FIRE ENDURANCE OF PRESTRESSED CONCRETE DOUBLE-TEE WALL ASSEMBLIES

Prepared by PCI Committee on Fire Resistance Ratings

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A fire test of a prestressed concrete double-tee wall assembly was conducted by Underwriters' Laboratories on July 22, 1969. The UL test report follows this report.

A standard fire (ASTM E 119) was applied to the flat surface with the stems away from the fire. The wall withstood the applied loading (equivalent to 800 lb. per lin. in.) for 2 hours of fire exposure without structural distress. The slab thickness was only 1½ in. and the temperature of the unexposed surface rose 250 F in about 21 minutes. It is logical to assume that a thicker slab (or an insulated slab) would perform better from a heat transmission standpoint without sacrificing structural performance.

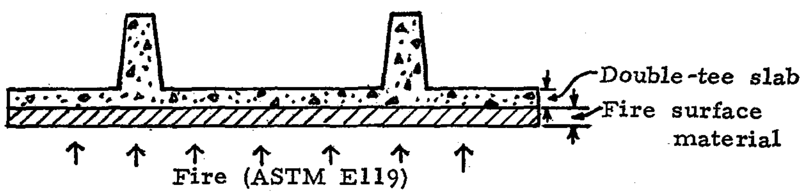
For many walls, some building codes modify or waive the heat transmission criterion depending on factors such as special separation, location and occupancy. For some buildings, however, the heat transmission requirement is included. It is possible to estimate accurately the thicknesses of many types of one-course and multi-course slabs that will provide 2-hour fire endurances based on the temperature rise of the unexposed surface.

One-course slabs

Data from fire tests of one-course con-

Table 1. Thicknesses of surface materials (in inches) to provide 2-hour fire endurances for double-tee slabs

Fire surface material	Double-tee slabs			
	Normal weight concrete		Lightweight concrete	
	1½ in.	2 in.	1½ in.	2 in.
Vermiculite-Type MK	1.0	0.80	1.0	0.75
Sprayed mineral fiber	1.1	0.80	1.1	0.80
Intumescent mastic	0.6	0.45	0.6	0.45
Carbonate aggregate concrete	3.1	2.6	3.0	2.5
Silliceous aggregate concrete	3.5	3.0	3.3	2.8
Lightweight aggregate concrete	2.5	2.2	2.3	1.8
Cellular concrete (30 pcf)	1.6	1.3	1.5	1.2
Perlite concrete (30 pcf)	1.7	1.5	1.6	1.3
Vermiculite concrete (30 pcf)	1.7	1.5	1.6	1.3



Double-tee wall with applied fire surface material

crete slabs indicate that the following thicknesses would be adequate for 2 hours:

Aggregate type	Slab thickness, in.
Carbonate	4.6
Siliceous	5.0
Structural lightweight	3.8

These thicknesses can be obtained either by casting the entire thickness at one time or by casting the slab as a two-course operation to achieve the total thicknesses indicated above.

Multi-course slabs

Double-tees are generally cast with a deck slab thickness of either 1½ or 2 in. Various materials can be applied to the "fire side" of the deck slab, i.e., the flat surface, to provide 2-hr fire endurance classifications. Also, sandwich construction can be used, i.e., an insulating material can be sandwiched between the double-tee slab and a concrete face slab. For example, a 2-in. double-tee slab of normal weight concrete with 1-in. polystyrene and a 2-in. normal weight concrete face slab, provides a 2-hr fire endurance.

Table 1 gives thicknesses of several surface materials that can be used to provide 2-hr endurances for double-tee slabs, 1½ and 2 in. thick, made of normal weight or structural lightweight concrete. The relation of materials is shown in the lower portion of Table 1.

Reference

1. Abrams, M.S. and Gustaferro, A. H., "Fire Endurance of Two-Course Floors and Roofs," *ACI Journal*, Proceedings Vol. 66, No. 2, Feb. 1969, pp. 92-102.

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File R4123-14
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Enclosed are the test data covering the fire endurance test conducted on a load bearing wall assembly using prestressed double-stemmed type precast concrete units.

The wall was constructed using two double-stemmed units on either side of a half size single stem unit. The units were connected as shown in Fig. 1.

The purpose of this test was to establish preliminary test data on the performance of the wall assembly by means of a fire endurance test. This test was conducted in accordance with the *Standard for Fire Test of Building Construction and Materials,* UL 263.

Inasmuch as the test was for developmental purposes, no classification will be promulgated. Accordingly, this letter and the attached test data conclude our work under File R4123, Assignment 68CH1668.

Reviewed by:

K. W. Howell

K. W. Howell
Engineering Group Leader
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Very truly yours,

W. H. Cunningham

W. H. Cunningham
Project Engineer
Fire Protection Department

Test method

The furnace fire was started exposing the interior side of the wall to gas flames of controlled severity and extent in accordance with the standard time-temperature curve.

The furnace temperatures were measured with 11 thermocouples symmetrically located in the furnace chamber. The unexposed surface temperatures were indicated by 12 thermocouples, each covered with a 6×6 in. dry asbestos pad. The temperatures of the steel prestressing strands located in the stems of the units were indicated by 15 thermocouples, three thermocouples in each stem. The locations of the unexposed surface thermocouples are shown in Figs. 2 and 5. The locations of the prestressing strand thermocouples are shown in Fig. 6. The locations of the furnace thermocouples are shown in Fig. 4.

The wall was loaded to produce a

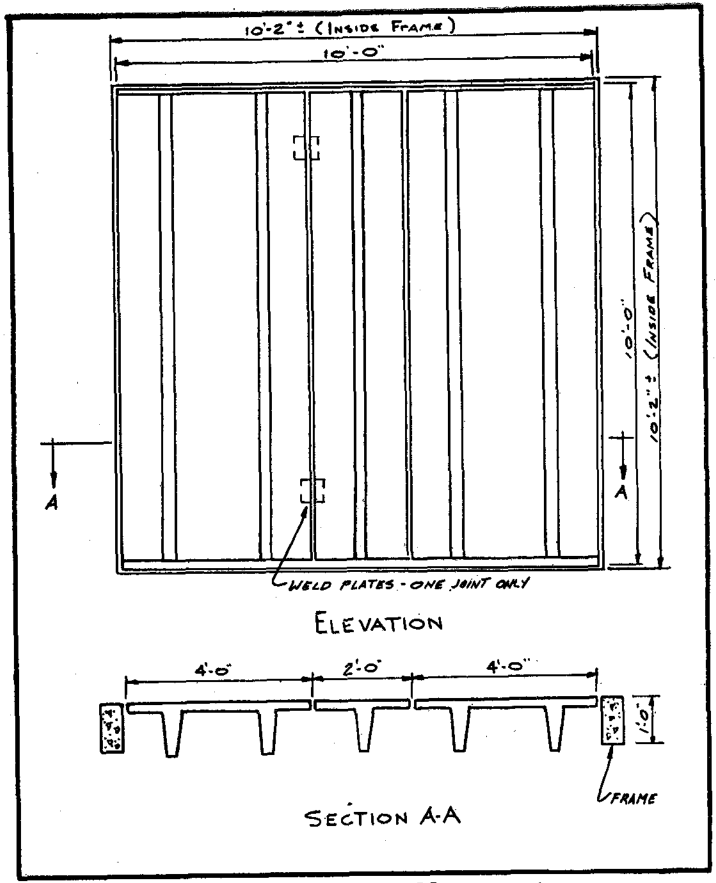

Fig. 1. Details of wall assembly in test frame

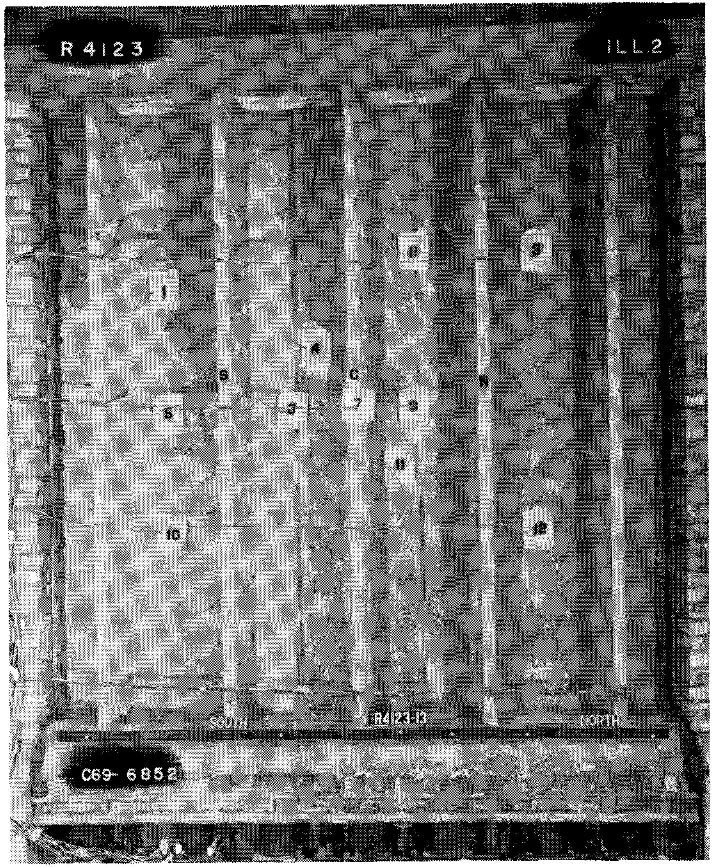

Fig. 2. Unexposed surface before fire test

live load of 800 lb. per lineal inch. This load was based upon the maximum recommended loading calculations.

The horizontal deflections of the wall were determined by measurements taken at the quarter and center points of the horizontal centerline of the unexposed surface. The reference line was a fine taut steel wire with one end fastened to the brickwork at one end of the test frame and the other end carried over a nail attached to the brickwork on the opposite side and weighted.

Vertical movement of the wall during application of the load and during the fire test was indicated by three extensometers placed under the loading beam at approximately the quarter and center points.

After the fire endurance test, the wall assembly was allowed to cool and then subjected to a live load of twice that carried during the fire endurance test.

Observations were made during the tests with special reference to stability, heat insulation, flame passage, water passage and smoke.

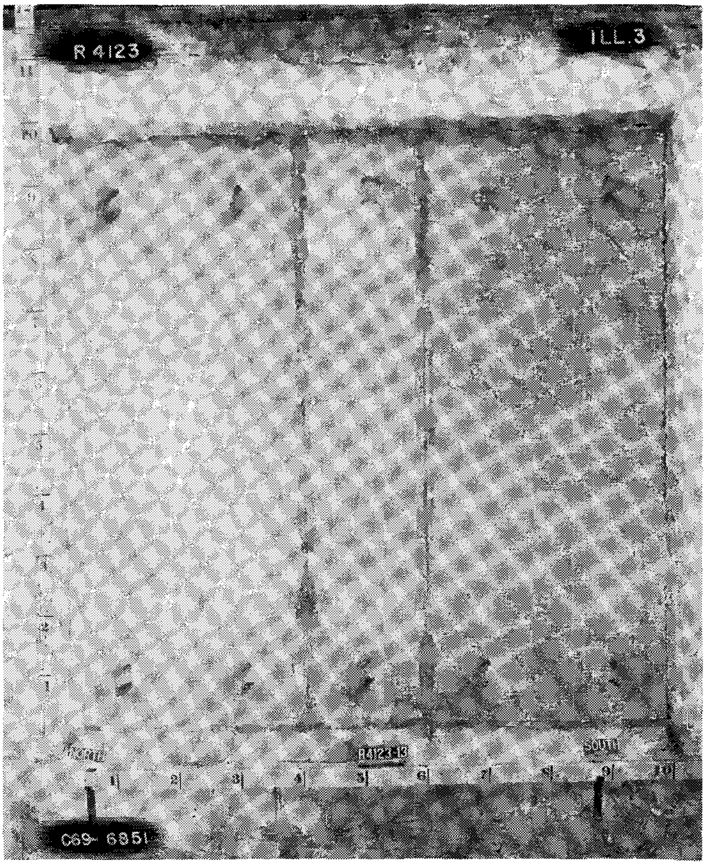

Fig. 3. Exposed surface before fire test

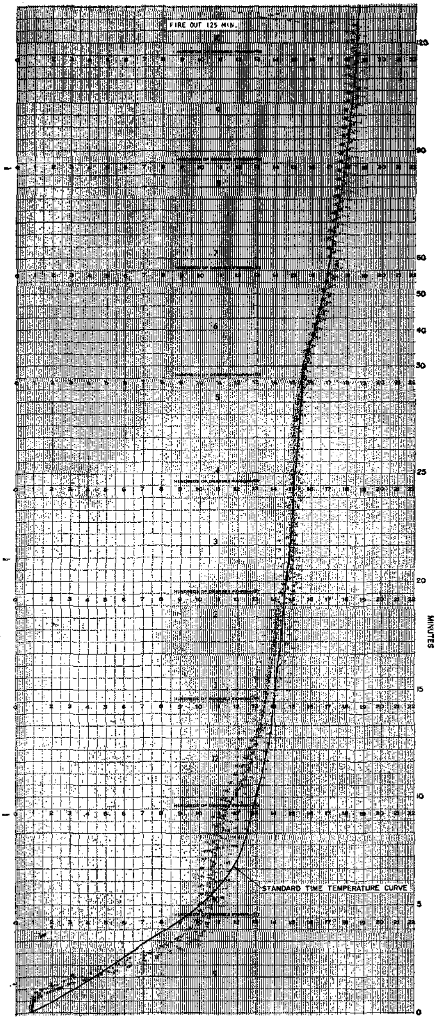

Fig. 4. Furnace temperatures during test

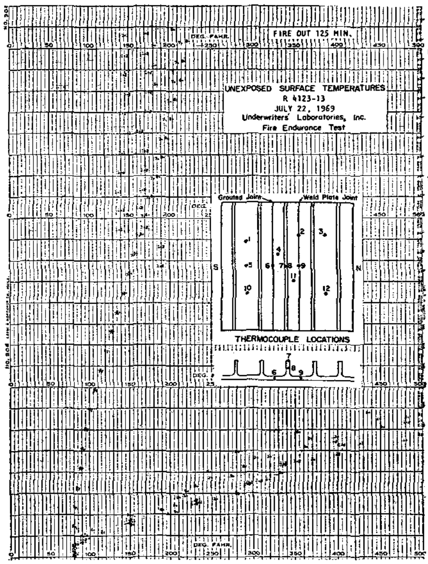

Fig. 5. Unexposed surface temperatures during test

Location	SOUTH						CENTERS			NORTH					
	South Tee			North Tee						South Tee			North Tee		
	A center	B center	B top ¼-pt	B bottom ¼-pt.	A center	B center	A center	B center	A top ¼-pt	A center	B center	B bottom ¼-pt.	A center	B center	B top ¼-pt.
Couple No.1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Graph No.1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

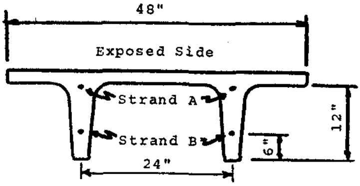

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Fig. 6. Locations of prestressing strand thermocouples

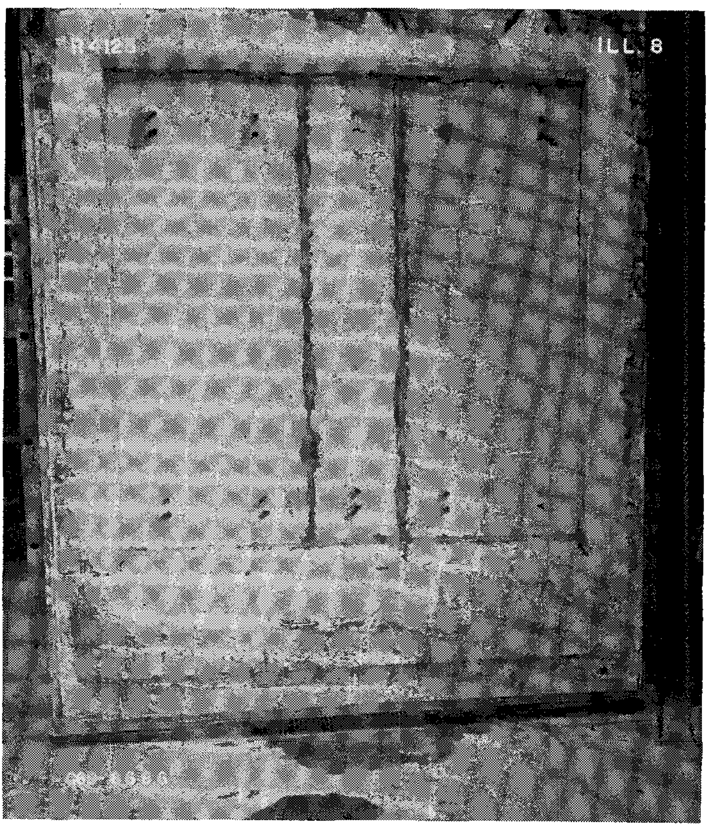

Fig. 7. Exposed surface immediately after fire test

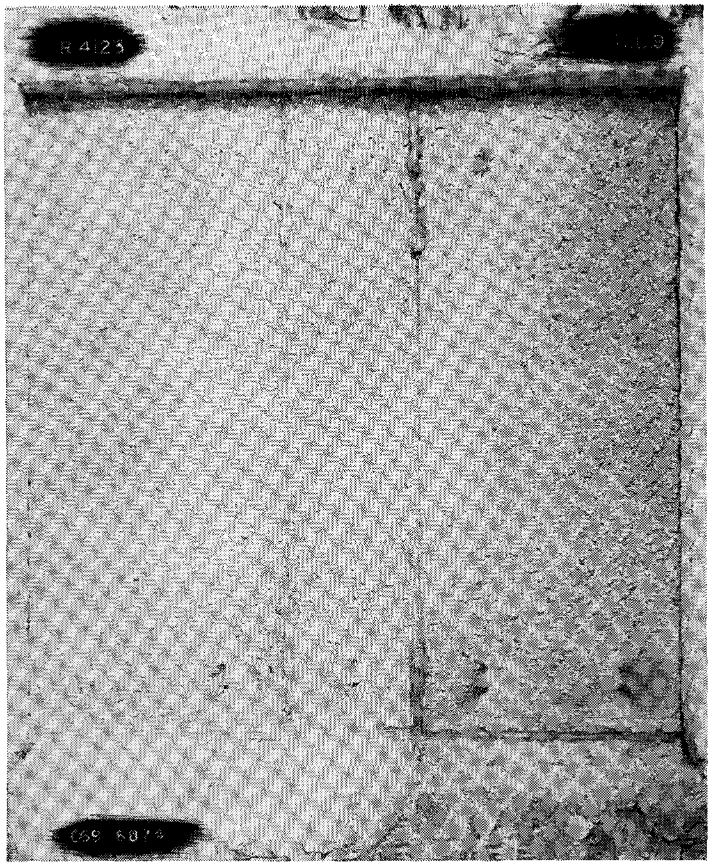

Fig. 8. *Cooled exposed surface after double load test*

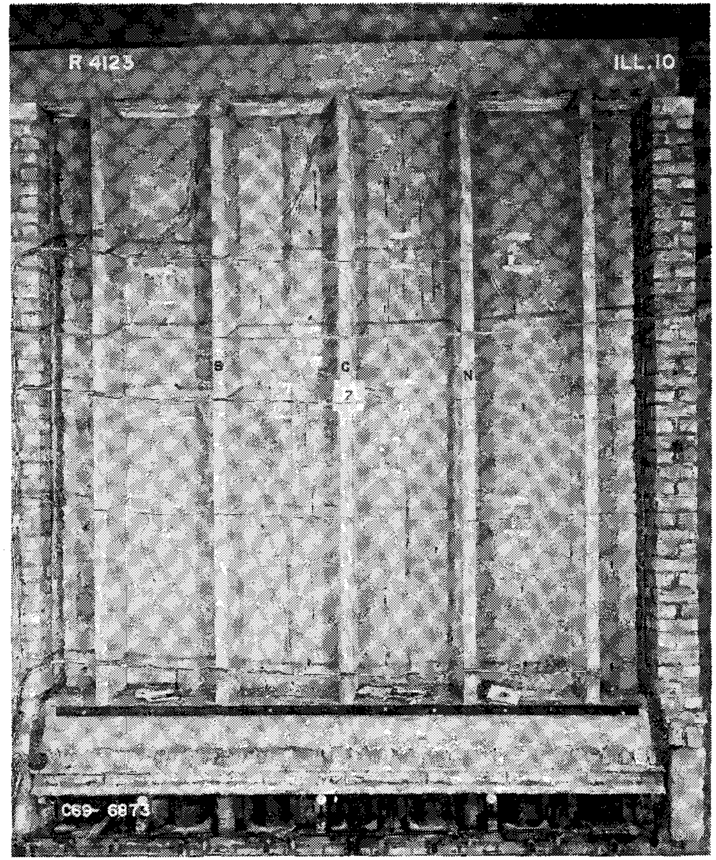

Fig. 9. *Cooled unexposed surface after double load test*

Fire endurance test

*Observation of exposed surface**

Time, min.	Observations
8	Visible bowing toward fire.
10	Cracking along intersection of second tee-panel plastic inserts beginning to melt.
14	Audible popping noises; steaming along lintel.
17	Moisture forming and steam emitting from cracks along bases of tees.
18	Continued popping and cracking noises; plastic inserts melting and running down upper wall surface.
21	All tees cracked; cracks increasing in width; more moisture forming at vertical cracks along bases of tees; fine horizontal craze cracks developing in all webs.
25	Fine vertical craze cracks developing in tees with maximum number in center tee; 4 ft. long crack in lower south joint.
27	Moisture disappeared from vertical cracks.
30	No change.
35	Craze cracks developing at both edges near vertical walls of test frame.
40	Fine crack under No. 3 thermocouple.
43	Vertical crack along entire length of vertical base of tee second from left; cracks at south joint extended to top of assembly.
50	Fine crack along lower north joint.
55	Plastic material continuing to ooze from holes between second, third and fourth tees.
62	Pad No. 12 fallen, pulling thermocouple from wall.
70	Pad No. 11 fallen, pulling thermocouple from wall.
107	Same with Pad No. 5.
120	No further change.
125	Fire out.
126	Panel out.

**The exposed surface became slightly lighter in color. There were no other changes in the appearance of the exposed surface for the duration of the fire endurance test.*

Total horizontal deflection, in.

Time, min.	South	Center	North
No load	0	0	0
Full load	0	0	0
25	+0.55	+0.55	+0.60
25	+0.75	+0.75	+0.80
60	+0.65	+0.75	+0.70
90	+0.55	+0.60	+0.70
105	+0.55	+0.60	+1.05
120	+0.55	+0.55	+0.60

+Indicates movement toward fire

Total vertical deflection, in.

Time, min.	South	Center	North
No load	0	0	0
Full load	−0.029	−0.043	−0.037
15	—	+0.018	+0.045
25	+0.049	+0.094	+0.131
45	+0.103	+0.139	+0.175
60	+0.222	+0.153	+0.187
75	+0.233	+0.165	+0.197
90	+0.239	+0.168	+0.202
105	+0.242	+0.171	+0.204
120	+0.243	+0.172	+0.205

+Indicates downward movement of wall
—Indicates upward movement of wall

Temperature of unexposed surface above 500 F

Couple number	Time, min.			
	37	60	90	120
1	708	975	1106	1145
2	546	881	1064	1092
3	565	888	1060	1176
4	698	962	1103	1106
5	716	996	1172	*
6	523	885	1064	1078
7	*	*	*	*
8	*	*	*	*
9	621	933	1091	1109
10	675	962	1096	1106
11	708	989	*	*
12	635	909	*	*

**No reading because thermocouple had pulled loose from wall*

Double load test

This excess load test was conducted on the wall previously subjected to the fire endurance test after cooling for approximately 24 hr. The wall carried the double load of 1600 lb. per lineal inch without cracking or spalling. The wall appeared exactly as shown in Fig. 8.

Total vertical deflection, in.

Applied load lb./1 in. in.	South	Center	North
800 (initial load reading)	0	0	0
1600	−0.072	−0.123	−0.113