathematical model for predicting the performance of the remaining sections without incurring the expense of fire testing.

5. CONCLUSIONS

Four BS476:Part 8 fire tests were carried out on shelf angle floor constructions based on a 406 x 178 mm x 54 kg/m universal beam and 125 x 75 x 12 mm angles supporting either 200 mm or 100 mm thick precast concrete slabs. The assemblies were subjected to different applied loads, based on BS449.

The BS4360 Grade 50B beam loaded to a design stress of 100 N/mm² using 200 mm thick slabs achieved a fire resistance of 94 min.

The BS4360 Grade 43A beam loaded to a design stress of 132 N/mm² using 200 mm thick slabs achieved a fire resistance of 70 min.

The BS4360 Grade 43A beam loaded to a design stress of 100 N/mm² using 100 mm thick slabs achieved a fire resistance of 43 min and 74 min at a deflection of L/20.

The BS4360 Grade 43A beam loaded to a design stress of 165 N/mm² using 100 mm thick slabs achieved a fire resistance of 29 min.

6. REFERENCES

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TABLE 1 CHEMICAL COMPOSITION OF THE STEEL SECTIONS USED IN THE FIRE TESTS

	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Cu	N	Nb	Sn	V
RS550 406 x 178 mm x 54 kg/m UB RS551 125 x 75 x 12 mm Angle Tested 24.5.84	0.18 0.16	0.015 0.25	1.50 1.39	0.018 0.026	0.015 0.021	0.03 0.06	0.005 0.002	0.03 0.02	0.004 0.003	0.03 0.04	0.003 0.006	0.001 0.001	0.003 0.004	0.088 0.057
RS558 406 x 178 mm x 54 kg/m UB RS559 125 x 75 x 12 mm Angle Tested 26.6.84	0.20 0.14	0.027 0.22	0.92 1.43	0.014 0.031	0.028 0.021	0.02 0.03	0.004 0.006	0.01 0.02	0.006 0.005	0.02 0.02	0.005 0.005	0.001 0.001	0.003 0.005	0.001 0.067
RS560 406 x 178 mm x 54 kg/m UB RS561 125 x 75 x 12 mm Angle Tested 11.7.84	0.22 0.12	0.03 0.33	0.89 1.35	0.026 0.019	0.025 0.011	0.04 0.02	0.004 0.003	0.03 0.02	0.004 0.043	0.04 0.02	0.005 0.007	0.001 0.001	0.005 0.005	0.001 0.051
RS640 406 x 178 mm x 54 kg/m UB RS641 125 x 75 x 12 mm Angle Tested 19.12.84	0.21 0.16	0.038 0.21	0.96 1.41	0.024 0.031	0.012 0.024	0.02 0.03	0.005 0.004	0.02 0.02	0.008 0.005	0.02 0.02	0.004 0.006	0.001 0.002	0.005 0.005	0.002 0.067
BS4360 Grade 43A Product Analysis	0.30 max.	0.55 max.	1.70 max.	0.06 max.	0.06 max.									
BS4360 Grade 50B Product Analysis	0.24 max.	0.55 max.	1.60 max.	0.06 max.	0.06 max.							0.003/ 0.10		0.003/ 0.10

TABLE 2 TENSILE TEST RESULTS FROM THE BEAMS AND ANGLES USED IN THE FIRE TESTS

Identity	Yield Stress N/mm^2	Tensile Strength N/mm^2	Elongation %
RS550 406 x 178 mm x 54 kg/m UB RS551 125 x 75 x 12 mm Angle Tested 24.5.84	407 397	564 575	29 30
RS558 406 x 178 mm x 54 kg/m UB RS551 125 x 75 x 12 mm Angle Tested 26.6.84	300 380	467 539	36 32
RS560 406 x 178 mm x 54 kg/m UB RS561 125 x 75 x 12 mm Angle Tested 11.7.84	280 381	478 518	32 32
RS640 406 x 178 mm x 54 kg/m UB RS641 125 x 75 x 12 mm Angle Tested 19.12.84	335 404	499 562	30 32
BS4360 Grade 43A Specification	255 (min.)	430/540	20 min.
BS4360 Grade 50B Specification	355 (min.)	490/620	18 min.

TABLE 3 SHELF ANGLE FLOOR TEST A - TEMPERATURE DATA SHEET

Sections 406 x 178 x 54 kg/m Grade 50 Beam (Tested at 43% of design load - BS449) Date 24.5.84
125 x 75 x 12 mm Grade 50B Angles

Concrete Floor 200 mm Slabs Failure Time 94 min

Thermocouple Location		Temperature, °C, After Various Times, min																						
		3	6	9	12	15	18	21	24	27	30	35	40	45	50	55	60	65	70	75	80	85	90	94
Lower Flange	F1	61	153	270	391	488	558	612	660	696	723	750	783	815	843	868	888	907	925	942	957	971	984	994
	F2	57	146	267	389	487	558	614	662	700	726	752	786	817	846	871	892	912	929	946	962	975	984	999
	F4	65	166	298	412	500	567	615	660	696	722	749	781	813	841	866	889	906	924	940	956	970	982	992
	F6	58	150	270	393	490	560	611	659	696	721	747	780	811	836	863	883	902	921	937	953	967	960	989
	F7	95	187	312	425	507	568	619	661	694	720	746	779	807	834	858	878	899	911	933	948	963	970	985
Mean Lower Flange		67	160	283	402	494	562	614	660	696	722	748	781	812	840	865	922	905	922	939	955	969	976	992
Web ¼ Position Exposed	W1	76	167	261	360	442	502	557	606	642	672	712	740	768	799	827	854	875	894	913	930	946	960	971
	W2	75	159	266	372	456	515	571	620	656	686	723	749	780	812	840	865	886	905	923	941	956	970	980
	W3	81	170	283	383	463	522	578	625	662	692	729	754	786	816	844	867	888	907	926	942	956	971	981
	W4	90	180	279	375	453	509	563	609	645	673	711	739	765	796	824	850	870	890	908	924	941	955	964
Mean Exposed Web		80	169	272	372	453	512	567	615	651	680	718	745	774	805	834	859	879	899	917	934	949	964	974
Web ¾ Position Unexposed	W5	20	21	26	30	36	43	50	58	68	78	97	108	120	131	142	153	163	173	183	195	207	220	229
	W6	20	21	26	31	37	46	54	64	75	88	110	127	141	153	165	177	190	202	214	226	236	249	257
	W7	19	21	27	32	37	45	54	63	75	88	106	118	128	139	150	163	176	188	199	210	223	232	246
	W8	19	21	26	31	37	45	53	62	71	84	104	121	134	141	143	148	153	162	176	193	210	228	240
Mean Unexposed Web		19	21	26	31	37	45	53	61	72	84	104	118	131	141	150	160	170	181	193	206	219	232	243
Upper Flange	F5	18	19	22	23	20	24	21	23	26	29	34	41	45	59	68	87	85	93	98	101	101	103	103
	F8	19	20	22	22	20	24	21	22	27	29	35	41	41	53	61	77	74	82	91	101	102	102	102
	F9	20	20	23	22	20	24	21	22	27	28	32	36	37	47	55	73	73	89	103	104	103	105	105
Mean Upper Flange		19	19	22	22	20	24	21	22	27	29	34	39	41	53	61	79	85	88	97	102	102	103	103
Exposed Flange (Angle)	F10	43	86	156	217	271	329	381	442	488	526	581	631	676	714	749	772	803	833	859	884	905	925	938
	F11	47	85	146	207	263	322	382	442	496	541	601	651	696	734	766	794	826	854	882	908	927	946	959
	F12	50	87	140	199	257	316	373	433	485	528	593	640	684	721	753	778	810	839	867	891	910	927	939
Mean Exposed Flange (Angle)		46	86	147	207	263	322	378	439	489	531	591	640	685	723	756	781	813	842	869	894	914	932	945
Unexposed Flange (Angle)	W9	22	41	83	92	127	165	204	242	278	312	363	407	447	482	516	548	579	605	629	652	672	693	708
	W10	22	38	60	91	125	165	204	245	284	321	372	413	448	484	519	550	580	605	630	654	676	698	714
	W11	23	39	62	93	129	171	211	252	291	326	374	415	455	493	528	561	590	617	643	667	689	711	726
Mean Unexposed Flange (Angle)		22	39	68	92	127	167	206	246	284	319	369	411	450	486	521	553	583	609	634	657	679	700	716
Angle Root	16	27	53	91	133	178	225	271	318	363	404	464	515	561	602	638	671	698	724	749	775	799	824	841
	17	27	50	83	121	165	211	258	308	356	400	464	518	566	606	642	674	702	728	753	779	804	828	844
	18	27	49	87	113	156	202	248	296	343	386	451	502	549	588	621	653	680	704	728	751	776	798	816
Mean Angle Root		27	50	87	122	166	212	259	307	354	396	459	511	558	598	633	666	693	730	743	768	793	816	833
Mean Atmosphere		429	516	627	687	714	734	776	792	800	827	846	863	883	901	920	934	950	966	977	990	1001	1014	1020
ISO Curve at 20°C		502	603	663	705	738	766	789	808	826	842	865	885	902	918	932	945	957	968	979	988	997	1006	1012
Central Beam Deflection, mm		5	12	26	36	46	55	63	69	77	80	88	96	104	109	114	118	121	127	133	137	142	146	150

TABLE 4 SHELF ANGLE FLOOR TEST B - TEMPERATURE DATA SHEET

Sections 406 x 178 x 54 kg/m Grade 43A Beam (Tested at 80% of design load - BS449) Date 26.6.84
125 x 75 x 12 mm Grade 50B Angles

Concrete Floor 200 mm Slabs Failure Time 70 min

Thermocouple Location		Temperature, °C, After Various Times, min																	
		3	6	9	12	15	18	21	24	27	30	35	40	45	50	55	60	65	70
Lower Flange	F1	91	185	317	425	535	607	654	685	707	724	742	770	798	824	851	874	894	914
	F2	85	178	310	415	533	606	655	687	709	728	747	776	806	835	862	885	903	922
	F4	91	204	341	440	538	606	652	683	705	722	738	765	794	822	852	877	896	914
	F6	86	180	313	419	531	603	651	683	704	723	740	767	796	822	850	874	892	910
	F7	104	205	333	431	534	602	649	680	702	719	738	766	795	822	851	874	893	911
Mean Lower Flange		91	190	323	426	534	604	652	684	705	723	741	769	798	825	853	877	896	914
Web ¼ Position (Exposed)	W1	107	192	295	377	469	537	585	620	648	669	700	727	745	775	803	833	856	878
	W2	96	184	299	389	490	556	605	639	663	685	715	736	765	796	826	853	873	894
	W3	103	195	304	384	482	550	600	635	662	685	716	737	767	800	830	857	878	898
	W4	133	217	319	394	483	547	594	628	655	677	708	734	757	789	819	847	869	889
Mean Exposed Web		110	197	304	386	481	547	596	630	657	679	710	733	758	790	819	847	869	890
Web ¼ Position (Unexposed)	W5	17	20	25	32	40	50	62	74	87	100	121	140	156	168	180	192	204	219
	W6	18	20	23	29	35	43	53	63	74	85	100	108	114	122	132	143	155	173
	W7	18	20	24	30	38	47	57	67	79	93	109	124	136	141	147	155	162	177
	W8	18	20	23	29	37	45	55	66	77	89	109	126	140	151	162	172	182	194
Mean Unexposed Web		18	20	24	30	37	46	57	67	79	92	110	124	136	145	155	165	176	191
Upper Flange	F3	17	17	17	18	19	19	21	22	24	26	30	37	46	55	63	71	79	87
	F5	18	19	18	18	19	20	21	23	24	27	33	40	49	59	69	77	85	92
	F8	18	18	19	19	20	21	23	35	48	67	88	96	96	97	97	98	98	99
	F9	17	17	17	18	19	20	22	23	26	29	34	40	48	55	64	74	84	97
Mean Upper Flange		17	18	18	18	19	20	22	26	30	37	46	53	60	66	73	80	86	94
Exposed Flange (Angle)	F10	67	133	202	257	326	391	447	482	504	515	539	596	648	708	752	781	811	839
	F11	66	112	176	233	309	373	423	446	490	547	612	660	704	738	768	794	823	851
	F12	67	116	178	241	321	391	450	495	531	561	607	651	689	722	748	772	798	826
Mean Exposed Flange (Angle)		67	120	185	244	319	385	440	474	508	541	586	636	680	723	756	782	811	839
Unexposed Flange (Angle)	W9	25	41	67	99	138	181	225	268	308	343	393	434	469	501	531	560	588	613
	W10	26	43	69	103	142	185	229	271	308	342	391	432	467	500	530	560	588	614
	W11	24	40	66	100	143	189	234	276	313	346	394	433	468	500	531	561	588	613
Mean Unexposed Flange (Angle)		25	41	67	101	141	185	229	272	310	344	393	433	468	500	531	560	588	613
Angle Root	16	33	57	96	135	183	235	285	330	367	402	452	500	545	587	626	661	690	716
	17	32	54	89	130	180	233	286	334	375	415	474	524	567	604	639	669	696	722
	18	36	59	97	139	191	245	297	345	387	424	476	516	551	584	614	644	674	703
Mean Angle Root		33	56	94	134	185	238	289	336	376	414	467	513	554	592	626	658	687	714
Mean Atmosphere		426	601	649	697	742	767	781	791	803	815	835	856	875	905	909	927	940	957
ISO Curve at 22°C		504	605	665	707	740	768	791	810	828	844	867	887	904	920	934	947	959	970
Central Beam Deflection, mm		7	17	28	39	50	60	69	77	83	89	95	105	112	119	125	134	142	150

TABLE 5 SHELF ANGLE FLOOR TEST C - TEMPERATURE DATA SHEET

Sections 406 x 178 mm x 54 kg/m Grade 43A Beam (Tested at 60% of design load - BS449)
125 x 75 x 12 mm Grade 50B Angles

Concrete Floor 100 mm Slabs

Date 19.12.84

Failure Time 43 min (L/30)
74 min (L/20)

Thermocouple Location		Temperature, °C, After Various Times, min																								
		3	6	9	12	15	18	21	24	27	30	33	36	39	43	45	48	51	54	57	60	63	66	69	72	74
Lower Flange	F1	100	224	354	472	563	626	667	695	718	734	746	760	775	797	806	820	834	847	859	871	881	892	902	913	919
	F2	83	199	328	453	553	623	668	699	722	733	751	765	781	802	811	825	840	852	865	875	885	895	905	914	921
	F4	100	227	356	471	563	623	664	693	715	731	743	756	771	791	802	817	831	846	859	870	880	890	900	910	918
	F6	92	215	347	471	567	631	671	702	723	736	751	765	780	802	811	825	837	846	853	861	873	882	891	901	910
	F7	97	218	343	460	556	621	664	694	717	733	744	758	773	795	805	820	832	842	853	860	873	881	890	898	907
Mean Lower Flange		94	217	346	465	560	625	667	697	719	733	747	761	776	797	807	821	835	847	858	867	878	888	898	907	915
Web ¼ Position (Exposed)	W1	130	252	364	464	542	593	628	655	675	694	714	726	735	755	766	782	795	809	822	836	849	860	872	883	889
	W2	145	280	397	502	577	626	656	684	704	722	739	746	761	785	795	810	821	834	848	859	872	881	891	901	908
	W3	120	254	379	486	567	620	655	680	700	719	736	743	757	780	791	807	819	834	848	859	871	881	891	901	909
	W4	134	257	369	469	547	598	632	659	680	693	716	728	738	755	766	784	799	814	828	841	852	865	875	886	895
Mean Exposed Web		132	261	377	480	558	609	643	669	690	707	726	736	748	769	779	796	808	823	836	849	861	872	882	893	900
Web ¾ Position (Unexposed)	W5	12	18	28	41	56	71	88	103	121	134	148	156	165	178	185	194	203	213	222	232	242	252	264	276	287
	W6	13	20	31	47	64	81	100	114	141	154	170	181	194	210	218	230	241	252	264	277	289	302	315	328	340
	W7	14	20	32	47	66	84	100	112	130	145	161	172	188	208	217	231	244	258	271	284	295	306	317	328	338
	W8	12	18	28	40	58	73	88	100	105	112	127	139	154	173	182	195	208	220	232	244	256	268	281	293	304
Mean Unexposed Web		13	19	30	44	61	77	94	107	124	136	151	162	175	192	200	212	224	236	247	259	270	282	294	306	317
Upper Flange	F3	11	11	13	16	21	28	39	55	72	92	98	100	101	106	109	113	117	122	128	135	142	150	158	166	175
	F5	11	12	14	21	33	51	67	80	90	94	96	101	108	117	121	127	131	135	139	145	152	161	173	189	206
	F8	9	10	13	19	32	55	78	86	94	102	116	124	135	150	157	167	176	186	198	209	219	231	247	267	286
Mean Upper Flange		10	11	13	19	29	45	61	74	85	96	103	108	115	124	129	136	141	148	155	163	171	181	193	207	222
Exposed Flange (Angle)	F9	54	108	159	219	274	323	369	416	454	491	528	553	579	613	630	654	672	690	708	724	740	753	764	778	790
	F10	78	154	216	290	353	404	445	486	520	552	589	615	638	670	685	707	723	739	754	766	781	794	809	823	834
	F11	64	105	150	202	252	299	352	400	442	477	512	534	557	592	607	633	655	678	698	716	734	750	764	775	788
	F12	59	113	167	225	286	337	386	432	471	503	535	555	576	609	625	651	673	694	713	731	746	758	773	789	803
Mean Exposed Flange (Angle)		64	120	173	234	291	341	388	433	472	506	541	564	587	621	637	661	681	700	718	734	750	764	777	791	804
Unexposed Flange (Angle)	W9	16	31	55	86	114	150	186	223	257	288	321	344	371	403	419	441	462	482	501	519	535	552	568	582	594
	W10	19	38	67	102	135	175	216	255	293	328	365	388	416	451	467	491	513	533	553	571	588	605	621	635	647
	W11	15	28	48	75	104	137	173	210	243	274	308	331	357	389	404	427	449	469	489	508	526	543	560	576	589
	W12	18	35	59	91	121	156	194	233	270	304	340	364	390	424	440	465	488	510	531	551	570	587	604	620	633
Mean Unexposed Flange (Angle)		17	33	57	88	118	154	192	230	266	298	333	357	383	417	432	456	478	498	518	537	555	572	588	603	616
Angle Root	R1	30	57	97	143	191	238	283	327	366	403	441	466	494	530	546	569	591	611	630	647	665	680	695	708	719
	R2	29	55	88	129	173	216	262	308	349	386	423	447	473	508	525	551	574	597	617	637	655	623	689	704	715
Mean Angle Root		29	56	92	136	182	227	272	317	357	394	432	456	483	519	535	560	582	604	623	642	660	676	692	706	717
Mean Atmosphere		517	616	649	711	739	755	770	783	794	804	816	825	831	849	853	863	873	882	891	900	907	917	923	935	939
ISO Curve at 13°C		495	596	656	698	731	759	781	801	819	835	849	862	874	888	895	905	914	922	931	938	946	952	959	965	970
Central Beam Deflection, mm		5	15	28	41	52	63	75	86	96	107	118	129	139	150	156	165	173	180	187	194	201	207	213	220	224

TABLE 6 SHELF ANGLE FLOOR TEST D - TEMPERATURE DATA SHEET

Sections 406 x 178 x 54 kg/m Grade 43A Beam
125 x 75 x 12 mm Grade 50B Angles

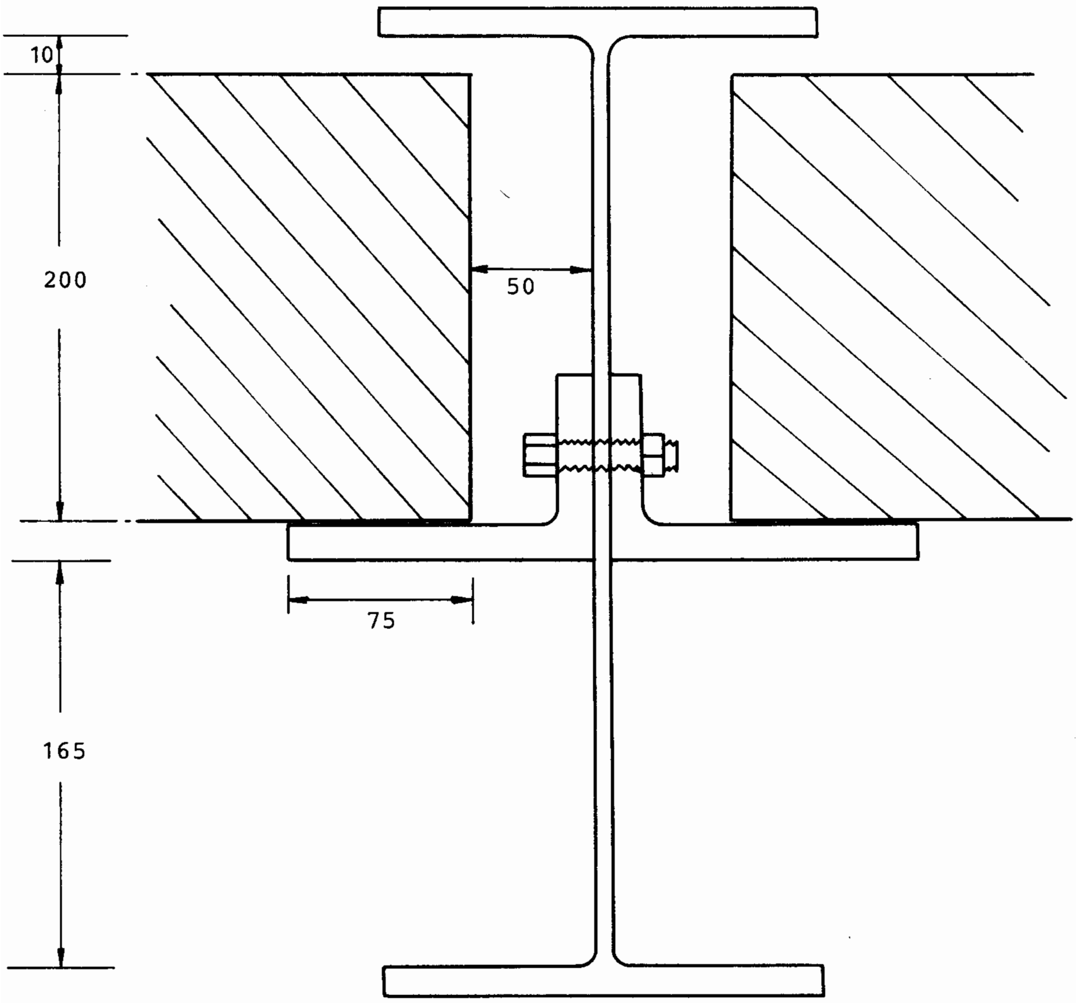
Date 11.7.84

Concrete Floor 100 mm Slabs

Failure Time 29 min

Thermocouple Location		Temperature, °C, After Various Times, min								
		3	6	9	12	15	18	21	24	29
Lower Flange	F1	74	219	339	480	571	627	668	697	724
	F2	97	241	355	492	529	634	675	705	735
	F4	74	217	339	479	570	627	669	700	733
	F6	93	243	363	498	587	673	678	709	738
	F7	75	213	337	479	572	631	674	705	734
Mean Lower Flange		83	227	347	486	576	631	673	703	733
Web ¼ Position (Exposed)	W1	88	235	343	466	545	596	635	669	709
	W2	89	247	361	492	572	617	656	686	724
	W3	85	230	345	479	561	613	653	683	719
	W4	89	234	341	464	543	596	636	667	707
Mean Exposed Web		87	236	347	475	555	605	645	676	715
Web ¾ Position (Unexposed)	W5	23	28	38	52	68	86	105	126	161
	W6	23	28	39	53	71	92	113	135	174
	W7	23	29	41	56	75	96	119	141	180
	W8	23	28	37	49	64	81	98	120	152
Mean Unexposed Web		23	28	39	52	69	89	109	130	167
Upper Flange	F3	22	23	24	28	35	44	56	69	99
	F5	22	22	24	28	34	45	58	74	95
	F8	23	23	25	28	34	43	54	69	98
	F9	23	23	25	29	35	44	54	67	96
Mean Upper Flange		22	22	24	28	34	44	55	70	97
Exposed Flange (Angle)	F10	90	161	217	292	355	411	465	513	578
	F11	75	157	211	290	352	409	458	501	561
	F12	79	164	226	300	366	429	472	514	573
Mean Exposed Flange (Angle)		81	161	218	294	358	416	465	509	571
Unexposed Flange (Angle)	W9	27	47	78	121	168	215	260	303	368
	W10	27	45	74	116	165	213	260	303	367
	W11	27	48	80	123	172	220	264	305	368
Mean Unexposed Flange (Angle)		27	47	77	120	168	216	261	303	368
Angle Root	16	34	67	106	159	214	267	318	366	437
	17	33	69	110	167	223	277	328	375	443
	18	33	68	108	163	221	275	324	370	440
Mean Angle Root		33	68	108	163	219	273	323	370	440
Mean Atmosphere		466	611	679	722	741	759	783	799	818
ISO Curve at 24°C		506	607	667	709	742	770	793	812	841
Central Beam Deflection, mm		5	20	29	44	58	74	93	113	150

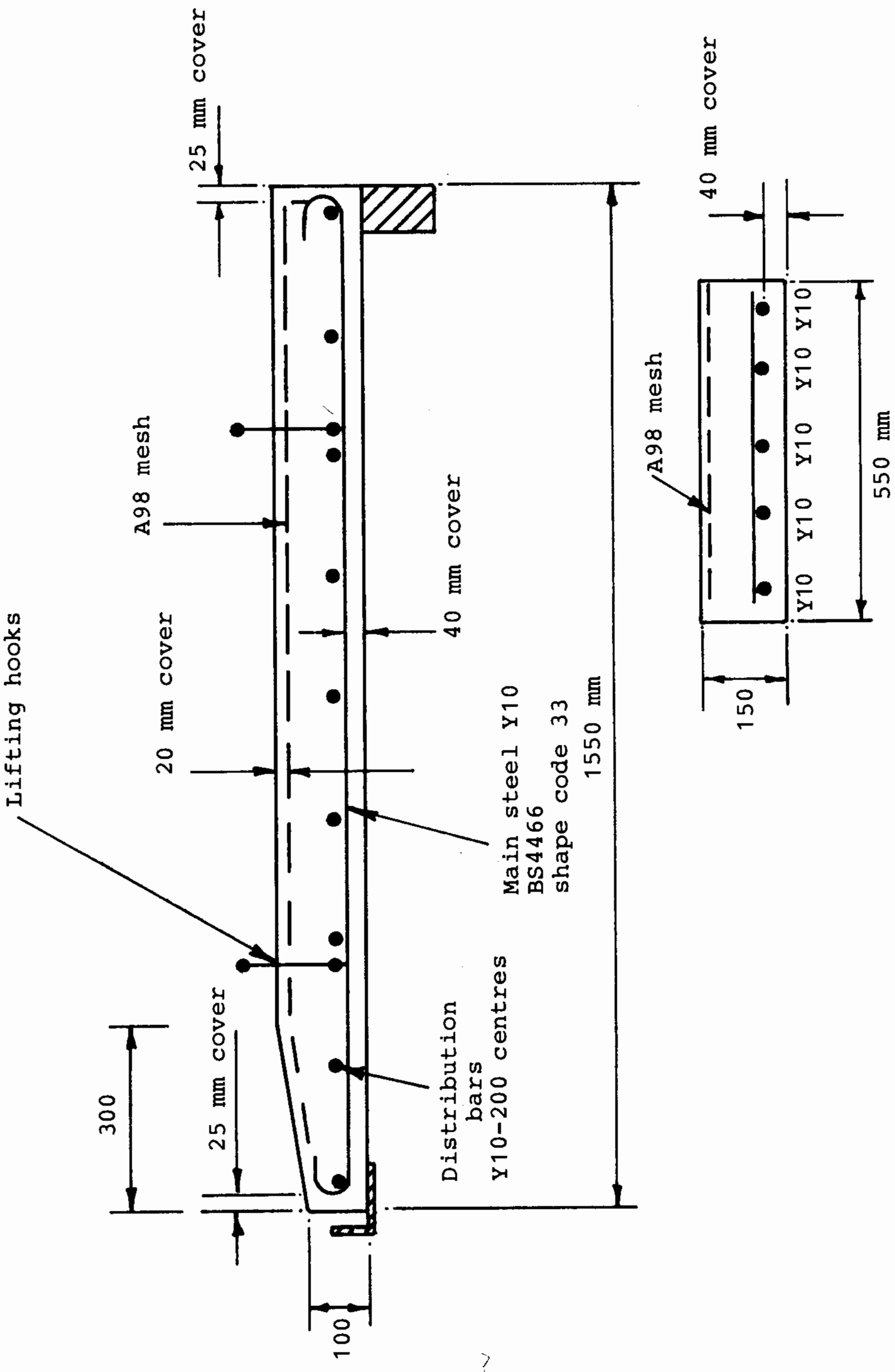
Beam size 406 x 178 mm x 54 kg/m
Angle size 125 x 75 x 12 mm
Bolts M20 Grade 8.8



Dimensions in mm

SCHEMATIC ILLUSTRATION OF A TYPICAL TEST ARRANGEMENT

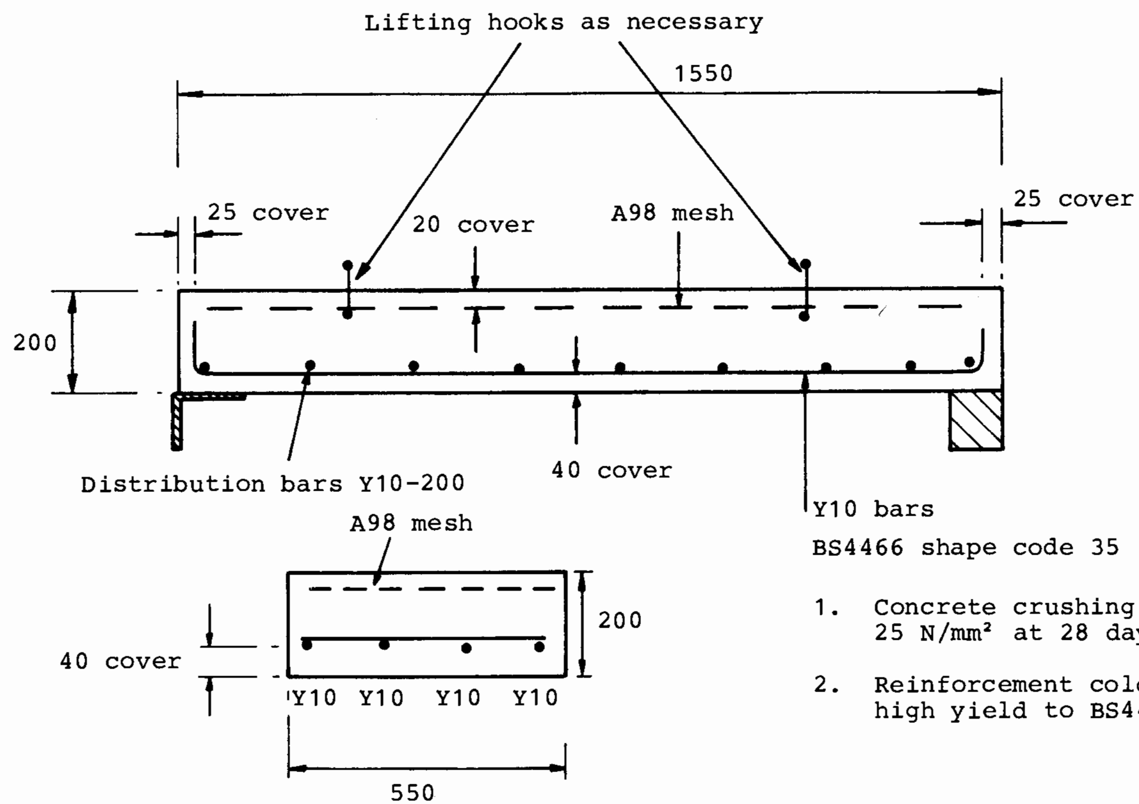
FIG. 1
(R1/8766)



TAPERED PRECAST CONCRETE FLOOR - UNITS USED IN THE TEST

FIG. 2(a)
(R2/6064)

All dimensions in mm



BS4466 shape code 35

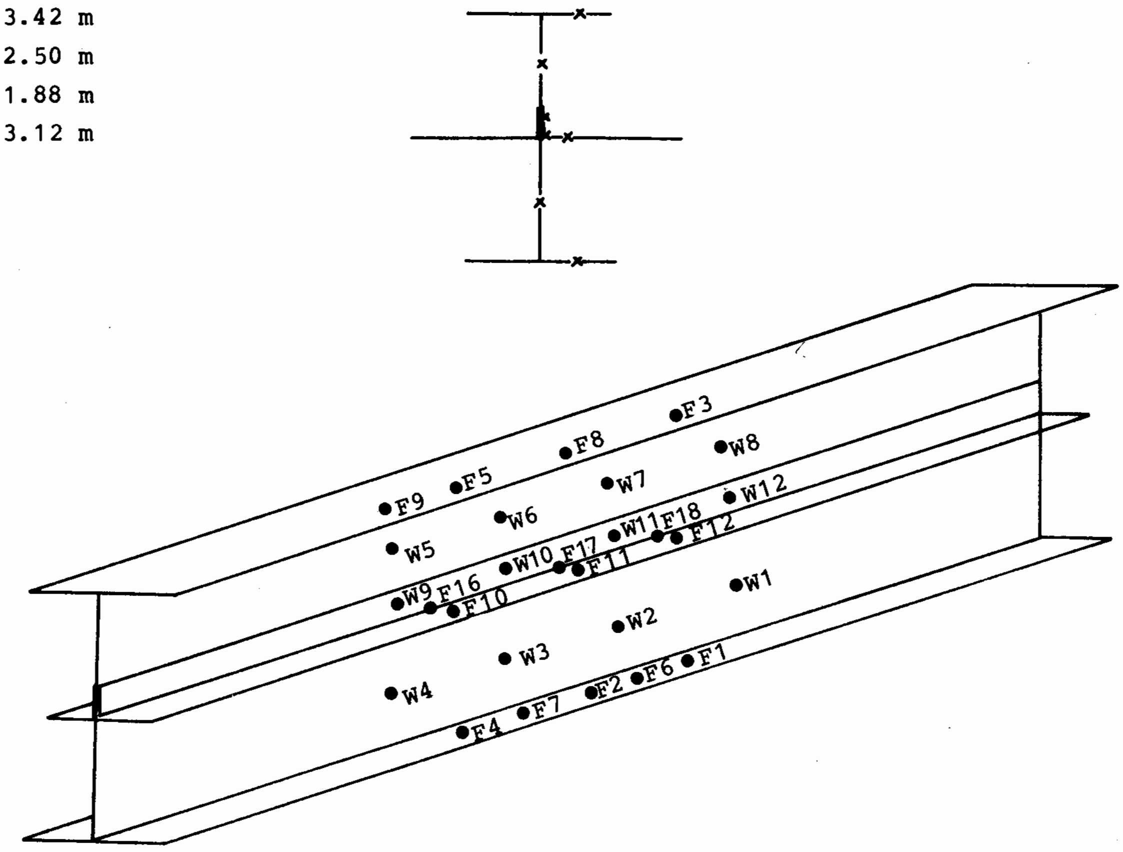
1. Concrete crushing strength 25 N/mm^2 at 28 days

2. Reinforcement cold worked high yield to BS4461

PRECAST CONCRETE SLAB DESIGNS USED IN TEST

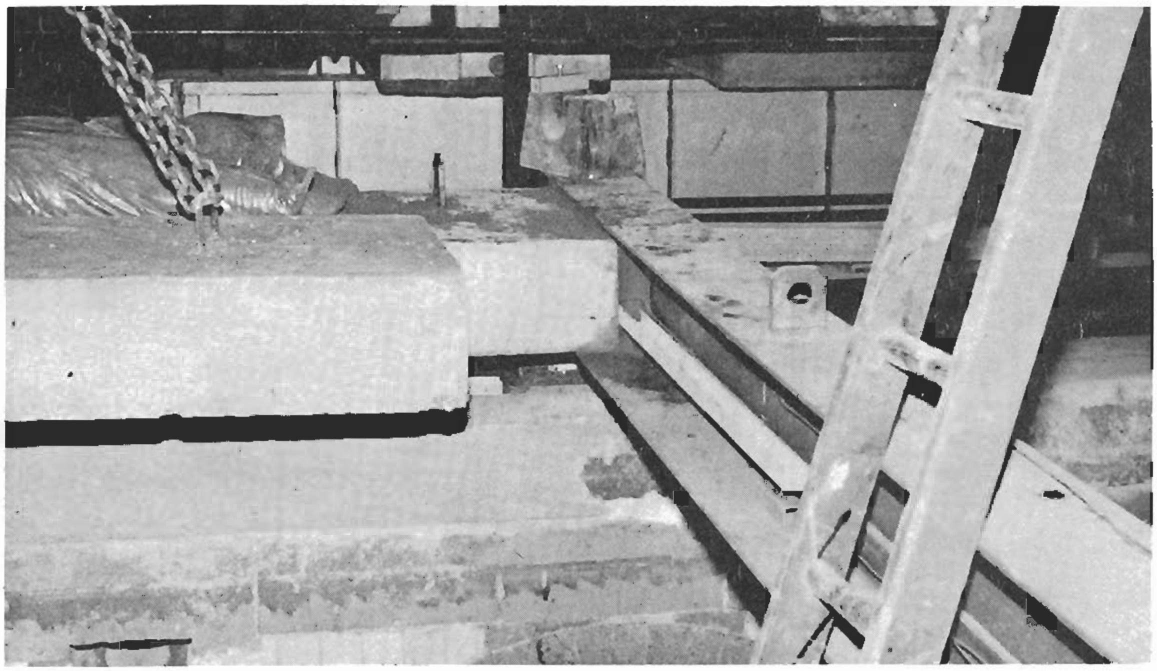
FIG. 2(b)
(R2/919)

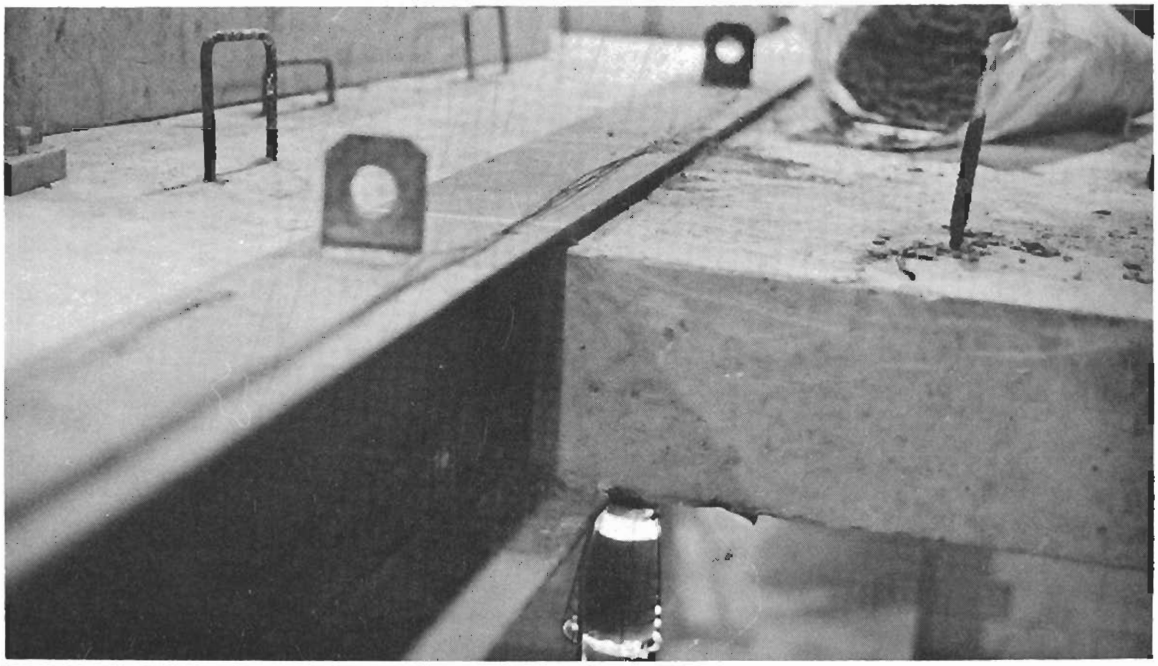
F9, W9, W4, W5	- 1.57 m
W10, F7, W3, W6	- 2.17 m
W11, F6, W2, W7	- 2.80 m
W12, W1, W8	- 3.42 m
F11, F2, F8, F17	- 2.50 m
F4, F10, F5, F16	- 1.88 m
F1, F12, F3, F18	- 3.12 m



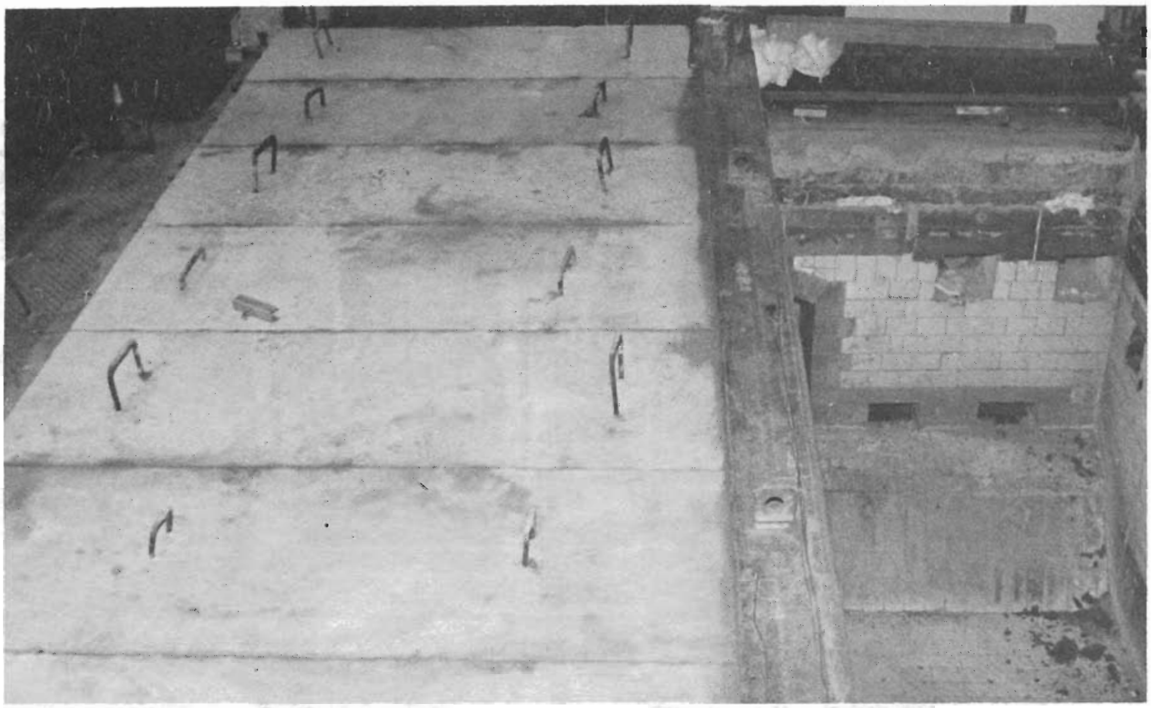
THERMOCOUPLE LOCATIONS USED ON TEST ARRANGEMENT

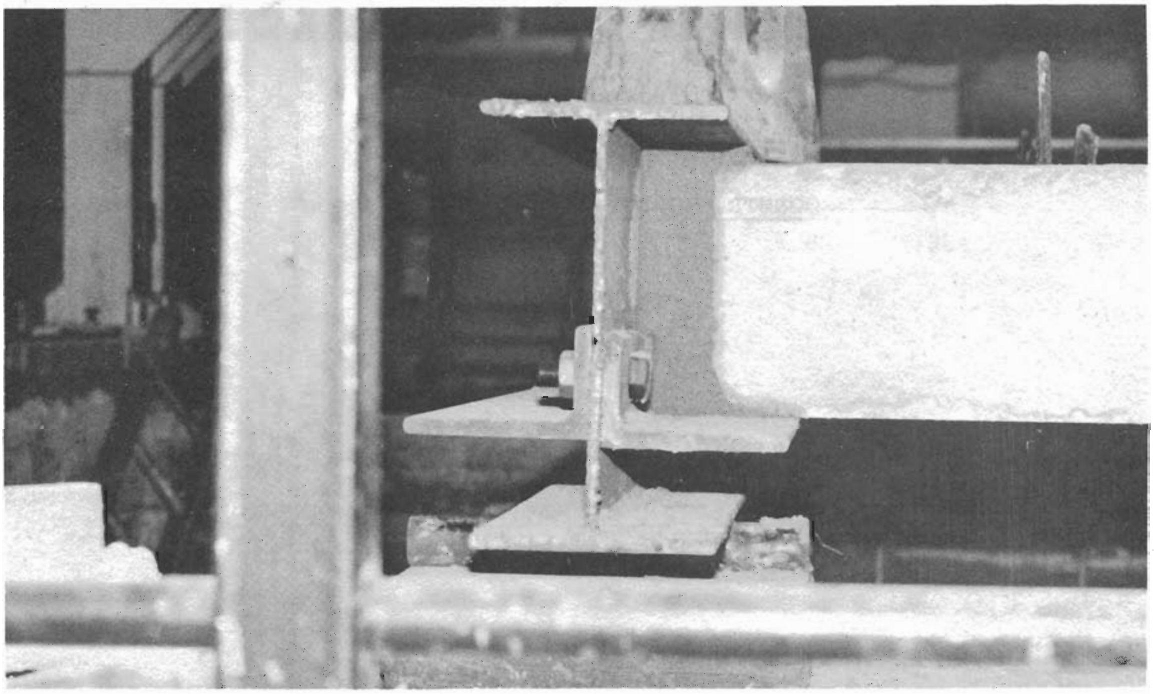
FIG. 3
(R2/920)



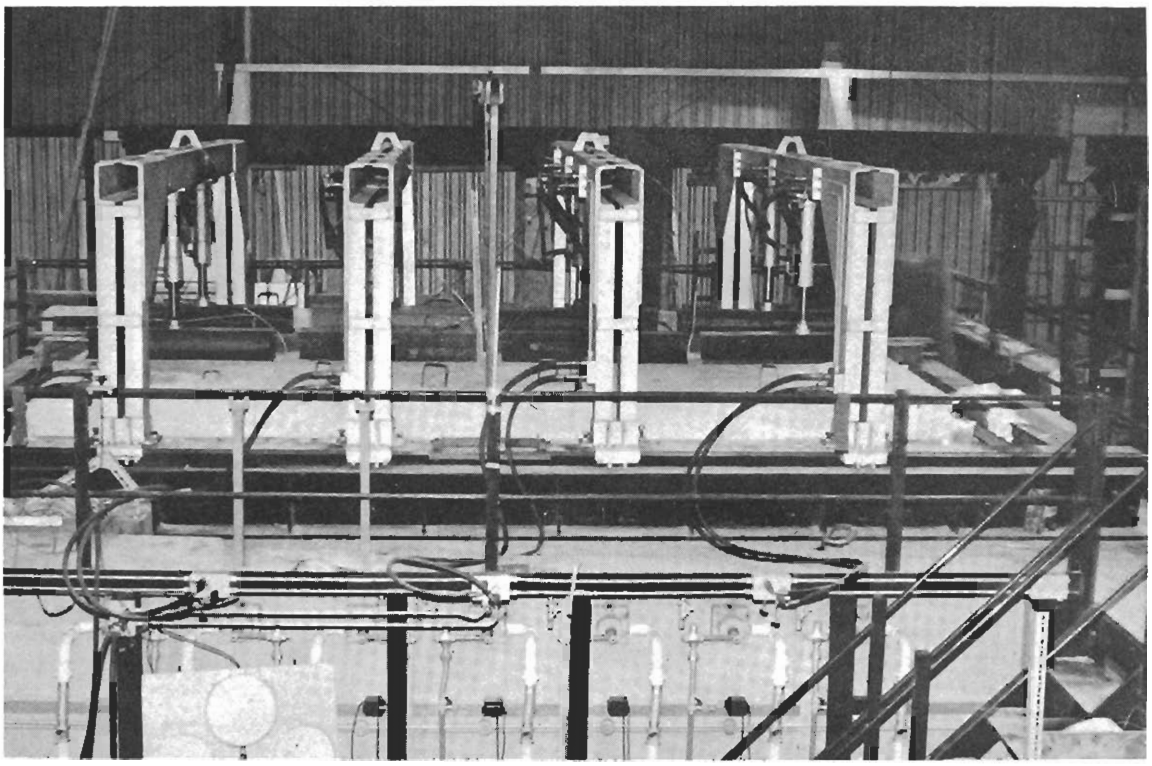


ASSEMBLY OF CONSTRUCTION FIG. 4

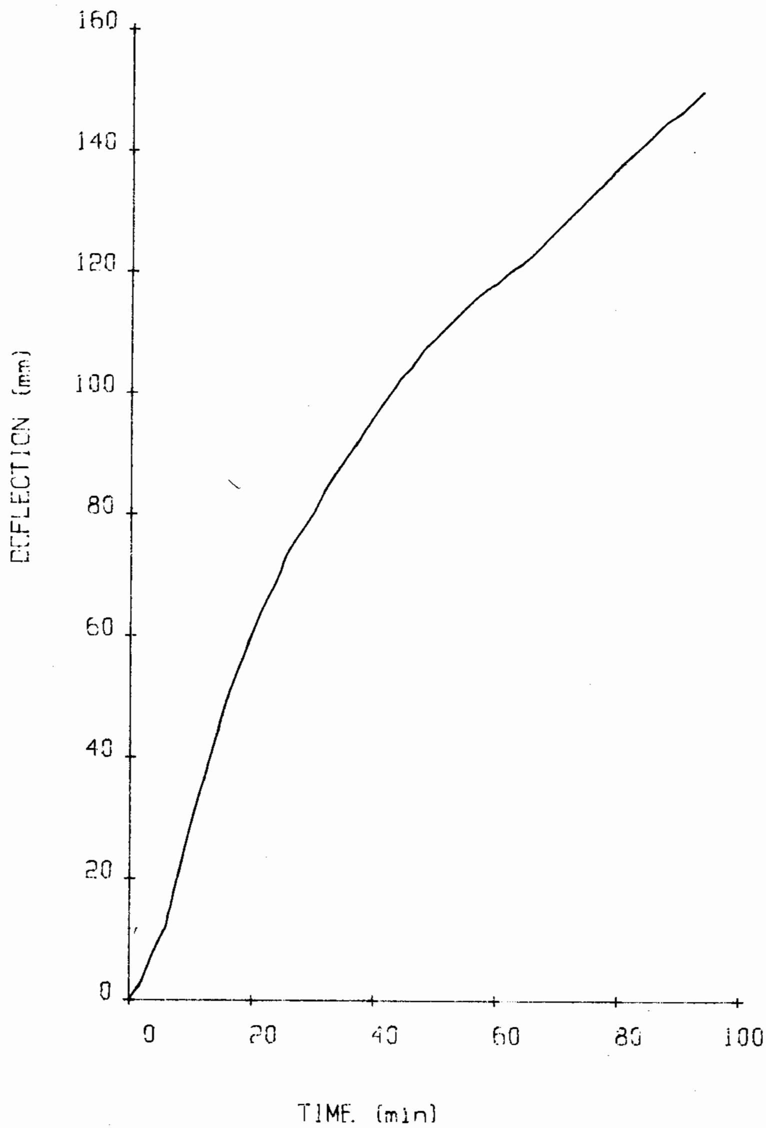




ASSEMBLY OF CONSTRUCTION FIG. 5

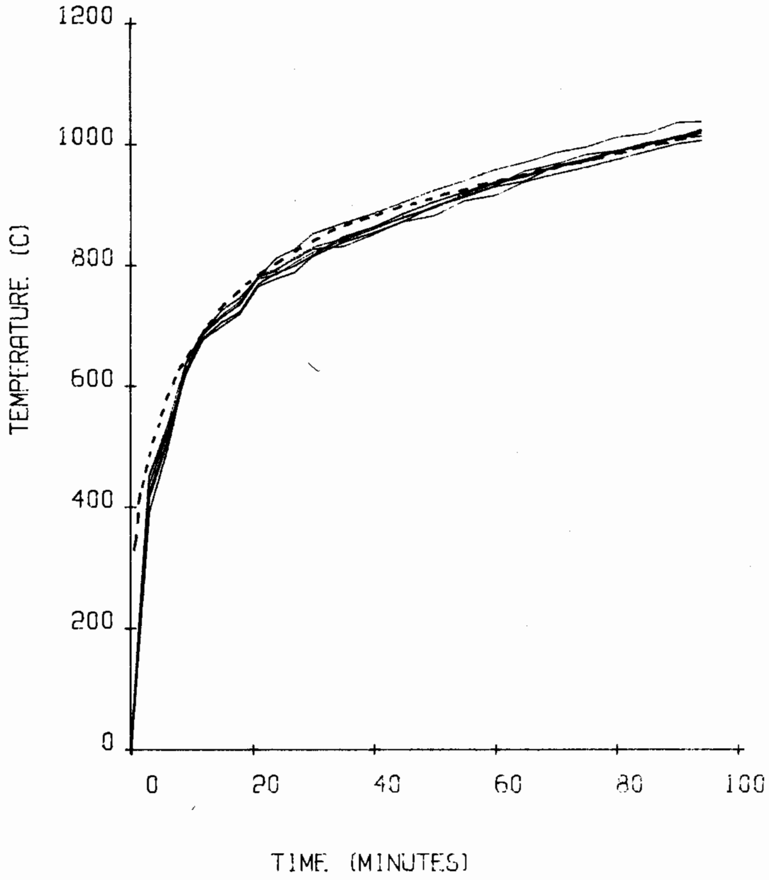


CONSTRUCTION PRIOR TO TESTING FIG. 6



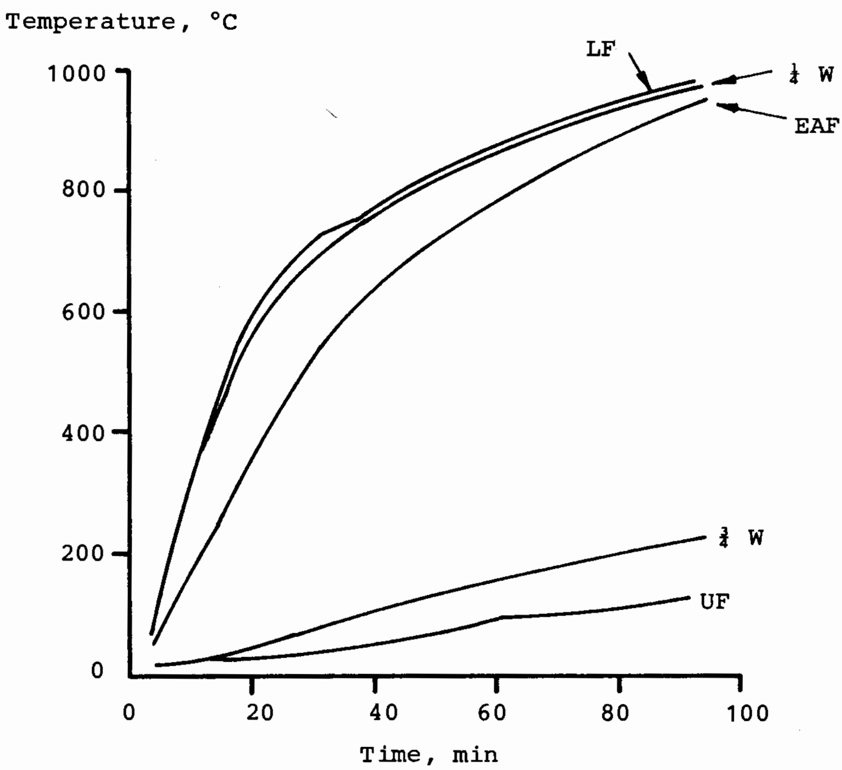
<u>CENTRAL VERTICAL DEFLECTION MEASURED ON THE 406 x 178 mm x 54 kg/m BEAM DURING TEST A</u>

FIG. 7



COMPARISON OF FURNACE ATMOSPHERE TEMPERATURES MEASURED IN TEST A WITH INTERNATIONAL TIME/TEMPERATURE CURVE

FIG. 8

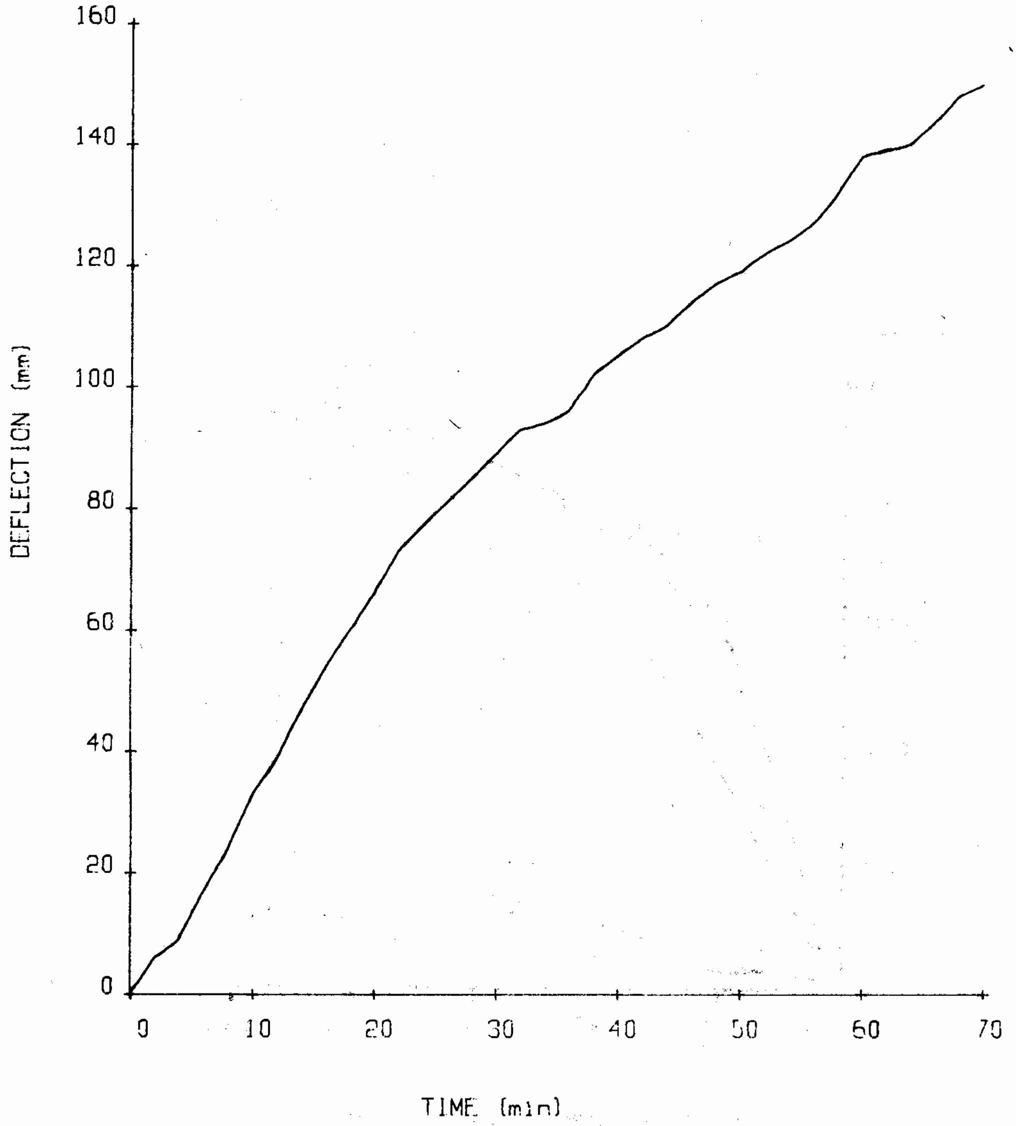


LF, UF = Lower, upper flange

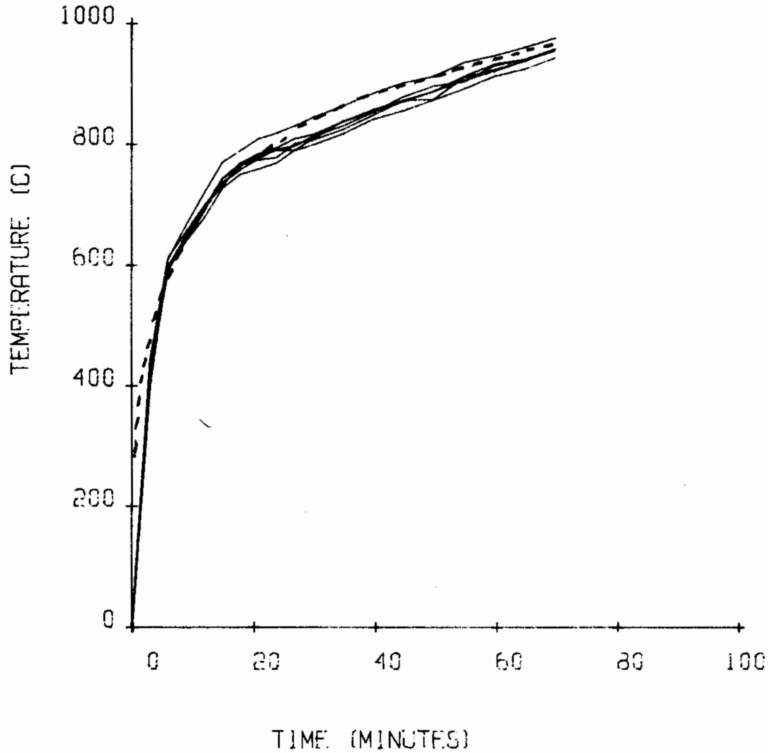
W = Web, EAF = Exposed angle flange

AVERAGE TEMPERATURES RECORDED AT DIFFERENT POSITIONS ACROSS A 406 x 178 mm x 54 kg/m SHELF ANGLE BEAM WITH 200 mm CONCRETE SLABS IN TEST A

FIG. 9
(R2/6065)

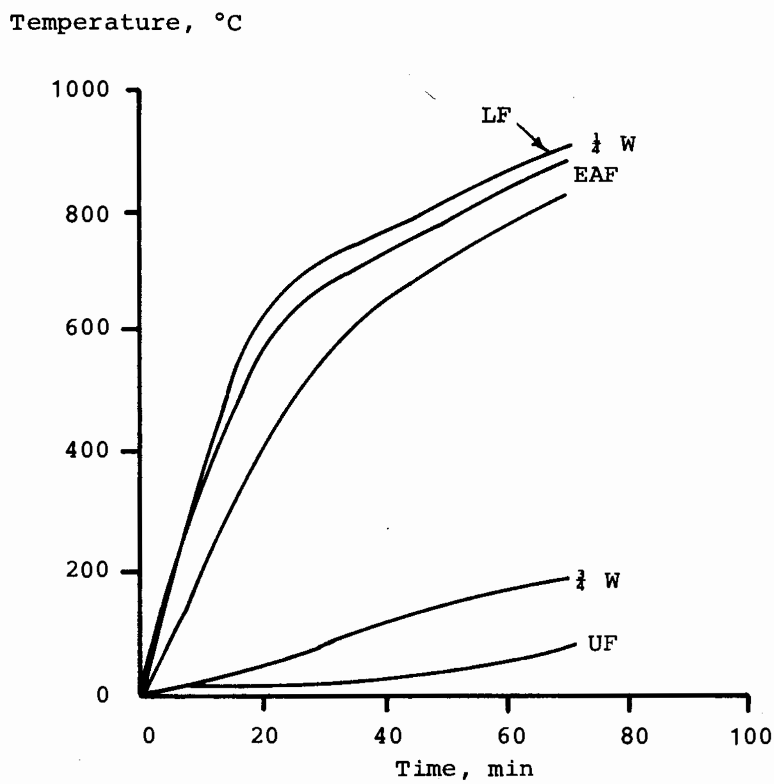


CENTRAL VERTICAL DEFLECTION MEASURED ON THE 406 x 178 mm x 54 kg/m BEAM DURING TEST B FIG. 10



COMPARISON OF FURNACE ATMOSPHERE TEMPERATURES MEASURED IN TEST B WITH INTERNATIONAL TIME/TEMPERATURE CURVE

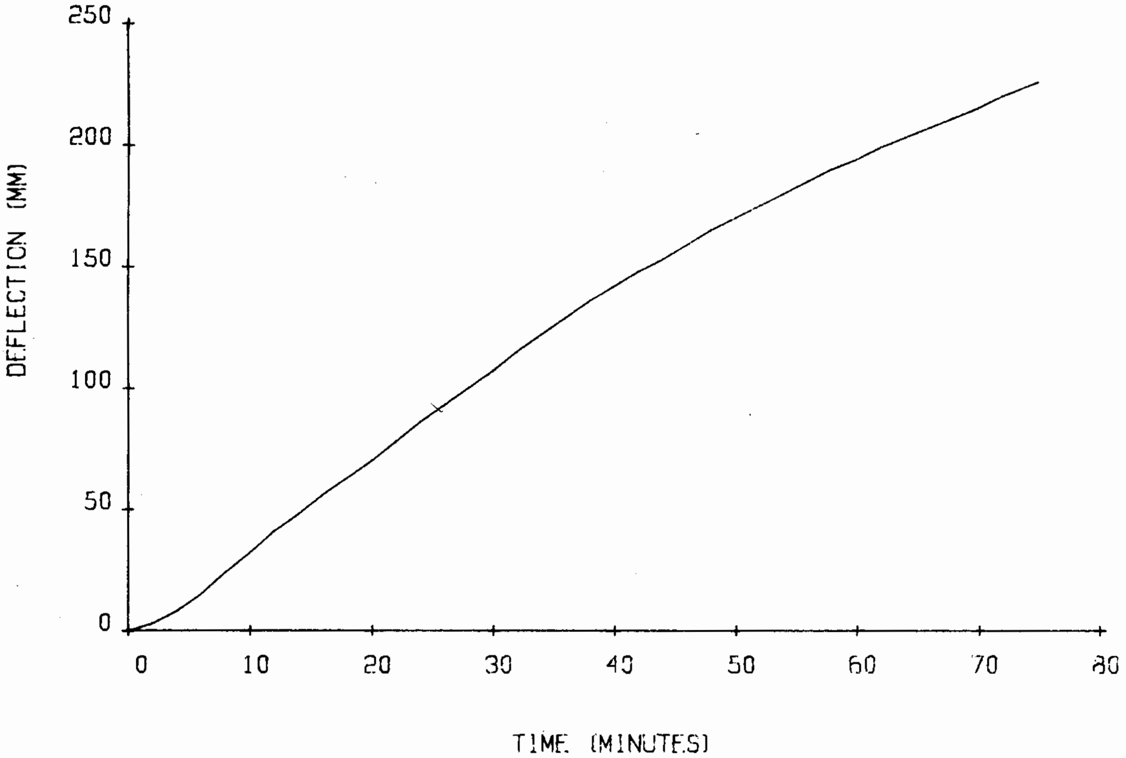
FIG. 11



LF, UF = Lower, upper flange
W = Web, EAF = Exposed angle flange

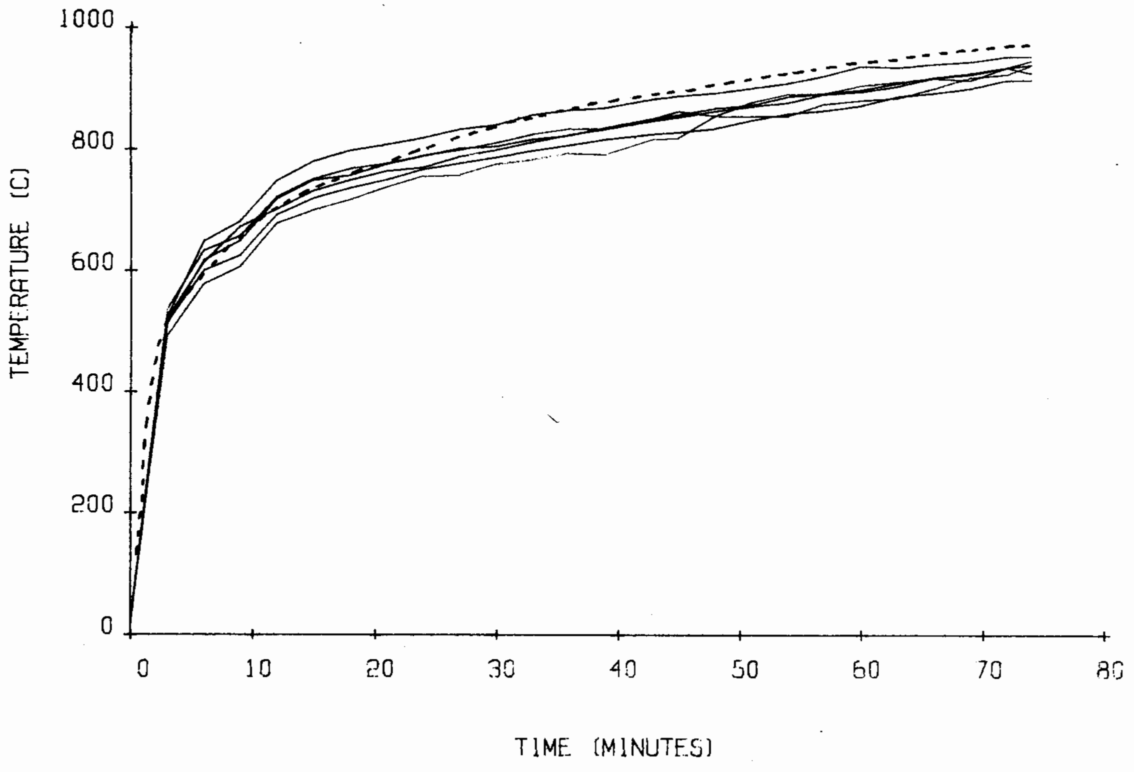
AVERAGE TEMPERATURES RECORDED AT DIFFERENT POSITIONS ACROSS A 406 x 178 mm x 54 kg/m SHELF ANGLE BEAM WITH 200 mm CONCRETE SLABS IN TEST B

FIG. 12
(R2/6066)



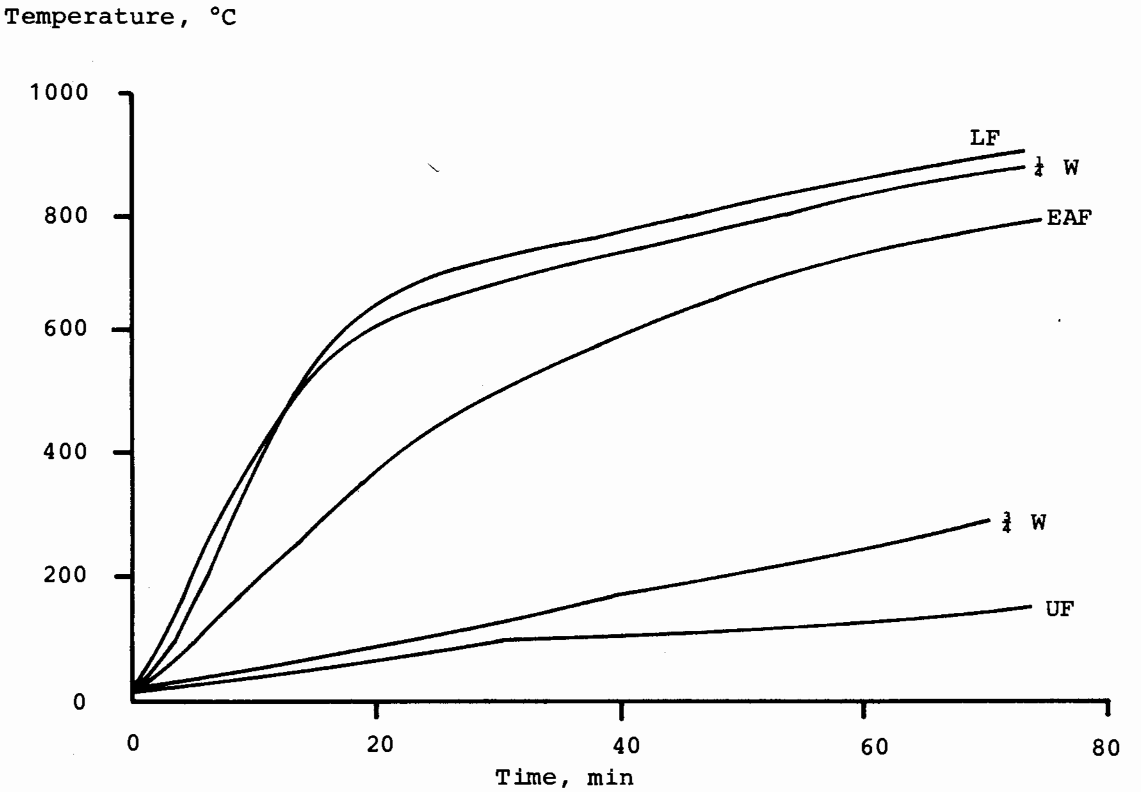
<u>CENTRAL VERTICAL DEFLECTION MEASURED ON THE 406 x 178 mm x 54 kg/m BEAM DURING TEST C</u>

FIG. 13



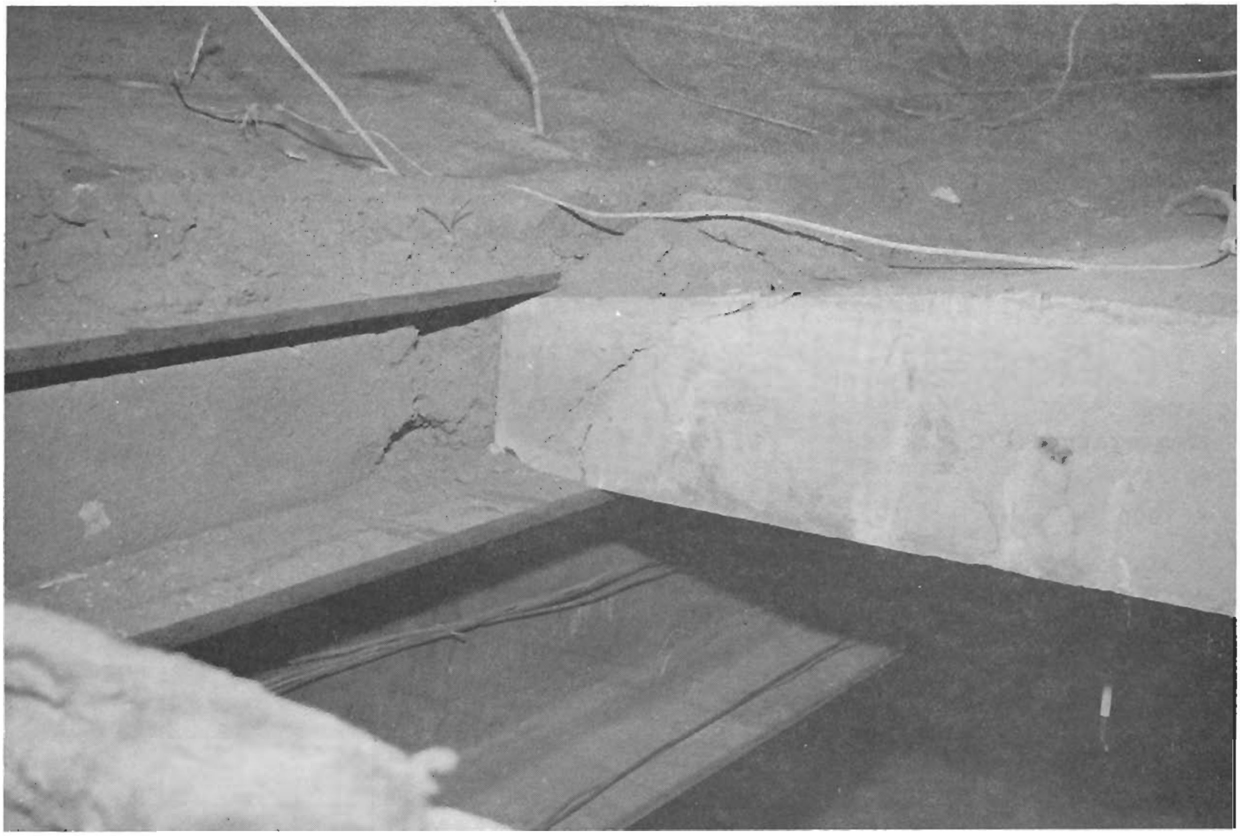
COMPARISON OF FURNACE ATMOSPHERE TEMPERATURES MEASURED IN TEST C WITH INTERNATIONAL TIME/TEMPERATURE CURVE

FIG. 14

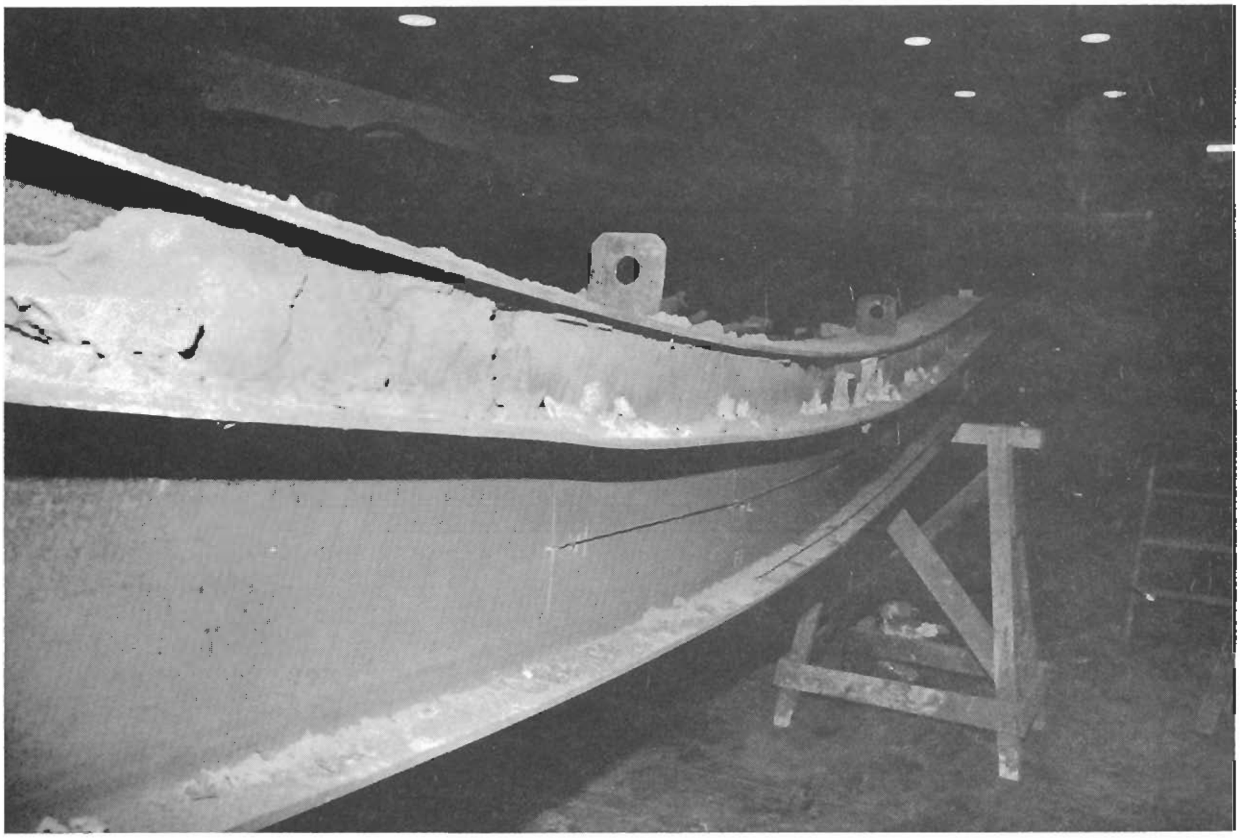


AVERAGE TEMPERATURES RECORDED AT DIFFERENT POSITIONS ACROSS A 406 x 178 mm x 54 kg/m SHELF ANGLE BEAM WITH 100 mm CONCRETE SLABS IN TEST C

FIG. 15
(R2/6067)

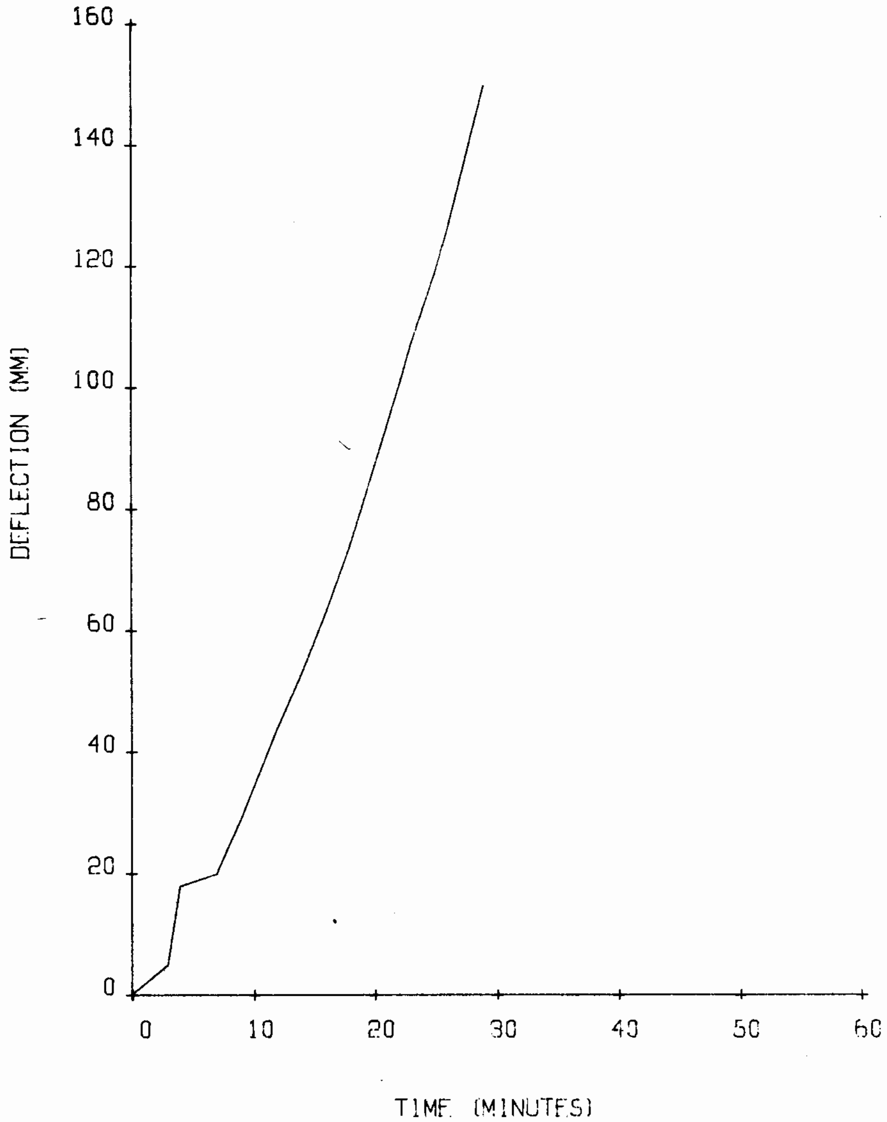


Cracks in 100 mm slab (a)



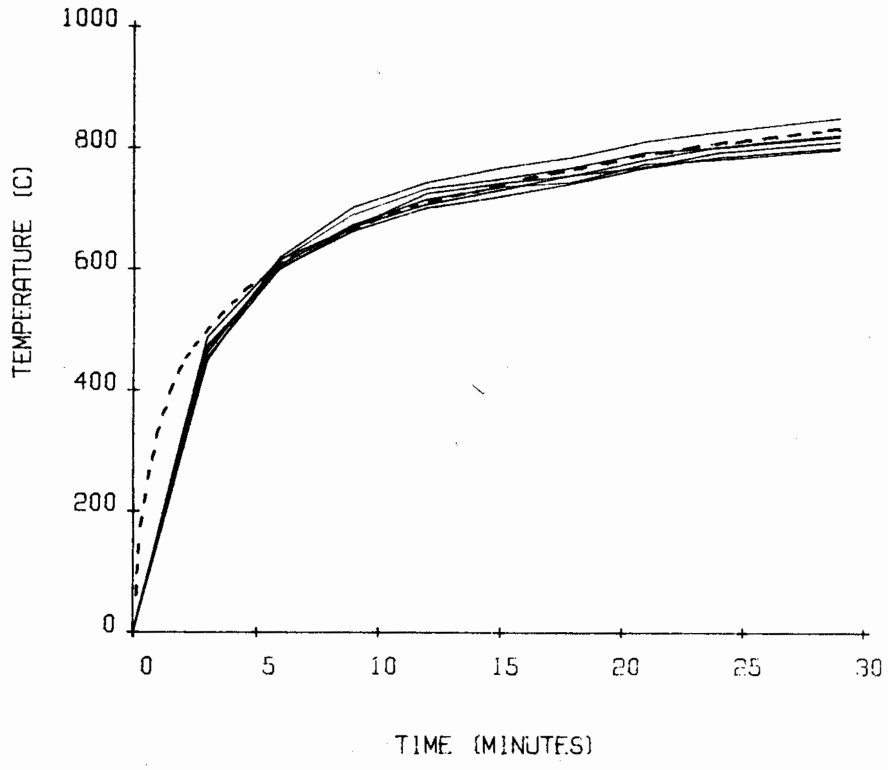
Uniform deflection of beam (b)

OBSERVATIONS IN TEST C FIG. 16

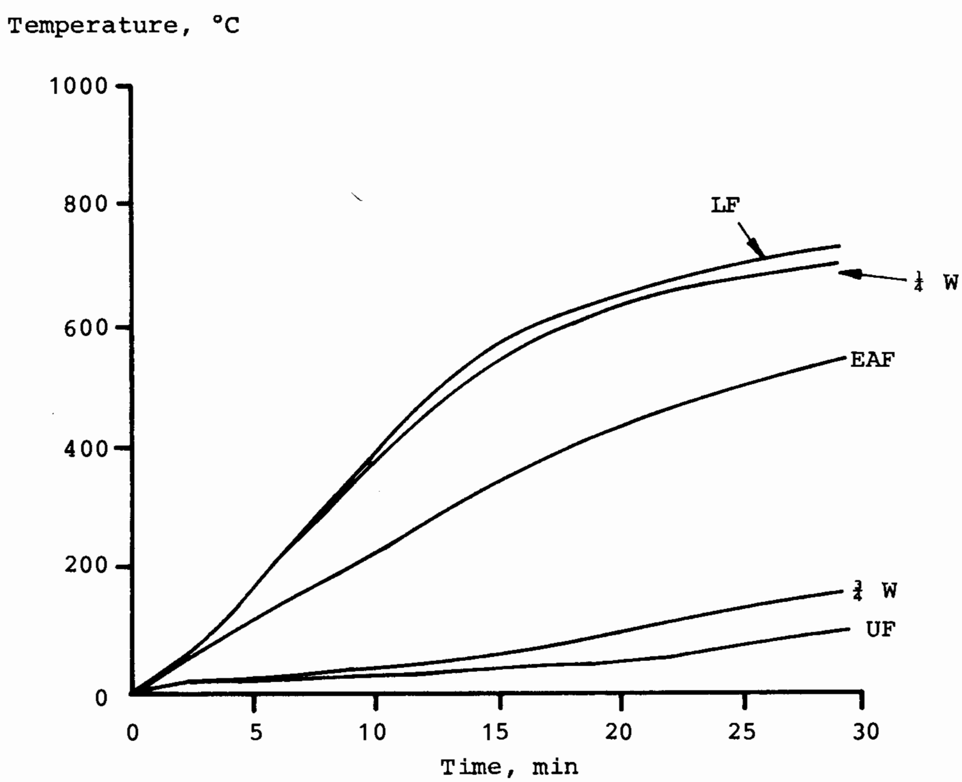


<u>CENTRAL VERTICAL DEFLECTION MEASURED ON THE 406 x 178 mm x 54 kg/m BEAM AND CONCRETE SLABS DURING TEST D</u>

FIG. 17



COMPARISON OF FURNACE ATMOSPHERE TEMPERATURES MEASURED ON TEST D WITH INTERNATIONAL TIME/TEMPERATURE CURVE — **FIG. 18**



AVERAGE TEMPERATURES RECORDED AT DIFFERENT POSITIONS ACROSS A 406 x 178 mm x 54 kg/m SHELF ANGLE BEAM WITH 100 mm CONCRETE SLABS IN TEST D

FIG. 19
(R2/6068)

APPENDIX 1 LOAD CALCULATIONS

406 x 178 mm x 54 kg/m UB Grade 43A
125 x 75 x 12 mm Shelf Angles
Effective Span 4.5 m

Maximum safe working uniformly distributed load = 271 kN

∴ Operating at 80% of maximum = 217 kN
60% of maximum = 163 kN

Total dead weight of cover slabs and spreader beams = 72 kN

∴ Reaction on each shelf angle $= \frac{72}{2} \times \frac{1}{2} = 18$ kN

Total force required on each shelf angle to produce maximum operating stress (165 N/mm²) in test beam $= \frac{271}{2} = 135.5 - 18 = 117.5$ kN

∴ Force required by each set of rams $= \frac{117.5 \times 1.6}{1.1} = 171$ kN

∴ Force required by each ram $= \frac{171}{4} = 42.75$ kN

Total hydraulic forces applied = 42.75 x 8 = <u>342 kN</u> - Test D

Total hydraulic forces applied for 80% loading = 236 kN - Test B
60% loading = 185 kN - Test C

406 x 178 mm x 54 kg/m UB Grade 50B
125 x 75 x 12 mm Shelf Angles
Effective Span 4.5 m

Safe working uniformly distributed load = 378 kN

Tested at 40% of maximum UDL = 163 kN

Total dead weight of cover slabs and spreader beams = 72 kN

∴ Reaction on each shelf angle $= \frac{72}{2} \times \frac{1}{2} = 18$ kN

Total force required on each shelf angle to produce design stress in test beam $= \frac{163}{2} = 81.5 - 18 = 63.5$ kN

∴ Force required by each set of rams $= \frac{63.5 \times 1.6}{1.1} = 92.36$ kN

∴ Force required by each ram $= \frac{92.36}{4} = 23.1$ kN

Total hydraulic force applied = 23.1 x 8 = <u>185 kN</u>

APPENDIX 2 TEST A

WARRINGTON RESEARCH CENTRE

Fire Research, Testing and Consultancy

Warrington Research
Consultants (Services) Limited
Holmesfield Road
Warrington WA1 2DS
Tel Warrington (0925) 55116
Telex 628743 WARRES G

W.R.C.S.I. 34140
25 May 1984 - LH/RC

Mr. G. Thompson
British Steel Corporation
Sheffield Laboratories
Swindon House
Moorgate
ROTHERHAM

Dear Sir,

FIRE RESISTANCE TEST RESULTS

We confirm the results of a fire resistance test carried out on your behalf in accordance with BS 476: Part 8: 1972, on a steel beam of serial size 406 mm by 178 mm by 54 kg/m, Grade 50B, which supported precast reinforced concrete slabs of overall size 1550 mm long by 550 mm wide by 200 mm deep on each side of the beam. The concrete slabs were supported on a continuous angle of size 125 mm by 75 mm by 12 mm thick Grade 50B on each side of the web of the beam. A total load of 184.8 kN was applied to the concrete slabs at $^1/8$, $^3/8$, $^5/8$ and $^7/8$ span positions. The load was calculated by the sponor to be 40% of the maximum allowable for the beam. The loading was applied at a distance of 500 mm away from the centre line of the beam and each side of the beam. The ends of the concrete slabs being supported by the steel beam, were bedded in a sand and cement mortar mix. The steel beam was unprotected. The test results were as follows:

Stability : 94 minutes
Re-load Test : Satisfied

Date of Test : 24 May 1984

Our full report will follow in due course.

Yours faithfully,

L.Healey

L.HEALEY
Technical Officer -
Structural Fire Protection
WARRINGTON RESEARCH CENTRE

WP Ref. 155

APPENDIX 2 TEST B

WARRINGTON RESEARCH CENTRE

Fire Research, Testing and Consultancy

Warrington Research
Consultants (Services) Limited
Holmesfield Road
Warrington WA1 2DS
Tel Warrington (0925) 55116
Telex 628743 WARRES G

Mr. G. Thompson,
British Steel Corporation,
Sheffield Laboratories,
Swindon House,
Moorgate,
Rotherham.

W.R.C.S.I. No. 34478
27th June 1984 - LH/RC

Dear Sir,

FIRE RESISTANCE TEST RESULTS

We confirm the results of a fire resistance test carried out on your behalf in accordance with B.S. 476: Part 8: 1972, on a steel beam of serial size 406 mm x 178 mm x 54 kg/m, Grade 43A which supported precast reinforced concrete slabs of overall size 1550 mm long by 550 mm wide by 200 mm deep on each side of the beam. The concrete slabs were supported on a continuous angle of size 125 mm by 75 mm by 12 mm thick Grade 50B on each side of the web of the beam. A total load of 263 kN was applied to the concrete slabs at 1/8, 3/8, 5/8 and 7/8 span positions. The load was calculated by the sponsor to be 80% of the maximum allowable for the beam. The loading was applied at a distance of 500 mm away from the centre line of the beam on each side of the beam. The ends of the concrete slabs being supported by the steel beam, were bedded in a sand and cement mortar mix. The steel beam was unprotected. The test results were as follows:

Stability : 70 minutes
Re-load test: Satisfied

Date of test: 26th June 1984

Our full report will follow in due course.

Yours faithfully,

L Healey

(L. HEALEY)
Warrington Research Centre

APPENDIX 2 TEST C

WARRINGTON RESEARCH CENTRE
Fire Research, Testing and Consultancy

Warrington Research
Consultants (Services) Limited
Holmesfield Road
Warrington WA1 2DS
Tel: Warrington (0925) 55116
Telex: 628743 WARRES G

W.R.C.S.I. 35217 - LH/LMC
7 January 1985

British Steel Corporation
Sheffield Laboratories
Swindon House
Moorgate
ROTHERHAM.

Dear Sirs,

FIRE RESISTANCE TEST RESULTS

We confirm the results of a fire resistance test carried out on your behalf in accordance with B.S. 476 : Part 8 : 1972 and to the draft amendment of the Standard, on a steel beam of serial size 406 mm x 178 mm x 54 kg/m, Grade 43A which supported precast reinforced concrete slabs of overall size 1550 mm long x 550 mm wide x 150 mm deep with one end of the concrete slabs tapering to 100 mm deep over a distance of 300 mm. The concrete slabs were positioned on each side of the beam. The concrete slabs were supported on a continuous angle of size 125 mm x 75 mm x 12 mm thick Grade 50 on each side of the web of the beam. The tapered ends of the concrete slabs rested on to the continuous angles. A total load of 184.8 kN was applied to the concrete slabs at 1/8, 3/8, 5/8 and 7/8 span positions. The load was calculated by the sponsor to be 60% of the maximum allowable for the beam. The loading was applied at a distance of 500 mm away from the centre line of the beam on each side of the beam. The ends of the concrete slabs being supported by the steel beam, were bedded in a sand and cement mortar mix. The steel beam was unprotected. The test results were as follows.

Stability (L/30)	:	43 minutes
Stability (L/20)	:	74 minutes (Test discontinued)
Re-load test	:	Satisfied
Date of Test	:	19 December 1984

Yours faithfully,

L. Healey

L. HEALEY
Warrington Research Centre

APPENDIX 2 TEST D

WRC

WARRINGTON RESEARCH CENTRE

Fire Research, Testing and Consultancy

Warrington Research
Consultants (Services) Limited
Holmesfield Road
Warrington WA1 2DS
Tel Warrington (0925) 55116
Telex 628743 WARRES G

W.R.C.S.I. No. 34142 - LH/SB

12th July 1984

British Steel Corporation
Sheffield Laboratories
Swindon House
Moorgate, Rotherham

Dear Sirs,

FIRE RESISTANCE TEST RESULTS

We confirm the results of a fire resistance test carried out on your behalf in accordance with B.S. 476: Part 8: 1972, on a steel beam of serial size 406 mm x 178 mm x 54 kg/m, Grade 43A which supported precast reinforced concrete slabs of overall size 1550 mm long by 550 mm wide by 150 mm deep with one end of the concrete slabs tapering to 100 mm deep over a distance of 300 mm. The concrete slabs were positioned on each side of the beam. The concrete slabs were supported on a continuous angle of size 125 mm by 75 mm by 12 mm thick Grade 50 on each side of the web of the beam. The tapered ends of the concrete slabs rested on to the continuous angles. A total load of 352 kN was applied to the concrete slabs at 1/8, 3/8, 5/8 and 7/8 span positions. The load was calculated by the sponsor to be 100% of the maximum allowable for the beam. The loading was applied at a distance of 500 mm away from the centre line of the beam on each side of the beam. The ends of the concrete slabs being supported by the steel beam, were bedded in a sand and cement mortar mix. The steel beam was unprotected. The test results were as follows:

Stability : 29 minutes
Re-load test: Satisfied

Date of test: 11th July 1984.

Yours faithfully,

(L. HEALEY)

Warrington Research Centre

INITIAL CIRCULATION

Swinden Laboratories

Mr. T.R. Kay
Dr. B.R. Kirby
Mr. J. Lessells
Mr. D.E. Wainman
Mr. E.F. Walker

Teesside Laboratories

Dr. R. Baker

GENERAL STEELS GROUP

BSC Plates, Sections and Commercial Steels

Steel House (Redcar)

Mr. G. Hogan
Mr. R.A.C. Latter
Mr. J.T. Robinson
Mr. M.J. Thorndike

Lackenby

Mr. C. Mortlock
Mr. E.D. Smith

Scunthorpe

Dr. M.J. Pettifor
Dr. T.J. Pike