Underwriters’ Laboratories Inc. Fire Test Reports for Inverted Tee Beams

PREFACE

The following reports, Underwriters’ Laboratories Inc. File R4123-12 and 12A, are the result of the fire testing of three inverted tee beams at Underwriters’ Laboratories, Northbrook, Illinois. The tests include one pretensioned beam; one post-tensioned beam with bonded tendon; and one post-tensioned beam with unbonded tendon. All three types of beams, as tested, will afford 4-hour protection against structural failure under exposure to fire.

Label service is available on pretensioned beams through the Follow-Up Program of Underwriters’ Laboratories, Inc. Since post-tensioned beams are generally constructed at the site, this type has not been placed under the Listing and Follow-Up Program; but, should the units be factory produced, this program can be established.

This test series is part of a continuing program of fire testing directed by the Prestressed Concrete Institute Committee on Fire Resistance Ratings:

HOWARD MAY, Chairman
FRANK ERSKINE
STEVEN GALEZEWSKI
DAVID LAGUE
SAM SELVAGGIO
GEORGE VAUGHT
ADOLPH WALSER

Copies are available at $1.50 each ($0.75 to PCI members) from PRESTRESSED CONCRETE INSTITUTE, 20 N. WACKER, CHICAGO, ILLINOIS 60606. Check or Money Order must accompany all orders. Copyright by the PRESTRESSED CONCRETE INSTITUTE, 1965.
File R4123-12
Assignment 64K336
August 30, 1965

REPORT on
PRESTRESSED PRETENSIONED CONCRETE
INVERTED TEE BEAMS

Prestressed Concrete Institute
Chicago, Illinois

GENERAL
The subject of this Report is a test assembly consisting of a precast-prestressed pretensioned concrete beam and two precast concrete filler slabs. The test assembly was constructed as shown on Figs. 1, 2, 3, and 4.

The object of the investigation was to establish a fire-resistance classification for this beam, when tested in accordance with Underwriters' Laboratories, Inc. Standard for Fire Tests of Building Construction and Materials, UL263 (ASTM E119, NFPA No. 251). 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 storing.

DESCRIPTION
Product Covered
The materials used in the assembly are described below:

Steel Supports
The steel angles used to support the beam at either end were 6 by 6 by 1 in. on top of which were placed two 1 by 3-in. steel bearing plates, a 6 by ¾-in. steel bearing plate, and three layers of ¾-in. thick asbestos paper. This provided a bearing surface of 5 in. at each
end of the beam.

The filler slabs were supported along the east and west edges of the furnace frame by 6 by 4 by \(\frac{3}{4}\) in. angles running the full length of the slabs.

The steel supports are shown on Figs. 2 and 3.

**Precast Concrete Filler Slabs**

The filler slabs were approximately 17 ft.-9 in. by 6 ft.-4\% in. by 6 in. thick, and were designed and manufactured by the submittor only for purposes of filling the furnace test frame and carrying the loading tanks used to impose the required live load on the beam.

**Precast Prestressed Pretensioned Concrete Beam**

The pretensioned beam was manufactured by the submittor and was of the configuration and design shown on Fig. 4. The longitudinal reinforcing steel was used only to secure the stirrups in their proper location and are not considered
in the design calculations.

Other properties of the beam are on file at Underwriters’ Laboratories, Inc. for future use in the Factory Inspection Program.

Erection of Test Assembly

The precast concrete beam was located along the north-south center line of the test frame and was supported by the steel supports described previously, which provided 5-in. bearing at either end. The ends of the beam were restrained by grouting tightly the space between the ends and the furnace frame with a high-strength, low-water control grout. The width of this grouted space averaged approximately ½ in. See Figs. 1, 2, and 3.

Two filler slabs were used, one located at either side of the beam. Each slab was supported on one side by the supporting angles and on the other by the ledge on the beam. The north and south ends of the slabs were unsupported. One-inch thick, 6-in. wide lengths of mineral fiber insulation were placed on supporting angles and the beam ledges prior to installation of the slabs in order to seal the furnace chamber. The slabs were placed so as to leave a gap between the slab edge and the beam of a minimum of ½ in. The spaces around the entire periphery of the slabs including the gap between the beam and

Fig. 2—End View of Furnace Set-Up, R4123-12

Fig. 3—Elevation of Furnace Set-Up, R4123-12
Fig. 4—Pretensioned Concrete Beam Detail

Fig. 5—Assembly During Construction-Pretensioned Beam

Fig. 6—Exposed Surface Before Tests-Pretensioned Beam
the slabs were packed tightly with asbestos fiber. See Figs. 1, 2, and 3. The beam is shown during installation on Fig. 5. The appearances of the exposed and unexposed surfaces of the assembly prior to the tests are shown on Figs. 6 and 7.

TEST RECORD NO. 1
Pretensioned Beam

Fire Endurance Test

This test was conducted in accordance with Underwriters’ Laboratories, Inc. Standard for Fire Tests of Building Construction and Materials, UL263 (ASTM E119, NFPA No. 251).

Samples

The test assembly was erected as described in "Erection of Test Assembly". The precast pretensioned concrete beam was dried for approximately 379 days prior to subjecting it to the fire endurance test. Of this, 315 days of the drying period were at an elevated temperature of 120°F. maximum, while the remaining drying period was at room temperature.

At the time of the fire test, the relative humidity of the beam as measured at various depths in a representative sample, constructed similar to and at the same time as the beam used in the test, ranged from 33 to 78.5 per cent. The humidities were measured at depths varying from 2 to 10 in. by means of moisture-sensitive electrical elements inserted in short lengths of pipe buried in the concrete.

Method

The standard equipment of Underwriters’ Laboratories, Inc. for testing floor or roof and ceiling constructions was used.

The temperatures in the furnace chamber were measured with 16 thermocouples, symmetrically located, 12 in. below the surface, as shown on Fig. 8.

The temperatures of the prestressing strands were measured by means of thermocouples wire-tied to the strands during the casting of the units. The temperature of the concrete was measured at various depths by means of thermocouples placed during casting. The locations of these thermocouples are shown on Fig. 9.

The deflection of the beam was observed through a surveyor’s level sighted on three vertical targets, each graduated in 0.10-in. incre-
ments. Target No. 1 was located at the north quarter point of the beam, Target No. 2 at the midpoint, and Target No. 3 at the south quarter point.

Throughout the test observations were made of the character of fire, its control, the condition of the surfaces, and all developments pertinent to the performance of the beam, with reference to the stability and to the fire-resistance performance.

The load applied to the beam was calculated to simulate a uniformly distributed load of 1773 plf. Of this load, 250 plf was contributed by the beam itself, 503 plf was contributed by the filler slabs, and 1020 plf was the superimposed live load.

This loading was calculated by the submittor, in accordance with the ACI Standard, Building Code Requirements for Reinforced Concrete, (ACI 318-63). The live load was applied approximately 19 hr. prior to the test. A maximum downward deflection of 0.10 in. was observed at the center of the beam at Target No. 2 as a result of the initial application of the load.

Results

Character and Distribution of Fire—The furnace fire was luminous and well-distributed, and the temperatures which developed followed the Standard time-temperature curve as outlined in the Standard; and as shown on Fig. 8.

Observation of the Exposed Surface—The beam was noted to be slightly discolored after 10 min. of exposure, but had returned to its original color by 30 min.

During the entire exposure, there was no apparent cracking, spalling, or any visible deterioration to the exposed surface of the beam.
Fig. 9—Prestressing Strand and Concrete Temperatures—Pre tensioned Beam
The furnace fire was extinguished at 255 min.

Observation of the Unexposed Surface—At 12 min., separations of approximately ½ in. between the top ends of the beam and the beam supports were noted. This separation remained throughout the test.

At 144 min., moisture was observed on top of the beam, at either end, at the location of the lifting hooks. This moisture remained throughout the test.

At 200 min., transverse hairline cracks with moisture present were noted across the top of the beam at three locations, the midpoint, the north quarter point, and approximately 2 ft. from the north end. These cracks did not vary and the moisture remained throughout the remainder of the test.

The furnace fire was extinguished at 255 min.

Deflection of the Beam—Tabulated below is the deflection of the beam during the fire endurance, hose stream, and excess load tests.

<table>
<thead>
<tr>
<th>Time, Min.</th>
<th>Deflection, In.</th>
<th>Target No. 1</th>
<th>Target No. 2</th>
<th>Target No. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.23</td>
<td>0.40</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0.40</td>
<td>0.60</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>0.45</td>
<td>0.65</td>
<td>0.55</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>0.48</td>
<td>0.70</td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>0.51</td>
<td>0.75</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>0.55</td>
<td>0.80</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>0.55</td>
<td>0.85</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>0.60</td>
<td>0.92</td>
<td>0.73</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>0.60</td>
<td>0.95</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>0.60</td>
<td>0.98</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>160</td>
<td>0.60</td>
<td>1.02</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>180</td>
<td>0.61</td>
<td>1.03</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>0.61</td>
<td>1.05</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>220</td>
<td>0.62</td>
<td>1.05</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>240</td>
<td>0.63</td>
<td>1.05</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>255 (Gas off)</td>
<td>0.63</td>
<td>1.05</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>264 (Hose stream)</td>
<td>0.63</td>
<td>1.01</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>22 Hr.</td>
<td>0.10</td>
<td>0.15</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>23 Hr. (Excess load)</td>
<td>0.30</td>
<td>0.50</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>(No load)</td>
<td>0.00</td>
<td>†0.10</td>
<td>†0.05</td>
<td></td>
</tr>
</tbody>
</table>

†—Indicates upward deflection.

Temperatures of the Prestressing Strands—Temperatures of the pre-stressing strands, while not required for classification purposes, were recorded and are shown on Fig. 9.

Hose Stream Test

Immediately after the 255-min. fire exposure, the exposed surface of the assembly was subjected for 8 min. to the impact, cooling, and eroding action of a 45-psi water stream applied from a 1¼-in. nozzle at a distance of 13 ft., and at an angle of 70 deg. from the normal.

The appearance of the beam after being subjected to the hose stream is shown on Fig. 10.

Excess Load Test

Sample

The beam previously subjected to the fire endurance and hose stream tests was subsequently subjected to the excess live load.

Method

Following the fire endurance test and hose stream test, the assembly was allowed to cool overnight. The additional live load of 1020 plf, which increased the total live load to 2040 plf, was then imposed on the beam.

Results

The maximum additional vertical deflection measurement observed as a result of the excess load in the assembly was 0.40 in., measured at Target No. 3.

Observations After Test

The hose stream eroded the bottom and sides of the beam as shown on Fig. 10. The depth of this erosion varied from ½ to ¼ in., and exposed a portion of one reinforcing bar on the west side of the
beam near the midspan.

Surfaces of the beam which had not eroded, apparently since they were not hit with the water stream, showed evidence of many fine hairline cracks.

The exposed and unexposed surfaces after test are shown on Figs. 10 and 11, respectively.

CONCLUSIONS

Fire-Resistance Properties

It is judged that precast pretensioned concrete inverted tee beams, of the configuration and design described herein, will afford 4-hr. protection against structural failure under exposure to fire, provided:
1. The beam is restrained at the ends.
2. Bearing of the beam on the supports is 5 in., minimum.

The beam carried the rated live load during the fire endurance and hose stream tests, and upon cooling, carried twice the rated live load without signs of undue deflection or strain.

The above classification is based on the conditions of acceptance for tests of floors and roofs specified in the Standard of Underwriters' Laboratories, Inc. for Fire Tests of Building Construction and Materials, UL263 (ASTM E119, NFPA No. 251).

The pretensioned prestressed concrete beam will be shown in the Building Materials List as Beam Design No. 39-4 Hr., and as illustrated herein.

**Practicability**

The precast concrete beam used in the test assembly was readily installed by qualified workers with tools and methods commonly used for construction work of similar nature. The character of the materials and the installation procedures as described in this Report, and in particular, the restraint and minimum bearing of the beam on the supports, appear to be significant factors in the fire-resistance performance.

**Conformity**

The test was conducted in accordance with the Standard, Fire Tests of Building Construction and Materials, UL263 (ASTM E119, NFPA No. 251). The materials used in this construction are judged to be in conformance with the definitions of "noncombustible" as defined by the Standard.

**Listing and Follow-Up Program**

Pretensioned precast concrete beams which conform to the design and cross-sectional dimensions given herein and on file, manufactured as specified, and found acceptable under the Follow-Up Program of Underwriters' Laboratories, Inc. will bear a label containing the following:

```
UNDERWRITERS' LABORATORIES, INC.
LISTED
PRECAST CONCRETE UNITS
FIRE RESISTANCE CLASSIFICATION
BEAM DESIGN NO. 39-4 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 pretensioned prestressed concrete inverted tee beams 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. 
Precast Concrete Units.

Manufacturer's name, City, State

Prestressed Concrete Inverted Tee Beams for Use In Beam Design No. 39–4 Hr.

Address

Label Service—See General-Information Card of above guide number.

See Guide No. 40 U18. for illustration of design numbers and fire-resistance classification.

Guide No. 40 U18

Floor or Roof and Ceiling Construction
and Beam Protection

Part 1—See Part 2 for Description of Numbered Items

Class B–4 Design

Design No. 39–4 Hr. (Beam Only)
Guide No. 40 U18.
Floor or Roof and Ceiling Construction August 30, 1965
and Beam Protection

Part 2—Description of Numbered Items.
Class B-4 Design

Design No. 39—4 Hr.

1. Precast Concrete Units—Listed by Und. Lab., Inc.
   Guide No. 40 U18.17.


Report by:            Reviewed by:
Roger S. Tansley     R. L. Parks
Project Engineer     Associate Managing Engineer
Fire Protection Department     Fire Protection Department

SUBMITTED:
Jack Bono
Managing Engineer
Fire Protection Department

The foregoing Recommendation has been accepted September 30, 1965.

UNDERWRITERS’ LABORATORIES, INC.
W. S. Austin
Vice President and Secretary
August 31, 1965

REPORT on PRESTRESSED CONCRETE INVERTED TEE BEAMS POST-TENSIONED

Prestressed Concrete Institute
Chicago, Illinois

GENERAL
The subject of this Report is two assemblies, each test assembly consisting of a precast-prestressed concrete beam and two precast concrete filler slabs. The test assemblies were all constructed as shown on Figs. 1, 2, and 3. In the first test, the precast-prestressed concrete beam was post-tensioned bonded and in the second test post-tensioned unbonded, as shown on Figs. 4 and 11, respectively.

The object of the investigation was to establish fire-resistance classifications for these beams, when tested in accordance with Underwriters' Laboratories, Inc. Standard for Fire Tests of Building Construction and Materials, UL263 (ASTM E119, NFPA No. 251). The fire tests were supplemented by other tests and examinations to determine the physical properties of the material used, and the practicability of handling, shipping and storing.

DESCRIPTION

Product Covered
The materials used in the assemblies are described below:

Steel Supports
The steel angles used to support the beams at either end were 6 by 6 by 1 in. on top of which were
placed two 1 by 3-in. steel bearing plates, a 6 by \( \frac{3}{4} \)-in. steel bearing plate and three layers of \( \frac{3}{8} \)-in. thick asbestos paper. This provided a bearing surface of 5 in. at each end of the beams.

The filler slabs were supported along the east and west edges of the furnace frame by 6 by 4 by \( \frac{3}{8} \)-in. angles running the full length of the slabs.

The steel supports are shown on Figs. 2 and 3.

**Precast Concrete Filler Slabs**

The filler slabs were approximately 17 ft.-9 in. by 6 ft.-4\( \frac{1}{2} \) in. by 6 in. thick, and were designed and manufactured by the submittor only for purposes of filling the furnace test frame and carrying the loading tanks used to impose the required live load on the beams.

**Precast Prestressed Post-Tensioned Bonded Concrete Beam**

The post-tensioned bonded concrete beam was manufactured by the submittor, and was of the configuration and design shown on Fig. 4.

The post-tensioning tendon used in this beam consisted of fourteen, \( \frac{3}{4} \) in. diameter high-tension, cold-drawn, stress-relieved wires, each having a guaranteed minimum tensile strength of 240,000 psi and conforming to ASTM A421-59T, Type BA. End anchorage was provided by means of a \( \frac{3}{8} \)-in. (0.375 in.) button head, cold-formed on each end of each wire after threading through the base plate at the fixed end and the anchor head at the movable end.

The wires were enclosed in a mortar-tight flexible-metal conduit, 1%-in. OD, unpacked and fully interlocked. Each end of the tendon was provided with trumpets and funnels, the trumpet measuring approximately 4-in. OD at the movable end and 2\( \frac{1}{2} \)-in. OD at the fixed end.

The above described tendon was supplied with grout pipes at either end and applicable caps and plugs, and was furnished in continuous lengths without splices and delivered completely fabricated, ready for placement in the forms. The anchoring hardware met the minimum requirements set forth in the ACI Standard, Building Code Requirements for Reinforced Concrete (ACI 318-63).

The tendon assembly was placed in the form in the deflected position, at the elevations shown on Fig. 4, and supported by high chairs. The reinforcing steel bars, deformed, structural grade billet steel \( f_s = 20,000 \) psi, of the sizes and locations as shown on Fig. 4, were placed in the form and supported by high chairs. The reinforcing bars were wire-tied to each other, and the tendon was secured in position by wire tying it to the reinforcing bars with three wires, one on each side and one from the top, at the midpoint and the quarter points. The longitudinal reinforcing steel was used only to secure the stirrups in their proper locations and as a nominal amount of steel to prevent cracking prior to tensioning, and was not considered in the design calculations. After all the steel was secured, the form was ready for concrete placement.

The concrete, mixed on location and transported to the forms by bucket, consisted of 1 part portland cement, 1\% parts sand and 3 parts crushed limestone (sized to pass the 1-in. sieve) by weight, mixed
with 5% gal. of water per sack of cement. The strength of the concrete as determined from four 6 by 12-in. cylinders, air-dried, was 6250 psi after seven days and varied from 8380 psi to 8740 psi averaging 8550 psi, after 28 days. The slump averaged 2½ in.

The concrete in the forms was vibrated thoroughly with special care taken at the ends of the beam near the anchors.

The beam was covered and steam-cured for a period of 14½ hr. at a maximum temperature, as recorded on top of the beam, of 95°F. A 6 by 12-in. concrete cylinder, made during the casting of the beam and steam-cured with it, indicated a strength of 3790 psi after 12 hr.

All fourteen wires in the tendon were stressed simultaneously with a 100-ton hydraulic jack. This was accomplished by threading a pull rod into the anchor head, securing the rod against the ram of the jack, and activating the jack thereby pulling the anchor head and stressing the wires. The wires were stressed to their maximum allowable design stress of 168,000 psi, in accordance with ACI Standard, Building Code Requirements for Reinforced Concrete (ACI 318-63). The computed stressing force was checked by comparing the pressure gauge to the actual elongation obtained. When the calculated stress had been obtained, the anchor head was secured in position with an anchor nut.

After the tendon was stressed to the required tension, a portable mixer and grout pump were connected to the grout pipe at one end of the beam by means of a hose. Clean water was then pumped through the conduit and out the grout pipe at the opposite end of the beam in order to flush and lubricate the conduit.

Water-cement grout consisting of 5 gal. of water and 1 lb. of plastic admixture per bag of Type III portland cement, and mixed for approximately 1½ min., was then pumped into the conduit, completely filling it, and allowed to run out the open end. The grout was pumped under a pressure of approximately 150 psi.

The grout was pumped continuously until the grout emerging from the open pipe was of the same consistancy as that in the mixer. The open pipe was then plugged and the pressure maintained at 150 psi for approximately 1 min. The hose connecting the mixer and pump to the grout pipe was then removed and the pipe plugged. The entire grouting operation was continuous and uninterrupted.

Concrete caps were then poured at each end of the beam, protecting the anchor assemblies, and the beam stored for shipment to the Laboratories.

Precast Prestressed Post-Tensioned Unbonded Concrete Beam

The post-tensioned unbonded concrete beam was manufactured by the submittor, and was of the configuration and design shown on Fig. 11.

The post-tensioning tendon used in this beam consisted of fourteen, ¼-in. diameter high-tensile, cold-drawn, stress-relieved wires, each having a guaranteed minimum tensile strength of 240,000 psi and conforming to ASTM A421-59T, Type BA. End anchorage was provided by means of a ½-in. (0.375 in.) button head, cold-formed on each end of each wire after threading through the base plate at the fixed
end and the anchor head at the movable end.

The wires were completely shop-coated with a non-volatile, low-friction mineral-oil base grease with a rust-preventing additive, and then wrapped with slippage sheathing consisting of a spirally wrapped double layer of waterproof kraft paper laminated with asphalt and reinforced with fiber glass.

The above described tendon was furnished in continuous lengths without splices and delivered completely fabricated, ready for placement in the forms. The anchoring hardware met the minimum requirements set forth in the ACI Standard, Building Code Requirements for Reinforced Concrete (ACI 318-63).

The tendon assembly was placed in the form in the deflected position at the elevations shown on Fig. 11 and supported by high chairs. The reinforcing steel bars, deformed, structural grade billet steel \(f_y = 20,000\) psi, of the sizes and locations shown on Fig. 11, were placed in the form and supported by high chairs. The reinforcing bars were wire-tied to each other, and the tendon was secured in position by wire tying it to the reinforcing bars with three wires, one on each side and one from the top, at the midpoint, and the quarter points. The longitudinal reinforcing steel was used only to secure the stirrups in their proper locations and as a nominal amount of steel to prevent cracking prior to tensioning, and was not considered in the design calculations. After all the steel was secured, the form was ready for concrete placement.

The concrete, mixed on location and transported to the forms by bucket, consisted of 1 part portland cement, 1\(\frac{1}{4}\) parts sand and 3 parts crushed limestone (sized to pass the 1-in. sieve) by weight, mixed with 5% gal. of water per bag of cement. The strength of the concrete as determined from four 6 by 12-in. cylinders, air-dried, was 6250 psi after seven days and varied from 8380 psi to 8740 psi, averaging 8550 psi, after 28 days. The slump averaged 2\(\frac{1}{2}\) in.

The concrete in the forms was vibrated thoroughly with special care taken at the ends of the beam near the anchors.

The beam was covered and steam-cured for a period of 14\(\frac{1}{2}\) hr. at a maximum temperature, as recorded on top of the beam, of 95°F. A 6 by 12-in. concrete cylinder, made during the casting of the beam and steam-cured with it, indicated a strength of 3780 psi after 12 hr.

All fourteen wires in the tendon were stressed simultaneously with a 100-ton hydraulic jack. This was accomplished by threading a pull rod into the anchor head, securing the rod against the ram of the jack, and activating the jack, thereby pulling the anchor head and stressing the wires. The wires were stressed to their maximum allowable design stress of 168,000 psi in accordance with ACI Standard, Building Code Requirements for Reinforced Concrete (ACI 318-63). The computed stressing force was checked by comparing the pressure gauge to the actual elongation obtained. When the calculated stress had been obtained, a sufficient number of steel shims were placed between the anchor head and the base plate in order to maintain the desired elongation.

Concrete caps were then poured at each end of the beam, protecting the anchor assemblies, and the beam
stored for shipment to the Laboratories.

Erection of Test Assemblies

Both test assemblies were erected in an identical manner.

The precast concrete beams were located along the north-south center line of the test frames, and were supported by the steel supports described previously, which provided 5-in. bearing at either end. The ends of the beams were restrained at their ends by grouting tightly the space between their ends and the furnace frame with a high-strength, low-water control grout. The width of this grouted space averaged approximately ¾ in. See Figs. 1, 2, and 3.

Two filler slabs were used for each assembly, one located at either side of the beam. Each slab was supported on one side by the supporting angles and on the other by the ledge on the beams. The north and south ends of the slabs were unsupported. One-inch thick, 6-in wide lengths of mineral fiber insulation were placed on supporting
angles and the beam ledges prior to installation of the slabs in order to seal the furnace chamber. The slabs were placed so as to leave a gap between the slab edge and the beams of a minimum of \( \frac{1}{4} \) in. The spaces around the entire periphery of the slabs including the gap between the beam and the slabs were packed tightly with asbestos fiber. See Figs. 1, 2, and 3.

The beam is shown during installation on Fig. 12. The appearances of the exposed and unexposed surfaces of the assemblies prior to the tests are shown on Figs. 5, 6, 13, and 14.

**TEST RECORD NO. 1**

*Post-Tensioned Bonded Beam Fire Endurance Test*

This test was conducted in accordance with Underwriters’ Laboratories, Inc. Standard for Fire Tests of Building Construction and Materials, UL263 (ASTM E119, NFPA No. 251).

**Samples**

The test assembly was erected as described in "Erection of Test Assembly".

The precast prestressed concrete beam was dried for approximately 377 days prior to subjecting it to the fire endurance test. Of this, 322 days of the drying period were at an elevated temperature of 120°
F. maximum, while the remaining drying period was at room temperature.

At the time of the fire test, the relative humidity of the units as measured at various depths in a representative sample, constructed similar to and at the same time as the units used in the test, ranged from 46.5 to 77 per cent. The humidities were measured at depths varying from 2 to 10 in. by means of moisture-sensitive electrical elements inserted in short lengths of pipe buried in the concrete.

Method

The standard equipment of Underwriters' Laboratories, Inc. for testing floor or roof and ceiling constructions was used.

The temperatures in the furnace chamber were measured with 16 thermocouples, symmetrically located, 12 in. below the surface, as shown on Fig. 7.

The temperatures of the post-tensioning tendon were measured by means of thermocouples wire-tied to the wires during the casting of the units. The temperatures of the reinforcing bars used in the units were measured by means of thermocouples wire-tied to the bars during the casting. The locations of these thermocouples are shown on Fig. 8.

The deflection of the beam was observed through a surveyor's level sighted on three vertical targets, each graduated in 0.10-in. increments. Target No. 1 was located at the north quarter point of the beam, Target No. 2 at the midpoint, and Target No. 3 at the south quarter point.
Throughout the test observations were made of the character of fire, its control, the condition of the surfaces, and all developments pertinent to the performance of the assembly, with reference to the suitability and to the fire-resistance performance.

The load applied to the beam was calculated to simulate a uniformly distributed load of 2048 plf. Of this load, 250 plf was contributed by the beam itself, 503 plf was contributed by the filler slabs, and 1295 plf was superimposed live load.

This loading was calculated by the submittor, in accordance with the ACI Standard, Building Code Requirements for Reinforced Concrete, (ACI 318-63). The live load was applied approximately 19 hr. prior to the test. A maximum downward deflection of 0.23 in. was observed at the center of the beam at Target No. 2 as a result of the initial application of the load.

**Results**

*Character and Distribution of Fire*—The furnace fire was luminous and well-distributed, and the temperatures which developed followed the Standard Time-Temperature curve as outlined in the Standard, and as shown on Fig. 7.
Observation of the Exposed Surface—The beam was noted to be slightly discolored after 9 min. of exposure, but had returned to its original color by 15 min.

During the entire exposure, there was no apparent cracking, spalling, or any visible deterioration to the exposed surface of the beam.

The furnace fire was extinguished at 255 min.

Observation of the Unexposed Surface—At 35 min., separations of approximately \( \frac{3}{8} \) in. between the top ends of the beam and the beam supports were noted. This separation remained throughout the test.

At 135 min., moisture was observed on top of the beam, at either end, at the location of the lifting hooks. This moisture dried at 222 min.

The furnace fire was extinguished at 255 min.

Deflection of the Beam—Tabulated below is the deflection of the beam during the fire endurance, hose stream, and excess load tests.

<table>
<thead>
<tr>
<th>Time, Min</th>
<th>Target No. 1</th>
<th>Target No. 2</th>
<th>Target No. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.34</td>
<td>0.53</td>
<td>0.39</td>
</tr>
<tr>
<td>20</td>
<td>0.47</td>
<td>0.69</td>
<td>0.48</td>
</tr>
<tr>
<td>30</td>
<td>0.54</td>
<td>0.79</td>
<td>0.56</td>
</tr>
<tr>
<td>40</td>
<td>0.57</td>
<td>0.83</td>
<td>0.61</td>
</tr>
<tr>
<td>50</td>
<td>0.62</td>
<td>0.89</td>
<td>0.64</td>
</tr>
<tr>
<td>60</td>
<td>0.64</td>
<td>0.91</td>
<td>0.67</td>
</tr>
<tr>
<td>80</td>
<td>0.66</td>
<td>0.94</td>
<td>0.69</td>
</tr>
<tr>
<td>100</td>
<td>0.71</td>
<td>0.99</td>
<td>0.72</td>
</tr>
<tr>
<td>120</td>
<td>0.73</td>
<td>1.03</td>
<td>0.75</td>
</tr>
<tr>
<td>140</td>
<td>0.74</td>
<td>1.06</td>
<td>0.76</td>
</tr>
<tr>
<td>160</td>
<td>0.75</td>
<td>1.07</td>
<td>0.78</td>
</tr>
<tr>
<td>180</td>
<td>0.77</td>
<td>1.09</td>
<td>0.78</td>
</tr>
<tr>
<td>200</td>
<td>0.77</td>
<td>1.11</td>
<td>0.79</td>
</tr>
<tr>
<td>220</td>
<td>0.79</td>
<td>1.13</td>
<td>0.81</td>
</tr>
<tr>
<td>240</td>
<td>0.81</td>
<td>1.16</td>
<td>0.81</td>
</tr>
<tr>
<td>255 (Gas off)</td>
<td>0.82</td>
<td>1.18</td>
<td>0.81</td>
</tr>
<tr>
<td>265 (Hose stream)</td>
<td>0.82</td>
<td>1.17</td>
<td>0.83</td>
</tr>
<tr>
<td>23 Hr. (Excess load)</td>
<td>0.34</td>
<td>0.51</td>
<td>0.33</td>
</tr>
<tr>
<td>24 Hr. (No load)</td>
<td>†0.21</td>
<td>†0.19</td>
<td>†0.19</td>
</tr>
</tbody>
</table>

†—Indicates upward deflection.
Fig. 8—Tendon and Reinforcing Bar Temperatures
Post-Tensioned Beam with Bonded Tendon
Temperatures of the Post-Tensioning Tendon and Reinforcing Steel—Temperatures of the post-tensioning tendon and reinforcing steel, while not required for classification purposes, were recorded and are shown on Fig. 8.

Hose Stream Test

Immediately after the 255-min. fire exposure, the exposed surface of the assembly was subjected for 8 min. to the impact, cooling, and eroding action of a 45-psi water stream applied from a 1½-in. nozzle at a distance of 13 ft., and at an angle of 70 deg. from the normal.

The appearance of the beam after being subjected to the hose stream is shown on Fig. 9.

Excess Load Test

Sample

The beam previously subjected to the fire endurance and hose stream tests was subsequently subjected to the excess live load.

Method

Following the fire endurance test and hose stream test, the assembly was allowed to cool overnight. The additional live load of 1295 plf, which increased the total live load

Fig. 9—Exposed Surface After Tests
Post-Tensioned Beam with Bonded Tendon

Fig. 10—Unexposed Surface After Tests
Post-Tensioned Beam with Bonded Tendon
to 2590 plf, was then imposed on the beam.

**Results**

The maximum additional vertical deflection measurement observed as a result of the excess load in the assembly was 0.32 in., measured at Target No. 2.

**Observations After Test**

The hose stream eroded the bottom and sides of the beam as shown on Fig. 17. The depth of the erosion was such as to expose approximately 4 ft. of reinforcing steel along the lower west edge of the beam, and a short length of reinforcing steel along the lower east edge.

Longitudinal cracks, a maximum of 1/8 in. wide, were noted in the bottom of the beam at several locations as shown on Fig. 9.

The exposed and unexposed surfaces after test are shown on Figs. 9 and 10, respectively.

**TEST RECORD NO. 2**

**Post-Tensioned Unbonded Beam**

**Fire Endurance Test**

This test was conducted in accordance with Underwriters' Laboratories, Inc. Standard for Fire Tests of Building Construction and Materials, UL263, (ASTM E119, NFPA No. 251).

**Samples**

The test assembly was erected as described in “Erection of Test Assembly”.

The precast prestressed concrete beam was dried for approximately 384 days prior to subjecting it to the fire endurance test. Of this, 329
Fig. 12—Assembly During Construction, R4123-12A

Fig. 13—Exposed Surface Before Tests
Post-Tensioned Beam with Unbonded Tendon

Fig. 14—Unexposed Surface Before Tests
Post-Tensioned Beam with Unbonded Tendon
days of the drying period were at an elevated temperature of 120°F. maximum, while the remaining drying period was at room temperature.

At the time of the fire test, the relative humidity of the units as measured at various depths in a representative sample, constructed similar to and at the same time as the units used in the test, ranged from 14 to 77.5 per cent. The humidities were measured at depths varying from 2 to 9 in. by means of moisture-sensitive electrical elements inserted in short lengths of pipe buried in the concrete.

**Method**

The standard equipment of Underwriters' Laboratories, Inc. for testing floor or roof and ceiling constructions was used.

The temperatures in the furnace chamber were measured with 16 thermocouples, symmetrically located, 12 in. below the surface, as shown on Fig. 15.

The temperatures of the post-tensioning tendons were measured by means of thermocouples wire-tied to the wires during the casting of the units. The temperatures of the reinforcing bars used in the units were measured by means of thermocouples wire-tied to the bars during the casting. The locations of these thermocouples are shown on Fig. 16.

The deflection of the beam was observed through a surveyor's level sighted on three vertical targets, each graduated in 0.10-in. increments. Target No. 1 was located at the north quarter point of the beam, Target No. 2 at the midpoint, and Target No. 3 at the south quarter point.

Throughout the test observations
Fig. 16—Tendon and Reinforcing Bar Temperatures
Post-Tensioned Beam with Unbonded Tendon
were made of the character of fire, its control, the condition of the surfaces, and all developments pertinent to the performance of the assembly, with reference to the stability and to the fire-resistance performance.

The load applied to the beam was calculated to simulate a uniformly distributed load of 1633 plf. Of this load, 250 plf was contributed by the beam itself, 503 plf was contributed by the filler slabs, and 880 plf was superimposed live load. This loading was calculated by the submittor, in accordance with the ACI Standard, Building Code Requirements for Reinforced Concrete, (ACI 318-63). The live load was applied approximately 18 hr. prior to the test. A maximum downward deflection of 0.22 in. was observed at the center of the beam at Target No. 2 as a result of the initial application of the load.

**Results**

**Character and Distribution of Fire**—The furnace fire was luminous and well-distributed, and the temperatures which developed followed the Standard Time-Temperature Curve as outlined in the Standard, and as shown on Fig. 15.

**Observation of the Exposed Surface**—The beam was noted to be slightly discolored after 6 min. of exposure, but had returned to its original color by 21 min.

During the entire exposure, there was no apparent cracking, spalling, or any visible deterioration to the exposed surface of the beam.

The furnace fire was extinguished at 255 min.

**Observations of the Unexposed Surface**—At 13 min., separations of approximately 7/8 in. between the top ends of the beam and the beam supports were noted. This separation remained throughout the test.

The furnace fire was extinguished at 255 min.

**Deflection of the Beam**—Tabulated below is the deflection of the beam during the fire endurance, hose stream, and excess load tests.

<table>
<thead>
<tr>
<th>Time, Min.</th>
<th>Target No. 1</th>
<th>Target No. 2</th>
<th>Target No. 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.27</td>
<td>0.37</td>
<td>0.26</td>
</tr>
<tr>
<td>20</td>
<td>0.42</td>
<td>0.55</td>
<td>0.40</td>
</tr>
<tr>
<td>30</td>
<td>0.48</td>
<td>0.59</td>
<td>0.50</td>
</tr>
<tr>
<td>40</td>
<td>0.54</td>
<td>0.73</td>
<td>0.53</td>
</tr>
<tr>
<td>50</td>
<td>0.58</td>
<td>0.80</td>
<td>0.57</td>
</tr>
<tr>
<td>60</td>
<td>0.60</td>
<td>0.82</td>
<td>0.60</td>
</tr>
<tr>
<td>80</td>
<td>0.64</td>
<td>0.86</td>
<td>0.64</td>
</tr>
<tr>
<td>100</td>
<td>0.67</td>
<td>0.90</td>
<td>0.65</td>
</tr>
<tr>
<td>120</td>
<td>0.67</td>
<td>0.92</td>
<td>0.67</td>
</tr>
<tr>
<td>140</td>
<td>0.68</td>
<td>0.93</td>
<td>0.67</td>
</tr>
<tr>
<td>160</td>
<td>0.69</td>
<td>0.93</td>
<td>0.69</td>
</tr>
<tr>
<td>180</td>
<td>0.69</td>
<td>0.94</td>
<td>0.69</td>
</tr>
<tr>
<td>200</td>
<td>0.70</td>
<td>0.95</td>
<td>0.69</td>
</tr>
<tr>
<td>220</td>
<td>0.71</td>
<td>0.95</td>
<td>0.69</td>
</tr>
<tr>
<td>240</td>
<td>0.72</td>
<td>0.95</td>
<td>0.66</td>
</tr>
<tr>
<td>255 (Gas off)</td>
<td>0.72</td>
<td>0.96</td>
<td>0.66</td>
</tr>
<tr>
<td>265 (Hose stream)</td>
<td>0.73</td>
<td>0.96</td>
<td>0.70</td>
</tr>
<tr>
<td>23 Hr.</td>
<td>†0.05</td>
<td>†0.07</td>
<td>†0.08</td>
</tr>
<tr>
<td>24 Hr. (Excess load)</td>
<td>0.07</td>
<td>0.15</td>
<td>0.10</td>
</tr>
<tr>
<td>(No load)</td>
<td>†0.25</td>
<td>†0.34</td>
<td>†0.28</td>
</tr>
</tbody>
</table>

†—Indicates upward deflection.

**Temperatures of the Post-Tensioning Tendon and Reinforcing Steel**—Temperatures of the tendon and reinforcing steel, while not required for classification purposes, were recorded and are shown on Fig. 16.

**Hose Stream Test**

Immediately after the 255-min. fire exposure, the exposed surface of the assembly was subjected for 8 min. to the impact, cooling, and eroding action of a 45-psi water stream applied from a 1¼-in. nozzle at a distance of 13 ft., and at an angle of 70 deg. from the normal.

The appearance of the beam after being subjected to the hose stream is shown on Fig. 17.
Excess Load Test

Sample

The beam previously subjected to the fire endurance and hose stream tests was subsequently subjected to the excess live load.

Method

Following the fire endurance test and hose stream test, the assembly was allowed to cool overnight. The additional live load of 880 plf, which increased the total live load to 1760 plf, was then imposed on the beam.

Results

The maximum additional vertical deflection measurement observed as a result of the excess load in the assembly was 0.22 in., measured at Target No. 2.

Observations After Test

The hose stream eroded the bottom and sides of the beam as shown on Fig. 17. The depth of the erosion was such as to expose approximately 3 ft. of reinforcing steel along the lower east edge of the
beam, and a short length of reinforcing steel along the lower west edge.

Longitudinal cracks, a maximum of ⅛ in. wide, were noted in the bottom of the beam at several locations as shown on Fig. 17.

The exposed and unexposed surfaces after test are shown on Figs. 17 and 18, respectively.

CONCLUSIONS

Fire-Resistance Properties

It is judged that post-tensioned concrete inverted tee beams, of the configurations and designs described herein, will afford 4-hr. protection against structural failure under exposure to fire, provided:

1. The beams are restrained at their ends.
2. Bearing of the beams on their supports is 5 in. minimum.

The beams carried their rated live loads during the fire endurance and hose stream tests, and upon cooling, carried twice their rated live loads without signs of undue deflection or strain.

The above classification is based on the conditions of acceptance for tests of floors and roofs specified in the Standard of Underwriters' Laboratories, Inc. for Fire Tests of Building Construction and Materials, UL263 (ASTM E119, NFPA No. 251). The materials used in this construction are judged to be in conformance with the definitions of "noncombustible" as defined by the Standard.

Listed and Follow-Up Program

It is not contemplated that the post-tensioned beams herein described will be placed under the Listing and Follow-Up Program of Underwriters' Laboratories, Inc. at this time, because it is understood that the construction of the units will occur in the field at the job site. However, should the units be factory produced, a Listing and Follow-Up Program can be established.

Report by:
Roger S. Tansley
Project Engineer
Fire Protection Department

Reviewed by:
R. L. Parks
Associate Managing Engineer
Fire Protection Department