Fire Tests of
Concrete Channel Slab Roof Deck Constructions
by
James V. Ryan
Fire Protection Section
Building Technology Division

Requested by
Department of the Army
Office of the Chief of Engineers

Approved for public release by the Director of the National Institute of Standards and Technology (NIST) on October 9, 2015.
Fire Tests of
Concrete Channel Slab Roof Deck Constructions

by
James V. Ryan

ABSTRACT

Two similar channel slab roof decks, with supporting beams, insulation, and built-up roofing, were subjected to fire endurance tests. They differed only in the type of insulation used. The results indicated fire resistances of about 50 min.

1. INTRODUCTION

At the request of the Office of the Chief of Engineers, Department of the Army, fire endurance tests were performed on two roof deck assemblies for warehouse constructions. Each test specimen consisted of a large concrete beam, concrete channel slab deck, insulation, 5-ply roofing, and expanded slag surfacing. The fire test numbers and dates were: Test 327, May 27, 1953, and Test 328, June 11, 1953.

2. TEST SPECIMENS

The two test specimens were alike in all details except the type of insulation. Each consisted of a reinforced concrete beam, 9 in. wide, by 10 in. deep, reinforced concrete channel slabs having 3 in. flanges and 1 in. web thickness, 2 in. of insulation, 5 plys of roll asphalt felt roofing, and expanded slag surfacing. All the concrete elements of the assemblies were precast and were placed together in the test furnace only a few days before the test.

2.1 Materials

(a) Beam. The beams for the tests were cast by experienced personnel of the National Bureau of Standards. Each beam was 9 in. wide, 10 in. deep, and 19 ft 10 in. long. With two exceptions the design and construction of the beam followed closely the proposed construction as detailed on Sheet 16 Drawing, Number 33-02-56 of "Beam schedules and Details of Special AMC Warehouse Floor on Grade 160' x 200'". One modification involved use of additional reinforcement at the mid-depth of the beam, and the other was necessitated by the limited size of the furnace and involved modification of the method of end support of the beam. For this purpose the natu-
of the 16 in. depth was notched 3 in. high and 5 in. short at each end. The reinforcing in each beam consisted of two 3/4 in. deformed rods 1 3/16 in. clear from the bottom, one 1 3/8 in. clear from each side; two No. 5 deformed rods similarly located in the top corners of the beam; a single No. 7 deformed rod in the center, 1 1/16 in. clear below the top; and two No. 6 deformed rods at the mid-depth, one 1 3/8 in. clear from each side. The latter pair of rods was not required in the design as submitted but was added to provide additional insurance that the beam would remain in useful condition throughout the test period. The reinforcing rods were assembled with two stirrups of 3/4 in. rods at each end. Chromal-alumel thermocouples were inserted into holes drilled in the rods to provide for measurement of the steel temperatures during the tests. The assembly of reinforcing rods was placed on chairs in the form and the concrete poured and thoroughly vibrated. The concrete mix was approximately 1:2:2:3:8 by weight of portland cement, Potomac river sand, and Potomac river gravel. The coarse aggregate was specified to be of 3/4 in. maximum particle size. A typical petrographic analysis of Potomac river gravel, as given in Table 2, the tests of steel columns Protoned with siliceous aggregate concrete, showed mineral content of 21 percent vein quartz, 38 percent quartzite, 23 percent sandstone, 12 percent chert, mica, and 8 percent others. As the concrete began to set, metal tabs were inserted along the top center line of the beam, to be bent down over the ends of the channel slabs during assembly. The strength of concrete cylinders 110 days after pouring averaged 4760 psi with a minimum of 4050 psi.

(b) Channel slabs. The reinforced concrete channel slabs were made by a commercial plant regularly engaged in the production of such slabs. They were 23-13/16 in. wide, 1 in. deep across the central web with 3 1/2 in. deep flanges. These flanges were 1 7/8 in. wide at the bottom. In each flange, a 1/2 in. deformed rod was located centrally and 1/2 in. from the bottom. The design had called for these rods to be 3/4 in. clear from the bottom but the manufacturer inadvertently supplied channel slabs with the rods 1/2 in. clear, a standard clearance. Wire mesh reinforcing, No. 10 x 6 wire, spaced 6 by 4 in. and 6 by 3 in. was centered in the depth of the 1 in. web. At one end of each channel slab, both flanges were copped or held 1/2 in.
less depth, from the bottom, for lengths of 3 in. The slabs were made in equal numbers of two lengths, 6 ft 3-1/8 in. and 5 ft 1-1/8 in. They were steam cured by the manufacturer.

Two of the channel slabs from the same group as those in the test specimens were tested for strength under the provisions of Federal Specification 2-6-531. The channel slabs were supported on pipes 5 ft on centers. The load was applied through two 1-beams placed transversely to the channel slab, one at each quarter point of the 6 ft span. The two channel slabs failed under applied loads computed to be equivalent to uniform, distributed applied loads of 1.08 and 2.62 lb/ft, respectively. Including the dead load of the slab, 1.2 lb/ft, the ultimate loads are 2.08 and 2.16 lb/ft, respectively. The tests were made the same day as the cylinder tests, but the exact age of the slab was not known. The manufacturer reported ultimate strengths of about 230 to 240 lb/ft of some other samples tested by him.

(c) Insulation. The insulations used in the two assemblies were each 2 in. thick. That in Test 327 was a slag of glass fibers, having a phenolic binder and an asbestos paper cover over the ends, one face, and 1-3/4 in. at each end of the other face. It came in 2 in. by 1 ft pieces and weighed approximately 4 lb per sq ft. It was stiff enough to handle easily and to be cut with a saw. The insulation in Test 328 was opaque fracture of lime glass which came in blocks 12 by 1 ft in. There were no evidence of any combustible component. It weighed 1.6 lb/ft, was practically rigid, and could be cut by a saw.

(d) Roofing. The roofing above the insulation consisted of hot asphalt, asphalt saturated as felt applied roofing, 1 layer of expanded slate. The slates were between 3/8 and 1/2 in. thick and weighed 1.5 lb/100 sq ft (nominal 1.4 lb/100 sq ft).

2.2 results:

The main beam for each test was placed with its centerline 5 ft 1-1/2 in. from the east side of the restraining frame at the furnace. The channel slabs were placed transversely to the beam with the upper ends resting thereon on the support ends on the bearing angles along the furnace sides. One at the 5 ft 3-1/8 in. slabs were placed between the beam and the
the whole area and the expanded asbestos distributed over the surface.

3. Test Equipment and Method

The tests were conducted in a furnace designed for tests of floors and roofs. It was in the form of an open-top box, in which the test specimen were built. The gas fires in the furnace were controlled so that the temperatures agreed as closely as possible with those of the time-temperature curve, defined in the Standard Methods of Fire Tests of Building Construction and Materials, ASTME-119, which include 1000° at 5 min, 1300° at 10 min, 1550° at 30 min, 1700° at 1 hr, and 1850° at 2 hrs.

3.1 Temperature Measurements

The temperatures at various locations were measured at 5 min intervals by means of chromel-alumel thermocouples connected to direct reading potentiometers and to recording potentiometers which made a printed record of each temperature measurement every 3 min. Twelve thermocouples, encased in porcelain tubes and iron pipes, were distributed in the furnace. Eight thermocouples were located at each of four levels; on top of the
channel slabs, in the middle of the insulation, on top of the insulation, and on top of the slab surfacing. The latter thermocouples were under felted asbestos pads 6 in. square and 0.1 in. thick, and each group was distributed symmetrically. Thermocouples had been placed on the beam reinforcement when the beam was cast, as described previously.

3.2 Loading

The assembly was designed to support anticipated loads of between 20 and 55 lb/ft² in addition to the dead load. Each specimen was tested under an applied load of 45 lb/ft². This load was provided by four hydraulic jacks located over the furnace and was distributed to 30 steel channels which bore on the test specimen. The total dead load on the slabs was about 20 lb/ft².

3.3 Test Criteria

The test methods followed specify that the fire endurance limit of a floor or roof structure shall be determined by any of the following: 1. passage through the specimen of flame or gases hot enough to ignite cotton waste; 2. failure to sustain the applied load; 3. transmission of heat through the specimen sufficient to raise the average temperature on the unexposed surface 250 degrees or the temperature at one point 325 degrees above its initial temperature. Each test was continued until one or more of these test criteria had been reached.

4. Results

The results are presented in abbreviated lists of test observations, descriptions of post test condition, and graphs of the various temperatures observed.

4.1 Test 327

The following are the more important observations and measurements made during the test of the roof deck incorporating glass fiber insulation.
The text on the page is not legible due to the low quality of the image.
(a) Test Log

TIME | OBSERVATION
--- | ---
0:06 | Spall 8 to 10 in. along lower west edge of beam at center span.
0:07 | Sound of additional spalling heard.
0:11 | Two jets of steam through roof.
0:16 | Blisters in roofing.
0:21 | Visible sa of lon. (east) channel slabs.
0:34 | Steam jets through roof changed to smoke.
0:39 | Lower reinforcing rods of beam exposed on west from spalling.
0:42 | Tag of channel slabs on east estimated at 2 to 3 in.
0:53 | Tag estimated 5 in., load removed.
1:03 | Cotton waste over center jet of smoke removed and found ignited.
1:10 | First crack in channel slab flange.
1:30 | The sag of the long channel slabs has increased to at least 10 in., causing openings under the east ends through which furnace fires are igniting the edge of the roof.
2:05 | Gas off. Repeated fires extinguished with water since 1:30.

(b) Condition after Test. Immediately after the gas fires were turned off, the discharge of fog and spray caused fire hoses were turned on the fires in the roofing. One channel slab on the east fell, greatly increasing the extent of the roofing fire. By the time all the fires were extinguished, all but one of the long channel slabs had dropped into the furnace from one of its end supports. The short channel slabs on the east remained in place and practically unreflected. The felt strips and asphalt under the insulation, the binder and asphalt paper backing of the insulation were all turned out. In many places the felt roofing was burned. The condition is shown in Figure 1.

(c) Temperatures. Control of the furnace fires throughout the test was such that the fire exposure severity, defined as the ratio in percent of the area under the graph of average furnace temperatures to the area under the standard time-temperature curve, was 94.6 percent. The temperature at one point on the unexposed surface had risen 325° F at 1 hr 55 min.
That at one point on the lower reinforcing rods of the beam reached 1200° at 10 min and the average of the lower rods reached 1000° at 1 hr 2 min. The temperatures observed during the test are indicated by the curves of Figure 2.

4.2 Test 326

The following are the more important observations and measurements made during the test of the roof deck incorporating foamed or frothed glass insulation.

(a) Test Lo

<table>
<thead>
<tr>
<th>Time (hr:min)</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Steam from edges of roof deck.</td>
</tr>
<tr>
<td>15</td>
<td>Roofing pulled up slightly in several places.</td>
</tr>
<tr>
<td>17</td>
<td>Large spall, 6 in. high by 4 to 5 ft long on lower east edge of beam, in north half, exposing reinforcing rod.</td>
</tr>
<tr>
<td>27</td>
<td>Long channel slabs (on east) sagged slightly.</td>
</tr>
<tr>
<td>30</td>
<td>Spall of lower west edge of beam in south half.</td>
</tr>
<tr>
<td>45</td>
<td>Long horizontal crack in center of beam about 1 in. from bottom of east face.</td>
</tr>
<tr>
<td>50</td>
<td>Load removed, channel slab sag 6 in. or more. Extremely smoky.</td>
</tr>
</tbody>
</table>

1:02

Slashes into furnace from between channels. Top intact.

1:21

Six cracks in west face of beam, from 1/2 to 1-1/2 ft long; four approximate the line of a catenary, other two near top center. 6 of long channels now 10 to 12 in.

1:30

Slight transverse sag in some of long channel slabs.

1:43

Places of long channel slabs cracking.

1:48

Gas off, slashes continue below channel joints.

(b) Condition after Test. The long channel slabs remained in place but retained sag of about 1 ft. The beam had three spalls of appreciable size along lower east end and cracks in each side. Much of the asphalt had run out the edges of the roof. The beam and under sides of the slabs are shown in Figure 3.
(c) Temperatures. The control of the furnace fires throughout the test was such that the fire exposure severity was 66.9 percent of the standard exposure. The exposure severity is not within the limits set in the standard test method. The low severity resulted from considerable difficulty in keeping the burners lit during the first half-hour of the test. The temperature at one point on the unexposed surface had risen 325 deg at 1 hr 30 min and the average had risen 250 deg at 1 hr 40 min. The temperature at one point on the lower reinforcing rods of the beam reached 1200 deg at 1 hr 20 min and the average reached 1000 deg at 1 hr 17 min. The temperatures observed during the test are indicated by the curves of figure 2.

5. SUMMARY AND CONCLUSIONS

The general behaviors of the two roof deck assemblies were similar. Each beam suffered some damage and the reinforcing within each was heated to high temperatures. The 3-3/4 in. channel slabs underwent considerable deflection, up to about 20 percent of their span.

5.1 Beams

The beams in the two tests were identical in design. Spalled along the bottom edges, exposing portions of the lower reinforcing rods to the hot furnace gases, cracks formed along the sides of each beam. The temperature of the lower reinforcing rods reached the temperatures of 1000 deg for the average and 1200 deg at one point at 1:02 and 0:47, respectively, in Test 327 and 1:17 and 1:29 in Test 326. The load applied to the assembly was not intended to stress the beam to its design capacity. Therefore, the fire endurance of the beam would be limited to 90 min without full load.

5.2 Roof Decks

The channel slabs, in the 3-3/4 in. length, did not spall at any time and did not crack until late in the tests but they did spall appreciably. The beam was to be noticeable within the first half-hour and became an extreme as to constitute load failure by 33 and 30 min in the two tests. Because of the fire exposure severities of 66.9 percent,
corrections of -2 and -3 in table and the corrected fire endurance limits are 51 min and 52 min, respectively. After the removal of the applied load, the air continued to increase, until, at the end of one test the channel slabs fell from place.

The glass fiber insulation and the glass-ash hastelloy seem to have been equal at low temperatures but the latter showed better resistance to heat transmission at high temperatures. However, the asphalt paper on the edges of the fiber filter insulation is combustible and provides a pathway for transmission of flame from the bottom of the insulation to the test. The binder in the fiber insulation is combustible but the glass in each fuse at high temperatures, losing its insulating value.

5.3 Complete Assembly

The combined assembly of beam, channel slabs, 2 in. of glass insulation, 5 ply roofing, and expanded slate surfacing has a fire endurance limit of about 50 min. The beam reinforcing is quickly exposed through spalling and, when fully loaded, would be due to lost strength losses. The channel slabs did not sag, but they sagged to a considerable degree. With difficulties, beam and channel slabs, can be attributed to insufficient thickness of concrete around the reinforcing steel.

either the contents of this report or the tests used by the National Bureau of Standards shall be used for advertising or promotional purposes.

on the Director by

A. F. Robertson
Chief, Fire Protection Section
Building Research Division

July 3, 1953