Underwriters' Laboratories, Inc.

Report R 4123-1

Floor or Roof Construction Consisting of Prestressed Concrete Double Tee Slabs

205 W. Wacker Drive

Chicago 6, Ill.
UNDERWRITERS' LABORATORIES, INC.

Report R4123-1

WITH TWO-HOUR FIRE RETARDANT SPECIFICATIONS FOR PRESTRESSED CONCRETE

COMMITTEE ON FIRE RESISTANCE RATINGS
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PRESTRESSED CONCRETE INSTITUTE

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PREFACE

This publication includes the expanded specifications for a two-hour fire retardant label service for prestressed concrete, and the original Underwriters Laboratories Report R 4123-1 on which the specifications are based.

The Underwriters Laboratories label service has been developed as a result of a series of fire tests conducted at their laboratories under a program sponsored by PCI and administered by the PCI Committee on Fire Resistance Ratings.
SPECIFICATIONS FOR TWO-HOUR FIRE RETARDANT
CLASSIFICATION

DESCRIPTION
OF
PRECAST CONCRETE UNITS

GENERAL:

This Procedure describes precast concrete units as shown in ILL. 1 for use in floor or roof and ceiling assemblies conforming to the usual limitations as to loads, bearing areas, and cross-sectional dimensions.

MANUFACTURING PROCESS:

The precast concrete units are cast in continuous fixed forms, which may extend several hundred feet. Individual slabs are separated by pairs of bulkheads.

Prior to the placing of concrete in the forms, the forms are made ready by placing in the stems, two to five prestressing strands, each stem, and then by applying a jacking force, applying tension to the wires. Caution: The inspector should stand clear during the tensioning of the strands, as the strands, if broken, can be dangerous. After the strands are tensioned, bulkheads are placed to determine the individual slab length. Each bulkhead has adjustments for holding the strands at predetermined end heights.

The strands are deflected or depressed at the middle of each individual slab by means of a cross beam attached to the form edges from which over each stem is a jacking device which pushes a hold-down device, see ILL. 2, to hold the strands at a certain depth, while the concrete is placed.

After the strands are deflected or depressed, wire fabric is placed so as to cover the area of the slab less 1 in. from the edges and located in about the middle of the slab thickness. Additional pieces of wire fabric are formed into angles, the thickness of the slab less 2 in. and placed with one leg in the stem and held 1 in. from the bottom by the other leg securely tied to the wire fabric in the middle of the slab as shown on ILL. 1.

Rebars, weld tie-plates and bearing plates, as shown by ILL._______(to be supplied in detail by manufacturer) are also placed in the bed.

At each corner of the slab, in the stem, U-shaped sections of excess strand are placed for use in lifting the slab after curing.

After the placement of the above, the casting bed is ready for concrete placement.

The concrete is mixed and transported to the bed using applicable methods. At the time of placing the concrete in the forms, a minimum of two (2) 6 by 12 in. compressive strength test cylinders molded as described herein under “Test Methods,” will be prepared; one from one end and the other from the other end of the bed being filled with concrete.

The concrete in the beds is vibrated in each stem and finished on the surface by suitable methods.

The slabs may be steam or hot oil cured or air dried for a period of time necessary to raise the concrete to the minimum strength required to release the stress in the wire strand.

After the 6 by 12 in. compressive test samples, cured in the same manner as the slabs, have reached the required minimum strength, the strands may be detensioned and/or cut and the slabs removed from the beds, stored, or shipped depending on the manufacturer’s wishes.
MATERIALS:

CEMENT

The cement shall be Portland cement furnished in bulk or bag.

AGGREGATE

The coarse aggregate used shall be limestone or gravel, maximum size passing a 1 in. screen.

The fine aggregate shall be clean, sharp sand.

PRESTRESSING STRANDS

The prestressing strand is made up of seven wires, the reel of which shall have marked on it that it conforms with ASTM A416-57T and so attested to by the manufacturer of the strand. Five sizes of strand are permissible as follows: 1/4, 5/16, 3/8, 7/16, and 1/2 in.

WIRE FABRIC

The wire fabric used shall be of welded steel wire, minimum size of 4 in. square and No. 10/10 gauge (wire diameter a minimum of 0.1205, average 0.1350, maximum 0.1483 in.) and a maximum of 12 in. square.

COMPOSITION OF CONCRETE:

The quantities of materials per batch of concrete shall be:

- lb. limestone or gravel coarse aggregate
- lb. sand fine aggregate
- lb. Portland cement

The size of the batch may vary but the proportions shall remain constant.

The water added to the aggregate-cement mix will vary but will yield a mix capable of being placed in the forms.

DESIGN OF UNITS:

The precast concrete unit shall conform to the dimensions as shown on ILL. 1 with special emphasis on the minimum side and bottom concrete cover to the strands.

CONCRETE STRENGTH:

The strength of the 6 by 12 in. concrete test cylinder, cured in a similar manner as the slab it is representing, shall have attained a minimum strength of 3500 psi prior to releasing the tensioning force and cutting of the strands in the slab.

FINISHED PRODUCT:

Marking — Each prestressed concrete slab complying with this description shall be eligible to bear the combination label containing the following information:

1. Manufacturer's name.
2. Inspection manifest reading:

UNDERWRITERS' LABORATORIES, INC.

®

INSPECTED

PRECAST CONCRETE UNIT

LABEL SIZE IN SQ. FT. ___ ISSUE NO. ___

3. Statement pertaining to classification:
   “Fire Retardant Classification”
   Floor or Roof and Ceiling Design
   No. 5—2 Hr.
INSTRUCTIONS FOR EXAMINATION AND TEST BY INSPECTOR

At regular inspections the inspector shall do the following:

1. Check the dimensions of the forms for compliance with ILL. 1.
2. Obtain a copy of the strand specifications attested to by the wire supplier that it complies with the applicable ASTM Standard.
3. Check location of the strands at both ends and middle.
4. Observe and record batching of concrete.
5. Supervise the making of at least two 6 by 12 in. compression test cylinders for each form bed of concrete slabs that is to be labeled.
6. Observe and record strength of concrete when strands are cut (tensioning released) by witnessing strength tests of representative 6 by 12 in. test cylinders.

At periodic intervals the Chicago office will require “proofing tests” of the manufacturer’s compression testing equipment conducted by a competent testing laboratory in the manufacturer’s area. The manufacturer will pay the cost of the proofing test.

TEST EQUIPMENT

Sufficient 6 by 12 in. steel molds for making compression test specimens.

A testing machine of any type of sufficient capacity which will comply with ASTM C39-49.

TEST METHOD

Compressive Strength Cylinders — At least two 6 by 12 in. cylinders shall be cast from each form bed of concrete slabs to be labeled, as follows:

The cylinder mold shall be filled one-third full and rodded, with a 5/8 in. diameter, 24 in. long rod rounded at the end, 25 strokes spread uniformly over the surface. The mold filled two-thirds full and rodded 25 strokes as before with the rod penetrating to the first layer. The mold filled to overflowing rodded 25 strokes, the excess struck off, and the surface troweled smooth.

The cylinders are then stored under the same conditions as the slab. Prior to test, the cylinders are capped with a suitable material that will prevent concentrated stresses and that is stronger than the concrete. The load at fracture of the cylinder shall be divided by the area in square inches to arrive at the strength per square inch.

Testing Machine — Shall be accurate to plus or minus 5 per cent and shall be provided with spherical bearing blocks. It shall be capable of maintaining a load rate of 20 to 50 psi per second.

(The manufacturer will furnish an accurate drawing 8-1/2 by 11 in. size for use as ILL. 1. For information purposes the sketch shown as ILL. 1 is included as a guide to that drawing.)

Illustration 2 will be a photograph of manufacturer’s type of hold-down device, a sample of which will be obtained during the initial inspection.)
Strand at Q, Span

Wire Fabric

Strand of Ends

varies to 60"

1-1/8" min.

1-1/8" min.

5 strands each leg

varies

varies

1-5/8" clear min.

1-5/8"

2" min.

Length varies

All dimensions shown are to be held

Subj. 784-1

I-5-61

ILL. 1
Retardant 4123-1
Application No. 57C7689A
May 12, 1958

REPORT
on
FLOOR OR ROOF CONSTRUCTION CONSISTING OF
PRESTRESSED CONCRETE DOUBLE TEE SLABS

Prestressed Concrete Institute
DESCRIPTION

GENERAL:

Prestressed concrete floor and roof slabs are of many designs. The subject of this report is a precast prestressed concrete double tee slab of the design shown on Figs. 1, 2, and 2A used to form a roof or floor test assembly as shown on Figs. 4 and 5.

To avoid delay for curing purposes, it was planned to conduct this investigation to determine the performance of the slabs under design load without a concrete topping.

THE INVESTIGATION

The purpose of this investigation was to establish a fire-retardant classification for the floor or roof assembly, consisting of double tee prestressed slabs when tested for load-bearing capacity, in accordance with Underwriters’ Laboratories, Inc.’s Standard for Fire Tests of Building Construction and Materials, UL263 (NFPA 251; ASTM E119). The necessary topping to satisfy heat transmission properties of the assembly was to be computed on the basis of available fire test data. The fire test was supplemented by other tests and examinations to determine the physical properties of the material used and the practicability of handling, shipping, and installing.

EXAMINATION AND TEST RECORD

The materials used in the assembly are described below in the order of use.

Steel Beams — The beams used to support the ends of the concrete units were 8-in. wide, 27-lb flange, structural steel members on the top of which rested 3-in. wide by 1½-in. thick steel bars. (See Fig. 1.)

Precast-Prestressed Concrete Double Tee Slabs — The slabs were manufactured at a local plant selected by the submittor, and were of the shape and design as shown on Figs. 1, 2, and 2A.

The slabs were of the draped-strand design wherein the strands are lower at the center of the T-slabs than at the ends as shown on Fig. 1. The two strands in each tee were held down at the middle of their span length by a hold-down device shown on Fig. 3. The ends of the strands were held by means of gauges to the heights as shown on Fig. 1 until the concrete had reached the required strength at which time the gauges were removed and the strand wires cut. Each strand was 5/16 in. diameter and contained seven wires.

The concrete was 1-in. maximum slump mix using sand, limestone, and high early strength cement. Compressive strength tests of representative 6- by 12-in. cylinders made of the mix as used in the slabs and steam cured in a similar manner developed a minimum of 6101 psi, a maximum of 7587 psi, and an average of 7142 psi at 28 days.

Data, such as tension applied to strands, mix, and strength of concrete when the strands were cut and other details concerning the manufacture of the units, are on file at Underwriters’ Laboratories, Inc. for use in connection with future inspections.

ERCTION OF TEST ASSEMBLY:

The precast-prestressed double tee slabs were provided in width so that three units completely filled the test furnace allowing 3-in. minimum bearing on supports at the ends. The space between the slabs and the furnace frame was grouted to provide restraint, on all edges. The joints between units were filled with rock wool so as to prevent the passage of smoke and flame.

The appearance of the test assembly after erection in the furnace is shown on Figs. 4 and 5.

FIRE ENDURANCE TEST:

The test was conducted in accordance with the Standard for Fire Tests of Building Construction and Materials of Underwriters’ Laboratories, Inc.

DESCRIPTION OF SAMPLE

The fire test assembly was erected as described in “Erection of Test Assembly,” and as shown on Figs. 1, 4, and 5.

At the time of the fire test, the units had aged 111 days. A relative humidity of
77 per cent was determined from an electrical moisture-sensing element located 2½-in. above the bottom of a tee, in a representative sample. Surface relative humidity, measured in a similar fashion, was approximately 42 per cent.

METHOD

The load applied to the test assembly was arranged to provide a uniformly distributed load of 40 psf. This load was specified by the submittor, and calculated on the basis of design formulas as shown in detail on Figs. 2 and 2A. The design, method, and calculations are shown, since a nationally recognized Standard has not been developed for prestressed concrete.

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 temperatures in the furnace chamber were measured with 12 thermocouples symmetrically located as shown on Fig. 5.

The unexposed floor surface temperatures were measured by thermocouples, Nos. 1 through 9, located as shown on Fig. 7. Thermocouple Nos. 10, 11, 12, and 13, as shown on Fig. 7, were peened into the top ends of the hold-down devices and covered with standard pads. Thermocouple Nos. 14 and 15 were attached to the lifting hooks, placed in each tee at the end of the slabs. See Fig. 4 for a general view showing lifting hooks and thermocouple locations.

The temperatures of the prestressing strands were measured by means of thermocouples affixed to the strands at depths of cover of 2, 2½, and 3 in., provided by the concrete.

The deflection of the floor was observed through a surveyor's level, placed on one side of the furnace, and sighted on five vertical targets, each graduated in 0.10 in. and located as shown on Figs. 4 and 7.

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

RESULTS

Observation During Application of Load—A maximum deflection of 0.07 in. occurred in the middle slab as indicated by Targets 2, 4, and 5 as a result of the load applied. No additional deflection occurred prior to the start of the fire exposure.

Character and Distribution of the Fire—The furnace fire was smoky and somewhat under the Time-Temperature Curve as shown on Fig. 6.

Observation of the Unexposed Surface—Approximately 5 minutes after the start of the fire exposure a crack parallel to, and 18 in. from, the west furnace frame developed in the west slab. At about 39 minutes, a similar crack 25 in. from the east furnace frame occurred in the east slab.

By 45 minutes a crack developed in the south end of the middle slab, and by 95 minutes corner cracks were apparent in the east and west slabs. The cracks continued to open throughout the test reaching a maximum of ⅛ in. by test termination.

Moisture appeared on the surface by 15 minutes and remained until approximately 95 minutes, when the surface appeared dry.

Observation of the Exposed Surface—Approximately 8 minutes after the start of the test a 6-in. diameter section at the joint between the middle and east slabs spalled to a depth of ¼ in. Starting at 12 minutes, a 6-in. long corner section of the second tee from the west edge spalled to a depth of approximately ¾ in., and spalling in the other tees continued until 20 minutes. No further spalling occurred. The maximum depth of spall appeared to be 1 in., exposing the wire fabric in one tee but no prestressing strands were exposed.

At about 47 minutes, a 2½-ft. long crack was noted in the soffit of the third tee from the west edge at the approximate centerline.

By 58 minutes hairline tension cracks, spaced about 12-14 in. apart began developing in all tees. By 78 minutes the tension cracks appeared open 1/16 in. and by 87 minutes
the cracks extended from the tee soffit to the underside of the slab and were open ⅛ in. As the test progressed, additional tension cracks formed and gradually opened. The test was terminated at 2 hours, 1 minute at the request of the submitter's representative at which time the maximum crack opening was about ¼ in.

The hose stream and double live load tests were not conducted.

Deflection of the Floor — A maximum downward deflection of 4.33 in. at the center of the middle slab was noted at the end of the fire test as indicated by Target 2, and as shown in the following table. The slab continued to deflect until 24 hours after the furnace fire was extinguished at which time equilibrium seemed to be reached.

<table>
<thead>
<tr>
<th>Time</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 minutes</td>
<td>0.02</td>
<td>0.07</td>
<td>0.02</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>5 minutes</td>
<td>0.20</td>
<td>0.44</td>
<td>0.12</td>
<td>0.36</td>
<td>0.44</td>
</tr>
<tr>
<td>10 minutes</td>
<td>0.18</td>
<td>0.50</td>
<td>0.09</td>
<td>0.38</td>
<td>0.49</td>
</tr>
<tr>
<td>15 minutes</td>
<td>0.03</td>
<td>0.68</td>
<td>0.23</td>
<td>0.10</td>
<td>1.10</td>
</tr>
<tr>
<td>30 minutes</td>
<td>0.33</td>
<td>1.90</td>
<td>0.34</td>
<td>0.57</td>
<td>1.00</td>
</tr>
<tr>
<td>45 minutes</td>
<td>0.20</td>
<td>1.03</td>
<td>0.45</td>
<td>0.66</td>
<td>1.25</td>
</tr>
<tr>
<td>60 minutes</td>
<td>0.26</td>
<td>1.98</td>
<td>1.04</td>
<td>0.86</td>
<td>1.70</td>
</tr>
<tr>
<td>75 minutes</td>
<td>0.28</td>
<td>2.58</td>
<td>1.54</td>
<td>1.21</td>
<td>2.17</td>
</tr>
<tr>
<td>90 minutes</td>
<td>0.48</td>
<td>3.38</td>
<td>1.99</td>
<td>1.46</td>
<td>2.60</td>
</tr>
<tr>
<td>105 minutes</td>
<td>0.73</td>
<td>3.38</td>
<td>2.54</td>
<td>1.81</td>
<td>3.05</td>
</tr>
<tr>
<td>121 minutes</td>
<td>0.93</td>
<td>4.33</td>
<td>2.64</td>
<td>2.06</td>
<td>3.30</td>
</tr>
</tbody>
</table>

Furnace fire extinguished at 121 minutes.

DEFLECTION — AFTER FURNACE FIRE EXTINGUISHED

<table>
<thead>
<tr>
<th>Time</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 minutes</td>
<td>1.16</td>
<td>4.73</td>
<td>2.92</td>
<td>2.29</td>
<td>3.53</td>
</tr>
<tr>
<td>1 hour</td>
<td></td>
<td>5.16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 hours</td>
<td></td>
<td></td>
<td>5.38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 Hours</td>
<td>1.68</td>
<td>5.88</td>
<td>3.42</td>
<td>3.29</td>
<td>4.15</td>
</tr>
<tr>
<td>96 hours</td>
<td>1.70</td>
<td>5.86</td>
<td>3.42</td>
<td>3.30</td>
<td>4.16</td>
</tr>
</tbody>
</table>

DEFLECTION — AFTER LIVE LOAD REMOVED

<table>
<thead>
<tr>
<th>Time</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 hours</td>
<td>1.93</td>
<td>5.20</td>
<td>3.27</td>
<td>2.92</td>
<td>4.03</td>
</tr>
</tbody>
</table>

Temperature of the Unexposed Surface — The initial average temperature of the unexposed surface was 68 F; therefore, the average limiting temperature was 138 F, and the maximum limiting individual temperature was 393 F. The average limiting temperature was reached by thermocouple No. 3 at 22 minutes as shown on Fig. 7.

Temperature of the Prestressing Strands — Temperature data of the prestressing strands were recorded and shown on Fig. 8.

OBSERVATIONS AFTER TEST:

After the sample had cooled and the load removed, it was noted that the middle slab had regained 0.60 in. from its maximum deflection, the west slab had further deflected 0.23 in., and the east slab regained 0.15 in.

From a straight edge placed on the centerline across the three slabs, as shown in Fig. 10 measurements were taken at the edges near the joints between adjacent slabs, and are tabulated below.

<table>
<thead>
<tr>
<th>Joint, In.</th>
<th>West</th>
<th>Middle</th>
<th>Middle</th>
<th>East</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-½</td>
<td>4-⅛</td>
<td>6</td>
<td>4-⅛</td>
<td></td>
</tr>
</tbody>
</table>

The unexposed surface of the west and east slabs had cracks 18 in. and 25 in. respectively, from the furnace side frames throughout their entire length. Each slab had diagonal cracks across their ends. The cracks were open to a maximum of ¼ in.

The exposed surface of the assembly was craze cracked with the tees spalled at
the corners. The depth of the spalled areas varied to a maximum of about 2 in., which occurred in the second tee from the left as shown on Fig. 9.

Some reinforcing wire fabric was exposed in the slab section and in the spalled areas in the tee section as shown on Fig. 9.

The tension cracks were open to a maximum of ¾ in. as shown on Fig. 9.

The double tee slabs were removed from the furnace frame by lifting them out in the same manner as was used in the initial installation. The units maintained their general distorted shape (see Fig. 10), during a period of a month stored outside.

RECORD IN SERVICE

Precast-prestressed double tee floor or roof units are relatively new, and to date no reports of field service have been received and no details of fire service are available.

Supervision of Product by Underwriters’ Laboratories, Inc.:

Precast-prestressed double tee units, conforming to the cross-sectional dimensions, design, and properties given herein and on file will be listed under the Label Service as “Precast Concrete Units,” Guide No. 40 U18.18C for use with the specified minimum thickness of concrete top fill.

CONCLUSIONS

FIRE-RETARDANT PROPERTIES:

Floor and roof assemblies, constructed of precast-prestressed double tees of the design and cross-sectional dimensions as described herein, when used with a poured-in-place concrete top fill 3 in. thick, will afford 2-hour protection against passage of flame and dangerous heat transmission, provided:

1. The assemblies are restrained at the edges.
2. Bearing on the supports is 3 in. minimum.
3. The concrete topping is not considered as a structural element of the assembly.

The assembly, as tested without concrete topping, carried the live load for 2 hours, 1 minute during fire exposure and continued to carry the live load until removed after approximately 100 hours had elapsed.

Previous published test results of monolithic reinforced concrete floors shows that 3 in. of a normal concrete topping in conjunction with the slabs tested, will provide 2-hour protection for the assembly against passage of flame and dangerous heat transmission.

The above limitations were the conditions under which the assembly was tested.

DESIGN AND CONSTRUCTION:

Precast-prestressed concrete members utilized in floor or roof constructions are of varied design. Only the units of the design and cross-sectional dimensions, and installed as given herein can be evaluated from the test information contained in this report.

PRACTICABILITY:

The precast-prestressed concrete double tee units of the design as given herein can be readily erected in the field by workmen familiar with such installations. The placing of the concrete top fill will require the usual supervision for such construction.

STRENGTH:

The precast-prestressed concrete units of the design tested, without normal concrete topping, showed stability under standard fire test conditions for 2 hours.

When the load-carrying capacity is derived from the design formulas as shown on Figs. 2 and 2A, the load-carrying capacity should not utilize the concrete top fill as a structural element until fire tests of the composite assembly evaluate it.

UNIFORMITY:

The precast-prestressed concrete units, as described herein, are of uniform character within limitations established under the Inspection Service contemplated.

CONFORMITY:

This construction was tested in accordance with the Standard for Fire Tests of Building Construction and Materials of Underwriters’ Laboratories, Inc., with the deviation from the Standard on the limiting aspects of heat transmission waived. Heat transmission properties, however, comply with the Standard when 3 in. of concrete topping is placed on the units at the job site as based on prior test data.
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 double tee units demonstrates that his product conforms with the design, dimensions, and specifications as set forth for the product used in this test.

Guide No. 40 U18.16C. Date File

Precast Concrete Units.

(Manufacturer, City, Zone, State).

For Floor, Roof, and Ceiling Design No. — 2 Hr.

(Street 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.


Precast Concrete Units.

Guide No. 40 U18.16C. Date

This classification includes precast concrete slabs and planks, hollow or solid, for use in bearing walls and floor or roof assemblies of the kind indicated in the following individual listings. The units are cast at the plant and consist of portland cement and fine and coarse natural or processed aggregates. The reinforcement may be wire fabric, deformed bars and/or high tensile strength wire strand. The fire-retardant classifications given in the following individual listings are based on installation methods shown in the indicated design sketches (shown under Guide No. 40 U18).

The label of Underwriters’ Laboratories, Inc. attached to the product is evidence that such product has been produced under the Factory Inspection and Label Service Program.

The Label Service of Underwriters’ Laboratories, Inc. includes inspection of concrete mix and strength, dimensions of unit, and location and type of reinforcement for compliance with specifications established on the basis of the product used in the fire test of individual structures.

Tests by: Report by: Reviewed by:
R. D. Bieniarz B. A. ZIMMER R. L. PARKS
D. Orals Project Engineer, Fire Senior Project Engineer
R. L. Parks Protection Department Fire Protection Department
H. Rustand
B. A. Zimmer

SUBMITTED:
A. J. STEINER
Managing Engineer, Fire Protection Department

The foregoing Recommendation has been accepted June 4, 1958.

UNDERWRITERS’ LABORATORIES, INC.
W. S. AUSTIN, Secretary

BAZ:MS
CLASS D - 2 DESIGNS
DESIGN NO. - 2 HR.

SAND-GRAVEL OR SAND-LIMESTONE CONCRETE TOP FILL 3000 PSI

PRECAST CONCRETE UNITS - LISTED BY U.L. INC., GUIDE NO. 40 U18.16C

MINIMUM BEARING 3 IN.
Plan of Test Section
Scale ¼" = 1'-0"

Note: The above slab make up provides for a clearance of \( \frac{3}{8} \) on all sides of the furnace opening.
TYPICAL SLAB SECTION

GENERAL NOTES

Concrete strength for design @ 28 days to be 5000 psi.
Prestressing steel: $A_g = 25000$ psi ultimate
Tensioning force each 5/8 strand = 10,150 lb
Allowable design live loads:
- Ultimate: $1.40L + 2.3LL = 40.3$ psf
- Max Tension: $0L + LL - 210 = 40.0$ psf
- Cracking: $0L + 1.5LL - 550 = 40.6$ psf

Actual depths of members tested were as shown, namely 2-1/2" for the slab and 8" total depth, but the contemplated thickness of the slab under Underwriters' Laboratories, Inc. inspection service will be 2" and the total depth 7-1/2" as shown in Figure 2 when used in conjunction with the required 3" topping.
SECTION PROPERTIES

\[\begin{align*}
\text{(2)(56)} & \quad \frac{A}{112} \times \frac{Y}{6.5} = 727.0 \\
\text{2 (4.58)(5.2)} & \quad 50.4 \times 2.75 = 138.7 \quad \bar{Y} = \frac{884}{167.4} = 5.28 \\
\text{4 (.5)(.458)(5.2)} & \quad \frac{5.0}{167.4} \times 3.67 = \frac{18.5}{884.2} \\
\text{e} & = 3.03 \quad \text{distance of } A_b \text{ from N.A.} \\
\end{align*}\]

\[\begin{align*}
\frac{1}{2} \text{(56)(2)}^3 & = 37 \\
2(1/2\text{(4.58)(5.2)})^3 & = 127 \\
4 (.36)(.458)(5.2)^3 & = 8 \\
112 \text{(1.22)}^2 & = 167 \\
50.4 \text{(2.53)}^2 & = 323 \\
5.0 \text{(1.61)}^2 & = 13 \\
\end{align*}\]

\[\begin{align*}
\frac{1}{675} & = I \text{ about N.A.} \\
\frac{675}{2.22} & = 304 \\
\frac{675}{5.28} & = 128 \\
\text{ST} & = \frac{\text{f}_{\text{ot}}}{167.4} - \frac{T \times (3.03)}{304} = -0.0040T \\
\text{SB} & = \frac{T \times (3.03)}{128} = -0.0297T \\
\end{align*}\]

DESIGN LIVE LOADS

CRACKING

1. Assume modulus of rupture = 550 psi for 5000 psi conc.
2. Design for DL + 1.5 LL at \( f_{\text{bottom}} = -550 \) psi.

\[\begin{align*}
f_{\text{ot}} & = f_{\text{ot}} + 550 - f_{\text{LL}} \\
M & = 8WL^2 = f(S) \\
W & = \frac{8(f)(s)}{L^2} \\
W_{\text{LL}} & = \frac{8(f)(s)}{12(1.5)(4.67)L^2} = \frac{8(f_{\text{LL}})(128)}{12(1.5)(4.67)L^2} = f_{\text{LL}} \times \frac{12.2}{L^2} \\
\end{align*}\]
CRACKING - (CONT)

Dead Load Moment \[= \frac{(167.4)(17.25)^2}{8} = 6.22\ -K\]

\[f_{c_{DL}} = \frac{6.22 (12)}{128} = 583\ psi\]
\[f_{ct} = 4 (10150)(.0297)(.85) = 1024\]

\[f_{c_{LL}} = 1024 - 583 + 550 = 991\ psi\]

\[W_{LL} = 991 \times \frac{12.2}{(17.25)^2} = 40.6\ PSF\]

ALLOWABLE TENSION

1. Allowable tension = 210 psi for 5000 psi conc.

2. Design for DL + LL at \(f_{c_{bottom}} = -210\ psi\)

\[f_{c_{LL}} = f_{ct} + 210 - f_{c_{DL}}\]

\[W_{LL} = 8 \left(\frac{f_{c_{LL}}}{128}\right) \frac{(18.3)}{(L^2)} = f_{c_{LL}} \times \frac{18.3}{L^2}\]

\[f_{c_{LL}} = 1024 - 583 + 210 = 651\ psi\]

\[W_{LL} = 651 \times \frac{18.3}{(17.25)^2} = 40.0\ PSF\]

ULTIMATE

Design for 1.4 DL + 2.3 LL

\[Kd = \frac{58000}{56 (5000)(.85)} = 0.244\]

\[j_d = 7.5 - 2.25 - 0.12 = 5.13\]

\[M_u = \frac{58000 (5.13)}{12} = 24.8\ -K\]

\[1.4\ M_{DL} = 1.4(6.22) = 8.70\ -K\]

\[M_u - 1.4\ M_{DL} = 24.8 - 8.70 = 16.1\ -K\]

\[2.3\ \left(\frac{W_{LL}}{8}\right) \frac{(4.67)(17.25)^2}{\#} = 16100\ #\]

\[W_{LL} = 40.3\ PSF\]

FIG. 2A
R 4123-1
Figure 3  R-4123-1
Wire Reinforcing strand, hold down device
Figure 4  R-4123-1

Unexposed surface before fire endurance test showing deflection targets, thermocouples and loading method.
Figure 5  R-4123-1
Exposed side before fire endurance test
FURNACE TEMPERATURES
R 4123-1
APRIL 3, 1958
Underwriters' Laboratories, Inc.
Fire Endurance Test

FIG. 6
UNEXPOSED SURFACE TEMPERATURES
R 4123-1
APRIL 3, 1958
Underwriters' Laboratories, Inc.

Fire Endurance Test

FIG. 7

- THERMOCOUPLE LOCATIONS
- TARGETS
Figure 9  R-4123-1
Exposed surface after fire endurance test
Figure 10  R-4123-1
Unexposed surface after fire endurance test
Figure 11  R-4123-1
Cross section of tee after fire endurance test
Figure 12  R-4123-1
Typical sections of slab after fire endurance test