Underwriters' Laboratories, Inc.
Report R4123-5-7-8

Floor or Roof Construction Consisting of Prestressed Concrete Single Tee Slabs

PCI
PRESTRESSED CONCRETE INSTITUTE

20 N. Wacker Drive
Chicago, Ill. 60606
UNDERWRITERS' LABORATORIES, INC.

REPORT R 4123-5-7-8

on

FLOOR OR ROOF CONSTRUCTION
CONSISTING OF
PRESTRESSED CONCRETE
SINGLE TEE SLABS

PCI COMMITTEE ON FIRE RESISTANCE RATINGS

ARMAND H. GUSTAFERRO, Chairman
FRANK G. ERSKINE
STEVEN GALEZEWSKI
HOWARD R. MAY
PAUL ROSENTHAL
GEORGE VAUGHT

Copies are available at $2.00 each ($1.00 to PCI members) from PRESTRESSED CONCRETE INSTITUTE, 20 N. Wacker Dr., Chicago, Illinois 60606. Check or Money Order must accompany all orders.
Copyright by the PRESTRESSED CONCRETE INSTITUTE, 1962.
PREFACE

This publication is a report on fire tests conducted on prestressed concrete single tees. Three tests were conducted: one with sand-gravel concrete units with restrained ends; one with sand-gravel concrete units with ends unrestrained; and one with lightweight concrete units with ends restrained. The lightweight concrete was made with an aggregate composed of expanded shale and natural sand.

As a result of these tests Underwriters Laboratories Inc. have concluded that lightweight single tee floor and roof assemblies similar to the one tested should receive a 3 hr. fire-retardant classification. Normal weight concrete single tee assemblies similar to the ones tested should receive a 2 hr. fire-retardant classification.
File R4123-5-7-8  
Assignment 61C4804  
February 1, 1962  

REPORT  

ON  

FLOOR OR ROOF CONSTRUCTION CONSISTING OF  
PRESTRESSED CONCRETE SINGLE TEE SLABS  

Prestressed Concrete Institute  
Chicago, Ill.
DESCRIPTION

GENERAL:

The subject of this Report is a precast, prestressed concrete single tee unit of the shape and design shown in Fig. 3. Four single tee units, used in two test assemblies were made of sand-gravel concrete and two units used in a third test assembly were made of expanded shale-sand concrete. Similar aggregate to that employed in the single tee units, was used in the placing of the concrete topping to form a roof or floor assembly as shown in Fig. 3.

To permit drying outside of the test frames, the concrete topping normally placed on the assembled slabs at the job site was placed on the individual slabs 16 to 21 days after the manufacture of the units. This permitted the topping to dry with the slabs.

THE INVESTIGATION

The object of the investigation was twofold: One was to establish fire retardant classifications for the floor or roof assemblies, and the other was to determine the effect of end restraint. The latter was accomplished by tests of two similar assemblies, one with and one without end restraint. The tests were conducted in accordance with the Standard of Underwriters' Laboratories, Inc. for Fire Tests of Building Construction and Materials, UL263 (NFPA 251, ASTM E119). The fire tests were supplemented by other tests and examinations to determine the physical properties of the materials used and the practicability of handling, shipping, and installing.

EXAMINATION AND TEST RECORD

The materials used in the assembly are described below:

Steel Supports—The steel angles used to support the ends of the 17 ft. 4 in. long concrete units were 6 in. by 8 in. by ¾ in. on top of which rested 3 in. wide by ⅛ in. thick steel bars which provided the recommended minimum bearing surface of 3 in. (see Fig. 3).

The concrete units, 16 ft. in length, were supported on 8 in. wide flange beams centered under the stems of the units and butt-welded to the supporting 6 in. by 8 in. by ¾ in. steel angles. On the top of the 8 in. beams, 3 in. wide by ⅛ in. thick steel bars were positioned to provide the recommended minimum bearing surface of 3 in.

Precast-Prestressed Concrete Single Tee Units—The single tee units were manufactured at a local plant selected by the submitter and were of the design and shape shown in Fig. 3, using two ½ in. nominal diameter, seven-wire tendons for prestressing purposes. The prestressing tendons were placed in a draped design wherein the tendons are lower at the center of the stem of the units than at the ends as shown in Fig. 3.

The concrete used in the sand and gravel units developed compressive strengths, as measured on representative 6 in. by 12 in. cylinders made at the same time as the units, ranging from a minimum of 7180 psi to a maximum of 1516 psi, with an average of 1301 psi at 31 days.

The concrete used in the expanded shale and sand units developed compressive strengths, as measured on representative 6 in. by 12 in. cylinders made at the same time as the slabs, ranging from a minimum of 1003 psi to a maximum of 7251 psi, with an average of 7092 psi at 31 days.

Other properties of the slabs are considered of a proprietary nature and are on file at Underwriters' Laboratories, Inc. for future use in the Factory Inspection Program.

Concrete Topping—The 3½ in. thick sand and gravel concrete placed on the single tees 21 days after casting the units was in the approximate proportions of one part portland cement, three parts sand, five parts ¾ in. pea gravel. The slump of the concrete determined during the placement averaged approximately 2½ in. The compressive strength as determined from representative 6 in. by 12 in. test cylinders varied from a minimum of 6154 psi to a maximum of 6685 psi, and averaged 6400 psi at 28 days.

The 3 in. thick expanded shale concrete topping placed on the lightweight single tee units 16 days after casting the units, was in the approximate proportions of one part portland cement, 2.9 parts fine expanded shale aggregate, one part expanded shale coarse aggregate by weight, using 4 oz. of air entraining agent per cubic yard of concrete. The compressive strength of the topping as determined from representative 6 in. by 12 in. test cylinders, ranged from a minimum of 6189 psi to a maximum of 7150 psi, averaging 6500 psi at 28 days.
ERECTION OF TEST ASSEMBLIES:

SAND AND GRAVEL CONCRETE UNITS
(TEST NO. 1—RESTRAINED SIDES AND ENDS)

The two precast, prestressed concrete slabs with topping were cast to fit within the restraining test frame and were positioned to provide 3 in. bearing on supports for each end of the stem of each unit. The clear span (between supports) was approximately 15 ft. 6 in. The sides of the units were butted together and welded at the matching weld plates provided in the topping at the center line edge of each unit. A high early strength, low water content grout was used to tightly fill the gaps between the units and the restraining frame along the sides and ends of the units and to close the joint between units.

The appearance of the exposed surface of the assembly before tests is shown on Fig. 4.

SAND AND GRAVEL CONCRETE UNITS
(TEST NO. 2—NO END RESTRAINT)

The two precast, prestressed concrete slabs with topping were cast to fit within the restraining test frame and were positioned to provide 3 in. bearing on supports for each end of the stem of each unit. The clear span (between supports) was approximately 16 ft. 8 in. The sides of the units were butted together and welded at the matching weld plates provided in the topping at the center line edge of each unit. A high early strength, low water content grout was used to tightly fill the gaps between the units and the restraining frame along the sides of the assembly and to close the joint between units. The space between the slab ends and the restraining frame was filled with mineral wool, thereby permitting at least 2½ in. at each end for expansion.

The appearance of the exposed surface of the assembly before tests is shown in Fig. 9.

EXPANDED SHALE AND SAND CONCRETE UNITS (TEST NO. 3)

The two precast, prestressed concrete slabs with topping were cast to fit within the restraining test frame and were positioned to provide 3 in. bearing on supports for each end of the stem of each unit. The clear span (between supports) was approximately 16 ft. 8 in. The sides of the units were butted together and welded at the matching weld plates provided in the topping at the center line edge of each unit. A high early strength, low water content grout was used to tightly fill the gaps between the units and the restraining frame along the sides and ends of the units and to close the joint between units.

The appearance of the exposed surface of the assembly before tests is shown in Fig. 13.

TEST RECORD NO. 1
(Sand and Gravel Concrete Units—
Restained Sides and Ends)

FIRE ENDURANCE TEST:

This test was conducted in accordance with the Standard of Underwriters’ Laboratories, Inc. for Fire Tests of Building Construction and Materials, UL263 (ASTM E119, NFPA 251).

DESCRIPTION OF SAMPLE

The test assembly was erected as described in “Erection of Test Assemblies” for test sample No. 1.

The precast concrete units were 311 days old and the concrete topping 290 days old when the assembly was subjected to the fire endurance test.

The individual precast, prestressed concrete slabs-topping combination, were subjected to high temperature curing for varying periods totaling approximately 55 days at temperatures between 120°-220°F at the plant of the submitter. The remainder of the conditioning was at normal room to 100°F temperatures.

A relative humidity of 77 per cent was recorded in the middle section of the stem and a relative humidity of 71 per cent was recorded in the concrete topping above the stem, by means of electronic moisture sensing elements placed in a representative full slab cured and stored in a similar manner to the test slabs.
METHOD

The load applied to the test assembly was arranged to provide a uniformly distributed load of 57.2 psf. This load was specified by the submittor, and calculated with design formulas based on load factors of 1.8 dead load plus 1.8 live load as recommended by ACI-ASCE Joint Committee 323 for prestressed concrete design.

Twenty hours after the floor was loaded, the furnace fire was started, exposing the assembly to flames of controlled extent and severity in accordance with the Standard Time-Temperature Curve.

The unexposed floor surface temperatures were measured by thermocouples, each covered with a 6-in. by 6-in. dry asbestos pad, located as shown in Fig. 5.

The temperature of the prestressing strands was measured by means of thermocouples affixed to the strands during the casting of the slab. The locations of these thermocouples are shown in Fig. 6.

The deflection of the floor was observed through a surveyor’s level, placed on one side of the furnace, and sighted on three vertical targets, each graduated in 0.10 in. and located at the center of the spans as is shown in Fig. 5.

Throughout the test, observations were made of the character of the fire, its control, the condition of the surfaces, and all developments pertinent to the performance of the assembly with reference to stability for use as a fire retardant.

RESULTS

Observations During Application of Load—During the loading a maximum deflection of 0.05 in. occurred at target No. 2. No additional deflection occurred prior to the start of the fire endurance test.

Character and Distribution of the Fire—The furnace fire was luminous and well distributed throughout the test. The temperatures developed conformed to the Standard Time-Temperature Curve as shown in the Standard for Fire Tests of Building Construction and Materials, UL263.

Observations of the Exposed Surface—By 16 min. the surface of the slabs had a black speckled appearance but by 20 min. the units started to turn light gray in color and the speckled appearance disappeared. Dark streaks, approximately 1 in. wide, started forming from the center joint of the two slabs perpendicular to the slab length, at 30 min., but by 32 min. had started to turn white and blend into the over-all color of the assembly. By 95 min. the assembly was a uniform light gray in color and there was no further change in color throughout the remainder of the test.

At 17 min. two concrete sections of the surface, one 6 in. long by 2 in. wide, the other 17 in. long by 3 in. wide delaminated from the surrounding area located on the east slab at the east-west center joint toward the north end of the assembly. By 59 min. the sections combined to make an area of delamination of 2½ ft. in length by 5 to 6 in. in width. At 60 min. the north end of this section was hanging down about 2 in. and at 71 min. the north part of the delaminated area fell into the furnace exposing wire fabric at that location. The remaining concrete continued to break off and fall until 150 min. had elapsed when the entire area under the delamination was exposed. There was no further enlargement of the area throughout the remainder of the test.

At 30 min. a section of the concrete grout covering the hold-down device, approximately 3 in. by 3 in. square and ½ in. thick, located at the midpoint of the west stem, delaminated from the surface and by 35 min. fell into the furnace chamber. By 40 min. a similar delamination and subsequent fall of the grout took place at the midpoint of the east stem. No further changes were noted at either hold-down area throughout the remainder of the tests.

At 200 min. a vertical hairline crack formed in the side of the east stem approximately 5 ft. from the south end of the assembly. By 230 min. similar vertical hairline cracks developed at the same location in the west stem and several additional cracks formed in the east stem. At 285 min. horizontal cracks formed in the east stem at the same location. The cracks did not appear to open up throughout the remainder of the tests. The test was terminated at 293 min.

Observations of the Unexposed Surface—Approximately 5 min. after the start of the fire exposure a crack developed in the joint between the east and west slab quickly opening up to ½ in. in width. By 25 min. it was noted that the slabs forming the test assembly were rotating sideward on their stems so as to raise the middle of the assembly as shown by the rise of target No. 2. This side rotation continued throughout the test, reaching a maximum
upward movement of 2.20 in. as shown by target No. 2, and developing a ½ in. wide crack between units at the top.

At 30 min. a hairline crack developed across the center of the east half of the assembly. By 35 min. a similar crack across the west half of the assembly was noted.

As the test progressed the center line cracks opened to a maximum width of ¼ in. in.

Steaming was first noted at 50 min. issuing from the ends of the assembly at the center joint. Moisture became apparent in the crack areas at the east-west center line at 80 min. Steaming at the ends, and moisture at the cracks, was apparent until 165 min. when the cracks appeared dry and steaming at the ends ceased.

Cotton waste was applied over the center line crack at 155 min. but no effects were noted until 253 min. when the cotton waste placed at the north end of the assembly ignited. At 285 min. cotton waste placed over the south end of the center line crack ignited.

Deflection of the Floor—The floor assembly deflected downward at the start of the fire exposure but started to move upward at the middle (target No. 2) at approximately 10 min. The sides of the assembly started to curl upward at approximately 30 min. for target No. 1, and 40 min. at target No. 3. This upward deflection continued during the remainder of the test as indicated in the following tabulation.

<table>
<thead>
<tr>
<th>Time, Min</th>
<th>Target Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>No load</td>
<td>0</td>
</tr>
<tr>
<td>Full load</td>
<td>0.02</td>
</tr>
<tr>
<td>10</td>
<td>0.23</td>
</tr>
<tr>
<td>20</td>
<td>0.28</td>
</tr>
<tr>
<td>30</td>
<td>0.22</td>
</tr>
<tr>
<td>35</td>
<td>0.19</td>
</tr>
<tr>
<td>40</td>
<td>0.18</td>
</tr>
<tr>
<td>45</td>
<td>0.12</td>
</tr>
<tr>
<td>50</td>
<td>0.05</td>
</tr>
<tr>
<td>55</td>
<td>0.02</td>
</tr>
<tr>
<td>60</td>
<td>+0.01</td>
</tr>
<tr>
<td>65</td>
<td>+0.05</td>
</tr>
<tr>
<td>70</td>
<td>+0.08</td>
</tr>
<tr>
<td>90</td>
<td>+0.18</td>
</tr>
<tr>
<td>120</td>
<td>+0.31</td>
</tr>
<tr>
<td>150</td>
<td>+0.42</td>
</tr>
<tr>
<td>180</td>
<td>+0.51</td>
</tr>
<tr>
<td>210</td>
<td>+0.60</td>
</tr>
<tr>
<td>240</td>
<td>+0.68</td>
</tr>
<tr>
<td>270</td>
<td>+0.77</td>
</tr>
<tr>
<td>293</td>
<td>+0.83</td>
</tr>
<tr>
<td>+0.84</td>
<td>+2.35</td>
</tr>
<tr>
<td>24 hr</td>
<td>0.11</td>
</tr>
<tr>
<td>Excess load</td>
<td>+0.02</td>
</tr>
<tr>
<td>All load removed</td>
<td>0.17</td>
</tr>
</tbody>
</table>

+ Indicates upward movement from original position before test.

Temperature of the Unexposed Surface—The initial average temperature of the unexposed surface before test was 71°F; therefore, the average limiting temperature was 321°F and the maximum limiting temperature was 396°F.

The maximum limiting temperature of 396°F was reached at 2 hr. 57 min. by thermocouple No. 2 as shown in Fig. 5.

Temperature of the Prestressing Tendons—Temperature of the prestressing tendons, while not required for classification purposes, was recorded and is shown in Fig. 6.

HOSE STREAM TEST:

This test was conducted on the assembly that was subjected to the fire endurance test. Immediately after the 293 min. fire exposure, the exposed surface of the floor as-
assembly was subjected for 4 min. to the impact, cooling, and eroding action of a 30 psi water stream applied from a 1½ in. nozzle at a distance of approximately 13 ft. and at an angle of 70° from the normal.

The exposed surface was uniformly incandescent when the furnace fire was extinguished. The general appearance of the exposed surface after the application of the hose stream is shown in Fig. 7. The hose stream eroded the slab surface to a maximum depth of 5/6 in., and the stems to a maximum of 1¾ in. The hose stream did not penetrate the assembly.

EXCESS LOAD TEST:

This test was conducted on the same assembly that was subjected to the fire endurance and hose stream tests after the assembly had been allowed to cool for 24 hr. An additional live load of 57.2 psf was applied to the assembly. This provided a total live load of 114.4 psf to the assembly.

The assembly carried the double live load of 114.4 psf without apparent signs of distress. As a result of this load the assembly was deflected downward a maximum of 0.25 in. at the middle of the span as shown by target No. 2.

OBSERVATIONS AFTER TESTS:

After the sample had cooled and double live load removed, it was noted that the assembly had risen at the center joint a maximum of 2½ in. Partial rotating of the individual slabs was evident in that the sides of the assembly were below the furnace frame edges. Aside from the upward movement of the center, the unexposed surface seemed relatively unaffected by the tests.

The exposed surface, where subjected to the effects of the hose stream was eroded to a maximum depth of 5/6 in. on the slab part of the individual units, exposing sections of the reinforcing mesh as shown in Fig. 7. The stems were eroded to a maximum depth of 1¾ in. in a rounded pattern with some of the vertical steel reinforcement stirrups exposed in the west stem. The concrete remaining was brittle and could be broken away by hand, crumbling into pieces of coarse aggregate and fine powder. The area of the slabs not touched by the hose stream was smooth and seemed relatively unaffected by the fire exposure and excess load tests.

TEST RECORD NO. 2
(Sand and Gravel Concrete Units)
No End Restraint

FIRE ENDURANCE TEST:

This test was conducted in accordance with the Standard of Underwriters’ Laboratories, Inc. for Fire Tests of Building Construction and Materials, UL263 (ASTM E119, NFPA 251).

DESCRIPTION OF SAMPLE

The test assembly was erected as described in “Erection of Test Assemblies” for test sample No. 2. The precast concrete units were 281 days old and the concrete topping 260 days old when the assembly was subjected to the fire endurance test.

The individual precast, prestressed concrete slabs-topping combination were subjected to high temperature curing for varying periods totaling approximately 55 days at temperatures between 120°-220°F at the plant of the submitter. The remainder of the conditioning was at normal room to 100°F temperatures.

A relative humidity of 77 per cent was recorded in the middle section of the stem and a relative humidity of 74 per cent was recorded in the concrete topping above the stem, by means of electronic moisture sensing elements placed in a representative full slab, cured and stored in a similar manner to the test slabs.

METHOD

The load applied to the test assembly was arranged to provide a uniformly distributed load of 50 psf. This load was specified by the submitter, and calculated with design formulas based on load factors of 1.8 dead load plus 1.8 live load as recommended by ACI-ASCE.
Joint Committee 323 for prestressed concrete design.

Twenty hours after the floor was loaded, the furnace fire was started, exposing the assembly to flames of controlled extent and severity in accordance with the Standard Time-Temperature Curve.

The unexposed floor surface temperatures were measured by thermocouples, each covered with a 6 in. by 6 in. dry asbestos pad, located as shown in Fig. 11.

The temperature of the prestressing strands was measured by means of thermocouples affixed to the strands during the casting of the slab. The locations of these thermocouples at the center of the spans as shown in Fig. 11.

The deflection of the floor was observed through a surveyor's level, placed on one side of the furnace, and sighted on three vertical targets, each graduated in 0.10 in. and located at the center of the spans as shown in Fig. 11.

Throughout the test, observations were made of the character of the fire, its control, the condition of the surfaces, and all developments pertinent to the performance of the assembly with reference to stability for use as a fire retardant.

RESULTS

Observations During Application of Load—During the loading a maximum deflection of 0.02 in. occurred at target No. 2. No additional deflection occurred prior to the start of the fire endurance test.

Character and Distribution of the Fire—The furnace fire was luminous and well distributed throughout the test. The temperatures developed conformed to the Standard Time-Temperature Curve as shown in the Standard for Fire Tests of Building Construction and Materials, UL263.

Observations of the Exposed Surface—There was no explosive spalling of the concrete surface during the fire exposure.

The surface changed in color from concrete gray to light brown to gray white during the test. At 205 min. a grid pattern of dark lines approximately 6 in. by 6 in. was visible on the slab surface. No further color changes were noted during the remainder of the test.

At 25 min. small dark areas approximately 3 in. square were noted on the soffits of the east and west stems at the north-south center line of the assembly. By 40 min. hairline cracks outlining the 3 in. by 3 in. area were discernible on the west stem soffit. At 50 min. some flaking away of the 3 in. by 3 in. area on the west stem was noted. At 275 min. a section 2 in. square and ½ in. in depth fell off the east stem from the location previously described. No further changes in the two-hold-down areas were noted during the remainder of the test.

At 120 min. short hairline cracks parallel to the long direction of the stem were noted on the soffit of the west stem at the north end of the assembly. By 195 min. similar short hairline cracks were noted at the center line on the soffit of the east stem. By 293 min. when the fire endurance test was terminated the crack previously described had opened to an approximate maximum of ½ in.

Observations of the Unexposed Surface—Approximately 4 min. after the start of the fire exposure, hairline cracks were noted developing in the joint between the slabs and also around the periphery of the furnace frame. The cracks gradually opened, reaching a maximum width of ½ in. when the test was terminated at 293 min.

At 30 min. light steaming was apparent from the north end of the center joint crack and at 47 min. the south end of the assembly began to show evidence of light steaming. By 54 min. moisture spots appeared at the center joint crack locations and at other areas principally over the stems of the individual units. Moisture was given off at these locations until 150 min. of exposure, at which time the moisture spots were dry and steaming had ceased.

By 50 min. it was noted that the north-west end of the west slab had moved upward approximately 1 in. from its original position. The south end of the slab was bowed upward approximately 1 in. at the same time. At 67 min. it appeared that the north-east edge of the east slab had moved upward approximately ¾ in. with the south-east edge behaving in a similar manner. By 206 min. both ends of the two slabs comprising the test assembly had moved upward an approximate maximum of 1½ in. No further changes were noted during the remainder of the fire test.

Deflection of the Floor—The floor assembly deflected downward, reaching a maximum deflection of 4.07 in. due to fire exposure.
DEFLECTION – IN.

<table>
<thead>
<tr>
<th>Time, Min.</th>
<th>Target Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>No load</td>
<td>0.02</td>
</tr>
<tr>
<td>Full load</td>
<td>0.48</td>
</tr>
<tr>
<td>10</td>
<td>0.91</td>
</tr>
<tr>
<td>30</td>
<td>1.23</td>
</tr>
<tr>
<td>40</td>
<td>1.44</td>
</tr>
<tr>
<td>50</td>
<td>1.59</td>
</tr>
<tr>
<td>60</td>
<td>1.64</td>
</tr>
<tr>
<td>90</td>
<td>1.86</td>
</tr>
<tr>
<td>120</td>
<td>2.07</td>
</tr>
<tr>
<td>150</td>
<td>2.28</td>
</tr>
<tr>
<td>180</td>
<td>2.47</td>
</tr>
<tr>
<td>210</td>
<td>2.61</td>
</tr>
<tr>
<td>240</td>
<td>2.81</td>
</tr>
<tr>
<td>270</td>
<td>2.97</td>
</tr>
<tr>
<td>293</td>
<td>3.11</td>
</tr>
<tr>
<td>After hose stream</td>
<td>3.15</td>
</tr>
<tr>
<td>24 hr.</td>
<td>2.74</td>
</tr>
<tr>
<td>Excess load</td>
<td>2.83</td>
</tr>
<tr>
<td>All load removed</td>
<td>2.59</td>
</tr>
</tbody>
</table>

Temperature of the Unexposed Surface—The initial average temperature of the unexposed surface before test was 73°F; therefore, the average limiting temperature was 323°F and the maximum limiting temperature was 398°F. The maximum limiting temperature of 398°F was reached at 2 hr., 29 min. by thermocouple No. 3 as shown in Fig. 11.

Temperature of the Prestressing Tendons—Temperature of the prestressing tendons, while not required for classification purposes, was recorded and is shown in Fig. 12.

Hose Stream Test:

This test was conducted on the assembly that was subjected to the fire endurance test. Immediately after the 293 min. fire exposure, the exposed surface of the floor assembly was subjected for 4 min. to the impact, cooling, and eroding action of a 30 psi water stream applied from a 1½ in. nozzle at a distance of 13 ft., and at angle of 70° from the normal.

The exposed surface was uniformly incandescent when the furnace fire was extinguished. The general appearance of the exposed surface after the application of the hose stream is shown in Fig. 10. The hose stream eroded the slab surface to a maximum depth of 

\[ \frac{1}{2} \text{ in.} \]

and the stems to a maximum of 1½ in. The hose stream did not penetrate the assembly.

Excess Load Test:

Description of Sample

This test was conducted on the same assembly that was subjected to the fire endurance and hose stream tests after the assembly had been allowed to cool for 24 hr.

Method

An additional live load of 50 psf was applied to the assembly. This provided a total live load of 100 psf to the assembly.

Results

The assembly carried the double live load of 100 psf without apparent signs of distress. As a result of this load the assembly deflected a maximum of 0.13 in.

Observations After Tests:

After the sample had cooled and double live load removed, it was noted that the assembly had recovered 0.40 in. of deflection from the maximum deflection recorded due to the fire endurance, hose stream, and excess loads tests as shown by target No. 2.

The unexposed surface seemed relatively unaffected by the tests.

The exposed surface, where subjected to the effects of the hose stream was eroded to
a maximum depth of $\frac{1}{2}$ in. on the slab part of the individual units exposing sections of the reinforcing mesh as shown in Fig. 10. The stems were eroded to a maximum depth of $1\frac{1}{2}$ in. in a rounded pattern with some of the vertical steel reinforcement stirrups exposed in the west stem. The concrete remaining was brittle and could be broken away by hand, crumbling into pieces of coarse aggregate and fine powder. The area of the slabs not touched by the hose stream was smooth and seemed relatively unaffected by the fire exposure and excess load tests.

**TEST RECORD NO. 3**

_(Expanded Shale and Sand Concrete Units)_

**FIRE ENDURANCE TEST:**

This test was conducted in accordance with the Standard of Underwriters’ Laboratories, Inc. for Fire Tests of Building Construction and Materials, UL263 (ASTM E119, NFPA 251).

**DESCRIPTION OF SAMPLE**

The test assembly was erected as described in “Erection of Test Assemblies” for test sample No. 3.

The precast concrete units were 430 days old and the concrete topping 414 days old when the assembly was subjected to the fire endurance test.

The individual precast, prestressed concrete slabs-topping combination, were subjected to high temperature curing for varying periods totaling approximately 52 days at temperatures of 100° to 220°F at the plant of the submittor. The remainder of the conditioning was at normal room to 100°F temperatures.

A relative humidity of 70 per cent was recorded in the middle section of the stem and a relative humidity of 40 per cent was recorded in the concrete topping above the stem, by means of electronic moisture sensing elements placed in a representative full slab cured and stored in a similar manner to the test slabs.

**METHOD**

The load applied to the test assembly was arranged to provide a uniformly distributed load of 50 psf. This load was specified by the submittor, and calculated with design formulas based on load factors of 1.8 dead load plus 1.8 live load as recommended by ACI-ASCE Joint Committee 323 for prestressed concrete design.

Twenty hours after the floor was loaded, the furnace fire was started, exposing the assembly to flames of controlled extent and severity in accordance with the Standard Time-Temperature Curve.

The unexposed floor surface temperatures were measured by thermocouples, each covered with a 6 in. by 6 in. dry asbestos pad, located as shown in Fig. 15.

The temperature of the prestressing strands was measured by means of thermocouples affixed to the strands during the casting of the slab. The location of these thermocouples are shown in Fig. 16.

The deflection of the floor was observed through a surveyor’s level, placed on one side of the furnace, and sighted on three vertical targets, each graduated in 0.10 in. and located at the center of the spans as shown in Fig. 15.

Throughout the test, observations were made of the character of the fire, its control, the condition of the surfaces, and all developments pertinent to the performance of the assembly with reference to stability for use as a fire retardant.

**RESULTS**

Observations During Application of Load—During the loading a maximum deflection of 0.10 in. occurred at target No. 3. No additional deflection occurred prior to the start of the fire endurance test.

Character and Distribution of the Fire—The furnace fire was luminous and well distributed throughout the test. The temperatures developed conformed to the Standard Time-Temperature Curve as shown in the Standard for Fire Tests of Building Construction and Materials, UL263.
Observations of the Exposed Surface—There was no explosive spalling of the concrete surface during the fire exposure.

At 7 min. a 12 in. long by 2 in. wide section of center joint grout approximately 4 ft. from the south end of the assembly fell into the furnace. Additional sections of grout fell from the same location during the next 15 min. resulting in a section of approximately 3 ft. in length from which the grout had fallen. No further fall of grout was noted throughout the remainder of the test.

The center grouted joint cracked from the fall-out area north to the end of the assembly at 46 min. and continued to widen reaching approximately \( \frac{7}{16} \) in. in width when the test was terminated.

By 36 min. evidence of moisture remaining in the slabs became apparent by dark streaks starting from the slab edges and continuing to the stems. At 60 min. the moisture streaks had disappeared.

At 12 min. a small dark spot was noted on the soffit at the center of the west stem. By 20 min. the outline of a section 3 in. by 3 in. in size was discernible and from the periphery of the spot, smoke was noted. Apparently a section of material used to form the opening for the hold-down device was inadvertently left in the slab, and then grouted over. By 46 min. the material had burned away and the strand temperatures which had shown a rise for the west stem (20 to 40 min. in Fig. 16) stabilized at the same relative position as the east stem.

There were no further changes throughout the remainder of the fire test.

Observations of the Unexposed Surface—Approximately 32 min. after the start of the fire exposure, hairline cracks were noted developing in the joint between the slabs and also around the periphery of the furnace frame. The cracks gradually opened reaching a maximum width of \( \frac{7}{16} \) in. when the test was terminated.

At 32 min. steaming was apparent at the ends of the slabs which continued throughout the remainder of the fire exposure.

The furnace fire was extinguished at 290 min.

Deflection of the Floor—The floor assembly deflected downward during the period of time from the start of the exposure until approximately 20 min. had elapsed. The assembly remained stable at this elevation for approximately 10 min. and then started to move upwards. This upward deflection although small continued during the remainder of the test as is indicated in the following tabulation.

### DEFLECTION — IN.

<table>
<thead>
<tr>
<th>Time, Min.</th>
<th>Target Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>No load</td>
<td>0</td>
</tr>
<tr>
<td>Full load</td>
<td>0.01</td>
</tr>
<tr>
<td>10</td>
<td>0.28</td>
</tr>
<tr>
<td>20</td>
<td>0.35</td>
</tr>
<tr>
<td>30</td>
<td>0.35</td>
</tr>
<tr>
<td>40</td>
<td>0.34</td>
</tr>
<tr>
<td>50</td>
<td>0.31</td>
</tr>
<tr>
<td>60</td>
<td>0.29</td>
</tr>
<tr>
<td>90</td>
<td>0.17</td>
</tr>
<tr>
<td>120</td>
<td>0.15</td>
</tr>
<tr>
<td>150</td>
<td>0.15</td>
</tr>
<tr>
<td>180</td>
<td>0.17</td>
</tr>
<tr>
<td>210</td>
<td>0.17</td>
</tr>
<tr>
<td>240</td>
<td>0.17</td>
</tr>
<tr>
<td>270</td>
<td>0.16</td>
</tr>
<tr>
<td>290</td>
<td>0.15</td>
</tr>
<tr>
<td>After hose stream</td>
<td>0.19</td>
</tr>
<tr>
<td>24 hr.</td>
<td>0.58</td>
</tr>
<tr>
<td>Excess load</td>
<td>0.65</td>
</tr>
<tr>
<td>All load removed</td>
<td>+0.02</td>
</tr>
</tbody>
</table>

+-Indicates upward movement from original position before test.
Temperature of the Unexposed Surface—The initial average temperature of the unexposed surface before test was 68°F; therefore, the average limiting temperature was 318°F and the maximum limiting temperature was 393°F. The maximum limiting temperature of 393°F was reached at 3 hr., 9 min. by thermocouple No. 2 as shown in Fig. 15.

Temperature of the Prestressing Tendons—Temperature of the prestressing tendons, while not required for classification purposes, was recorded and is shown in Fig. 16.

HOSE STREAM TEST:

This test was conducted on the assembly that was subjected to the fire endurance test. Immediately after the 290 min. fire exposure, the exposed surface of the floor assembly was subjected for 4 min. to the impact, cooling, and eroding action of a 30 psi water stream applied from a 1½ in. nozzle at a distance of 13 ft. and at an angle of 70° from the normal.

The exposed surface was uniformly incandescent when the furnace fire was extinguished. The general appearance of the exposed surface after the application of the hose stream is shown in Fig. 14. The hose stream eroded the slab surface to a maximum depth of ¾ in. and the stems to a maximum of 1½ in. The hose stream did not penetrate the assembly.

EXCESS LOAD TEST:

This test was conducted on the same assembly that was subjected to the fire endurance and hose stream tests after the assembly had been allowed to cool for 24 hr.

An additional live load of 50 psf was applied to the assembly. This provided a total live load of 100 psf to the assembly.

The assembly carried the double live load of 100 psf without apparent signs of distress. As a result of this load the assembly deflected a maximum of 0.10 in. as shown by target No. 2.

OBSERVATIONS AFTER TESTS:

After the sample had cooled and the double live load removed, it was noted that the assembly had deflected 0.89 in. below its original position before loading and tests, as shown by target No. 2.

The exposed surface, where subjected to the effects of the hose stream was eroded to a maximum depth of ¾ in. on the slab part of the unit and to depths of 1½ in. on the stems. The concrete remaining was hard and would not crumble or flake. The ends of some of the vertical stirrups in the units were exposed due to the action of the hose stream but no mesh or prestressing tendons were exposed as shown in Fig. 14.

The unexposed surface seemed unaffected except for the crack at the center line which had closed to hairline size.

BAZ

CONCLUSIONS

FIRE-RETARDANT PROPERTIES:

Sand-Gravel Concrete Units—Floor or roof assemblies, constructed of precast, prestressed sand-gravel concrete single tee slabs of the design and cross sectional dimensions as described herein, when used with a non-rein in-place limestone or sand and gravel concrete top fill, 3½ in. thick, will afford 2 hr. protection against passage of flame and dangerous heat transmission, provided that bearing on the supports is 3 in. minimum.

Both the fully restrained and unrestrained floor assemblies, as tested, carried their live loads for 4 hr., 53 min. during fire exposure, and the floors remained intact and prevented passage of flame or dangerous heat transmission for the required 120 min. exposure period. The floor assemblies successfully withstood the application of the hose stream, applied in accordance with the requirements as to pressure and duration for a 2 hr. fire endurance exposure. Both assemblies carried the excess load without visible signs of distress.

Although the sand and gravel concrete slabs were somewhat massive for the size of the test specimen, thereby tending to reduce major differences in performance, the deflection characteristics revealed the effect of end restraint, in comparison with no end restraint. The restrained slabs moved upward at the center a maximum of 2.30 in. In the case of the unrestrained slabs, during the fire exposure, a maximum downward deflection of 4.13 in. occurred.

Expanded Shale and Sand Concrete Units—Floor or roof assemblies, constructed of precast, prestressed expanded shale and sand concrete single tee slabs of the design and cross
sectional dimensions as described herein, when used with a poured-in-place expanded shale concrete top fill, 3 in. thick, will afford 3 hr. protection against passage of flame and dangerous heat transmission, providing that bearing on the supports is 3 in. minimum.

The floor assembly, as tested, carried the live load for 4 hr., 50 min. during fire exposure, and the floor remained intact and prevented passage of flame or dangerous heat transmission for the required 180 min. exposure period. The floor assembly successfully withstood the application of the hose stream, applied in accordance with the requirements as to pressure and duration for a 3 hr. fire endurance exposure. The assembly carried the excess load without visible signs of distress.

Since the foregoing assemblies withstood 4 hr., 50 min. plus of fire exposure and then successfully withstood the hose stream and excess load tests, and in view of experience on similar assemblies, the design illustrations for the two classifications show a reduction in strength of the concrete topping from that as tested, to a figure more closely approximating normal construction practices, namely a compressive strength of the concrete topping of 3000 psi. Previous investigations have indicated that the lower strength concrete toppings perform as well as the higher strength concrete toppings for these type of assemblies.

CONFORMITY:

These constructions were tested in accordance with the Standard of Underwriters’ Laboratories, Inc. for Fire Tests of Building Construction and Materials. These constructions are considered noncombustible in accordance with the National Board of Fire Underwriters’ definition of noncombustibility.

FOLLOW-UP PROGRAM:

Precast, prestressed concrete single tee units conforming to the design and cross sectional dimensions given herein and on file, made like those investigated and found acceptable and produced under the Factory Inspection Program of Underwriters’ Laboratories, Inc. will bear a label with the following statement:

Units made of sand-gravel concrete:
UNDERWRITERS’ LABORATORIES, INC.

®

INSPECTED
PRECAST CONCRETE UNITS
FIRE RETARDANT CLASSIFICATION
FOR USE IN FLOOR OR ROOF AND CEILING DESIGN NO. 44–2 HR

Units made of expanded shale and sand concrete:
UNDERWRITERS’ LABORATORIES, INC.

®

INSPECTED
PRECAST CONCRETE UNITS
FIRE RETARDANT CLASSIFICATION
FOR USE IN FLOOR OR ROOF AND CEILING DESIGN NO. 36–3 HR
RECOMMENDATION

TO THE FIRE COUNCIL OF UNDERWRITERS' LABORATORIES, INC.: 

We recommend promulgation of listing cards in the forms presented below whenever a manufacturer of precast, prestressed concrete single tee units demonstrates that his product conforms with the design, dimensions, and specifications as set forth for the products as used in these tests.

Guide No. 40 U18.17. Date File
Precast Concrete Units.

_________________________________________________________________________

(Manufacturer, City and State)

Prestressed sand and gravel concrete single tee units for use in:
   Floor or Roof and Ceiling Design No. 44 - 2 Hr.
   or Prestressed sand and expanded shale concrete single tee units for use in:
   Floor or Roof and Ceiling Design No. 36 - 3 Hr.

_________________________________________________________________________

(Address)

Label Service—See General Information Card of above guide number

See Guide No. 40 U18 for illustration of design numbers and fire retardant classification, Figures 1 and 2.

Report by: Reviewed by:
B. A. ZIMMER/signed R. L. PARKS/signed
Senior Project Engineer Assoc. Managing Engineer
Fire Protection Department Fire Protection Department

SUBMITTED:
JACK BONO/signed
Managing Engineer, Fire Protection Department

The foregoing Recommendation has been accepted

UNDERWRITERS' LABORATORIES, INC.
W. S. AUSTIN/signed
Vice President and Secretary

BAZ:LCR
Class D-2 Designs
Design No. 44 - 2 Hr

Sand-Gravel or Sand-
Top Fill 3000 psi

With or Without End Restraint

Minimum Bearing 3 in.

Precast Concrete Unit
Guide No. 40 UL8,1

Minimum total thickness

F

Concrete
Guide No. 40 U18

General Information (Cont'd)

Floor or Roof and Ceiling Constructions

Class C-3 Designs
Design No. 36 - 3 Hr.

With or Without End Restraint

Expanded shale concrete topping
3000 psi, 1 part cement:
2.9 parts fine aggregate,
1 part coarse aggregate by weight:
4 oz air entraining agent per cubic yard.

4-1/2" minimum total thickness

3"

7" minimum

Minimum Bearing 3 in.

Precast Concw Units - Listed By U.L. Inc.,

Guide No. 40 U18.17
Fig. 4—Exposed surface of test assembly No. 1 before tests.
Fig. 7—Exposed surface of test assembly No. 1 after subjected to optional hose stream test.
Fig. 8—Unexposed surface of test assembly No. 1 after tests.
Fig. 9—Exposed surface of test assembly No. 2 before test.
Fig. 10—Exposed surface of test assembly No. 2 after subjected to optional hose stream test.
Fig. 13—Exposed surface of test assembly No. 3 before tests.
Fig. 14—Exposed surface of test assembly No. 3 after subjected to optional hose stream test.
Fig. 17—Unexposed surface of test assembly No. 3 after tests.