Underwriters' Laboratories, Inc. Report R4123-13

ROOF AND CEILING CONSTRUCTION CONSISTING OF PRESTRESSED CONCRETE DOUBLE-STEMMED UNITS AND VARIOUS INSULATION MATERIALS

Prestressed Concrete Institute

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The following report, Underwriters' Laboratories, Inc., File R4123-13, represents the results of a unique, cooperative venture in the field of building materials. There was a definite gap in the knowledge of fire resistance of insulated concrete roof slabs. Each manufacturer of insulating materials was faced with the problems of cost and of the complex technology of concrete in fire tests in order to determine a realistic fire resistance rating on his material. The prestressed concrete industry, through its Institute, took the leadership in establishing an unusual testing program that would fill the knowledge gap. It made available to the roof insulation manufacturers its existing and extensive knowledge on the fire resistance of precast, prestressed concrete elements and devised a test procedure, with the cooperation of Underwriters' Laboratories, that could determine performance of basic materials in full-scale test and other materials in related small-scale tests.

The obstacles of know-how and cost were overcome. As a result, a large number of manufacturers, who already had appropriate U. L. ratings on materials used in roof construction, joined forces with the Prestressed Concrete Institute in a most worthwhile and sorely needed program.

Label service is now provided through the Follow-Up Program of U. L. on prestressed concrete stemmed units (double-tees, single-tees) with several different types of rigid insulation, and two types of insulating concrete and one of insulating mastic for roof fill. The universality and importance to the building industry is at once apparent.

This test series is part of a continuing program of fire testing directed by the Prestressed Concrete Institute Committee on Fire Resistance Ratings.
File R4123-13
Assignment 64K337
June 8, 1966

Roof and Ceiling Construction Consisting of Prestressed Pretensioned Concrete Double-Stemmed Units and Various Insulation Materials

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REPORT
on
Roof and Ceiling Construction Consisting of
Prestressed Pretensioned Concrete Double-
Stemmed Units and
Various Insulation Materials

Prestressed Concrete Institute
Chicago, Ill.

Armstrong Cork Co.
Lancaster, Pa.

Lexsuco, Inc.
Solon, Ohio

The Philip Carey Mfg. Co.
Cincinnati, Ohio

Owens-Corning Fiberglas Corp.
Granville, Ohio

Expanded Shale, Clay and
Slate Institute
Washington, D.C.

Perlite Institute
New York, N.Y.

Grefco, Inc.
Los Angeles, Calif.

Reflecto-Barrier Sales Co., Inc.
Hartford, Conn.

Johns-Manville Corp.
New York, N.Y.

Silbrico Corp.
Chicago, Ill.

Vermiculite Institute
Chicago, Ill.
GENERAL
The subject of this Report is a fire-resistance classification of a roof assembly consisting of precast, pre-tensioned concrete units supporting various roof insulating materials covered with a built-up roof covering. The investigation included a full-scale fire test in accordance with the Standard, "Fire Tests of Building Construction and Materials", (UL-263) and a series of small-scale fire tests.

PLAN OF INVESTIGATION
The investigation was intended to develop a 2-hr roof and ceiling classification applicable to a variety of roof-insulation systems and materials. To accomplish this objective, a full-scale roof assembly was constructed and tested. The slab portion of this construction was then duplicated in 3 by 3-ft. specimens and tested on a small-scale furnace. Using the results of these duplicate small scale tests as benchmarks, the other roof-insulation systems were then tested on the small-scale furnace and the results compared. It was intended that the total investigation would provide data on a full-scale fire test demonstrating the structural performance representative of all insulation systems and a temperature-transmission end point for one insulation system by which the other systems could be compared by means of small-scale fire tests.

The investigation considered the following variations:
1. The pretensioned concrete units were to be of double or single-stemmed configuration.
2. The coarse aggregate used in the prestressed units was to be either rotary kiln expanded shale or gravel.
3. The roof insulation (with vapor barrier and adhesive, if appropriate) was to be any one of eight different systems manufactured by the submittors and was to be of various thicknesses.

The insulation systems are grouped into the following general types:

a. Insulating Concrete—A concrete consisting of lightweight aggregate and portland cement.
b. Insulation Boards—The boards are composed of mineral and/or vegetable fibers and binders, factory-formed into semirigid sheets. The systems include an adhesive for attachment to the roof structure and a vapor barrier for condensation control.
c. Insulating Mastic—An insulation consisting of perlite aggregate and an asphalt binder mixed at the job site, poured and rolled down on the roof structure.

The results of previous tests of concrete units indicated that the double-stemmed units had higher temperature-transmission properties and a greater deflection at a comparable time than the single-stemmed units under fire exposure. This is because the double-stemmed units were less massive and had thinner slab sections. Accordingly, the double-stemmed units were selected as representative of both types and used in the test assembly.

In order that the classification cover the two types of aggregate (Item 2 above), half of the units used in the full-scale fire test were made with coarse aggregates of expanded shale (rotary kiln) and half with gravel.

For the full-scale fire test, an insu-
lation board system containing an adhesive and vapor barrier was selected as being representative of all the insulation systems considered. The insulation board system was selected because it provided the least amount of structural assistance to the pretensioned units. It should be noted, however, that all the insulation systems considered provide very little structural assistance. Also, the insulation board system provided the minimum heat sink for whatever adverse effect it would have on the structural performance of the units.

The investigation included tests of the various materials, or an evaluation of past tests, to determine compliance with the definition of “non-combustible.” The fire tests were supplemented by other tests and examinations to determine the physical properties of the materials for use in factory follow-up inspections.

**DESCRIPTION**

**(Full Scale)**

The materials used in the full scale assembly are described in order of installation.

**Steel Supports**—The angles used to support the ends of the concrete units were 6 by 4 by ¾-in. steel angles on the top of which rested 3-in. wide by ½-in. thick steel bars which provide the recommended minimum bearing surface of 3 in. (See Fig. 1.)

**Precast Prestressed (Pretensioned) Concrete Units**—The units were manufactured at a plant selected by the submitter and were of the configuration shown in Fig. 1. Other properties of the units and their methods of manufacture are considered of a proprietary nature and are on file at Underwriters’ Laboratories, Inc. for future use in the Factory Inspection Program.

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**Fig. 1**—Plan, Section and Elevation of Test Slabs
The units will be listed in the Building Materials List as "Precast Concrete Units," Guide No. 40 U18.17, under Label Service.

**Roof Insulation**—The fiberboard used as the roof insulation was a nominal 24 by 48 by 1 in. and is presently listed in the Building Materials List as "Mineral and Fiber Boards," Guide No. 40 U18.12I, under Label Service.

**Vapor Barrier**—The vapor barrier used between the insulation material and the concrete slab was 4-mil polyvinyl-chloride film supplied in rolls. This vapor barrier is presently listed in the Building Materials List as "Sheathing Materials," Guide No. 40 U18.17V, under Label Service.

**Adhesive**—The adhesive used to adhere the vapor barrier to the slab, the first layer of insulation to the barrier, and second layer of insulation to the first, is presently listed in the Building Materials List as "Adhesive," Guide No. 40 U18.1¼, under Label Service.

**Roof Covering**—The roof covering consisted of Type 15 perforated asphalt-saturated rag-felt and hot-mopping asphalt, without gravel surfacing, for use in built-up roof coverings listed by Underwriters' Laboratories, Inc. in the Building Materials List, Guide No. 360 018, under Label Service.

**ERECTION OF TEST ASSEMBLY**

The precast prestressed pretensioned concrete units were provided in nominal 4 and 3-ft widths in order to completely fill the opening in the furnace frame. The four units, two manufactured with sand-gravel concrete and two with expanded shale concrete, were placed into the furnace frame and were supported at their ends on the 3-in. wide bearing plate. The clear span of the units was measured to be 16 ft. 11 in.

The individual units were butted together, the space between the ends of the units and the furnace frame varied from 1 to 2 1/2 in., and the

![Fig. 2—Test Slabs Assembled in Furnace Frame](image-url)
Fig. 3—Addition of 2-in. Rigid Insulation

Fig. 4—Test Specimen Ready for 3-Ply, Built-Up Roofing
space between the sides of the units and the furnace frame varied from \( \frac{3}{8} \) to \( 1\frac{1}{4} \) in.

Adjacent units were tied together by the use of weld plates, located as shown in Figs. 1 and 2. Steel plates, 2 by 4 by \( \frac{3}{4} \) in., were placed on each pair of adjacent, butted, weld plates and welded to the weld plates the full length of each plate (4 in.) on both sides.

The spaces between the ends and sides of the units and the furnace frame were completely filled with a high-early strength low-water content grout.

The adhesive was applied to the surface of the slabs in \( \frac{1}{8} \)-in. wide strips, approximately 6 in. on center, at a rate of approximately 0.4 gal. per 100 sq. ft. The vapor barrier, supplied in rolls 32 in. wide, was placed on the slab and pressed into the adhesive, overlapping adjacent sheets 2 in. Additional adhesive, also applied in \( \frac{1}{8} \)-in. wide strips, 6 in. on center, and at a rate of approximately 0.4 gal. per 100 sq. ft., was applied on top of the vapor barrier.

The first layer of nominal 1-in. thick fiberboard insulation was pressed into the second coat of adhesive with the joints in the east-west direction staggered, as shown in Figs. 3 and 4.

A third application of adhesive, again at the rate of 0.4 gal. per 100 sq. ft. and in \( \frac{1}{8} \)-in. wide strips, 6 in. on center, was applied to the first layer of insulation. The second layer of nominal 1-in. thick insulation was then placed on top of the first and pressed into the adhesive. The insulation in the second layer was located so that the butted joints did not coincide with those in the first layer, but were offset in both the north-south and east-west direction. The completed insulation installation is shown in Fig. 4.

The standard built-up roof covering was composed of Type 15 asphalt-saturated rag felt applied to the fiberboard insulation with dead-
level grade hot-mopped asphalt. Three layers of felt were used with the asphalt hot-mopped beneath the first layer, between each layer, and the surface finished with a flood coat. The total application of asphalt was approximately 85 lb. per 100 sq. ft.

The completed roof surface is shown in Fig. 5.

The exposed surface of the test assembly prior to test is shown in Fig. 6.

TEST RECORD NO. 1
(Full Scale)
FIRE ENDURANCE TEST

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

SAMPLE

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

The precast prestressed (pretensioned) concrete units were dried approximately 230 days prior to subjecting them to the fire endurance test. Of this, approximately 200 days of normal temperature drying occurred at facilities other than the Laboratories’ while 30 days of normal temperature drying occurred at facilities of the Laboratories.

At the time of the fire test the relative humidity of the units ranged from 69 to 76 per cent, and averaged 72 per cent. The humidities were determined by moisture-sensitive electrical elements inserted in short lengths of pipe in representative samples, cured and stored in the same manner as the test units.

METHOD

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

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

The temperatures of the unexposed surface of the assembly were measured with 16 thermocouples, each covered with a 6 by 6-in. asbestos pad, and located as shown in Fig. 8.

The temperatures of the prestressing strands were measured by means of thermocouples attached to the strands during the casting of the slab. The locations of these thermocouples are shown in Fig. 9.

The deflection of the floor was observed through a surveyor's level, placed on one end of the furnace and sighted on six vertical targets, each graduated in 0.10-in. increments, and located as shown in Fig. 8.

Throughout the test, observations were made of the character of the fire, of the conditions of the exposed and unexposed surfaces, and of all other events relative to the fire-resistant performance of the assembly.

The load applied to the test assembly was arranged to provide a uni-
formly distributed live load of 76 psf. This load was specified by the submitor and calculated in accordance with the requirements as outlined in the Building Code Requirements for Reinforced Concrete, (ACI 318-63). The load was applied approximately ½ hr. prior to the fire test. A maximum downward deflection of 0.08 in. was observed as a result of the initial application of the load.

RESULTS

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, “Fire Tests of Building Construction and Materials”, UL263, and as shown in Fig. 7.

Observations of the Exposed Surface—There were no cracks noted in the first 28 min. of exposure.

At 28 min., a 3-in. long by 10-in. high section of the west stem of the east unit fell out, approximately 2 ft. from the north furnace wall, thereby exposing the prestressing strands in this area. It was then noted that this stem contained a crack throughout its entire length, approximately 4 in. below the slab portion of the unit.

At 31 min., 3 by 10-in. sections of the west stem of the west-center unit and the east stem of the west unit fell out, again approximately 2 ft. from the north furnace wall, exposing the strands in these areas. It was also noted that these stems contained cracks throughout their entire lengths, approximately 4 in. below the slabs.

At 35 min., the exposed interior portions of the above-mentioned three stems began to spall with loud reports. The spalling continued for approximately 25 min. There were no apparent cracks in the slabs at this time.

At 100 min., a crack was noted 1 in. from the bottom of the east stem of the west-center unit at the north end. This crack was approximately 3 ft. in length. At this time, cracks a maximum of ¼ in. in width, were noted in the slabs of the west and west-center units. These cracks were few in number and were approximately 3 to 10 ft. in length.

At 110 min., a ½-in. wide vertical crack was observed in the east stem of the west-center unit. This crack extended 10 in. up into the stem and opened to ¾ in. wide at 140 min.

At 120 min., hairline tension cracks were noted in the bottom of all stems, extending approximately 1 in. into the stem.

At 134 min., the joint between the west and west-center unit was approximately 1 in. wide.

At 140 min., additional cracks in the slabs were noted, and all of the above-mentioned cracks had widened and lengthened.

The furnace fire was extinguished at 145 min.

Observation of the Unexposed Surface—At 31 min., heavy smoke was noted to be coming from the east-center portion of the deck. At 43 min., heavy smoke was emitting from under the built-up roof along all four edges of the assembly.

At 90 min., smoke was noted from the center of the deck. All the above-mentioned heavy smoke continued throughout the remainder of the test.

At 140 min., the assembly was noted to be deflecting at a rapid rate.

The furnace fire was extinguished at 145 min.

Deflection of the Assembly—The following is a tabulation of the deflection of the assembly during the fire exposure.
Temperatures of the Unexposed Surface—The initial average temperature of the unexposed surface before test was 78°F. Therefore, the average limiting temperature was 328°F, and the individual limiting temperature was 403°F. At 2 hr., the average surface temperature was 219°F, and the maximum individual temperature was 282°F, as shown in Fig. 8.

Temperature of the Prestressing Strands—Temperature of the prestressing strands, while not required for classification purposes, was recorded as shown in Fig. 9.

OBSERVATIONS AFTER TEST

The test assembly collapsed during application of a hose stream thereby making it impossible to note the condition of the exposed and unexposed surfaces after test.

TEST RECORD NO. 2
(Small Scale)

SUPPLEMENTARY SMALL-SCALE FIRE TESTS AND FLAME SPREAD TESTS

The submitters requested that the Laboratories conduct a series of small-scale fire tests on various types and thicknesses of roof insulation materials, and evaluate various types of sheathing materials and adhesives, for the purpose of listing these materials for use in the roof and ceiling assembly described previously in this Report.

The insulation materials were to be evaluated for temperature-transmission characteristics and, where appropriate, it was to be determined if these materials would classify as “noncombustible” as defined in the Standard, “Fire Tests of Building Construction and Materials,” UL263.
Fig. 9—Prestressing Strand Temperatures
Fig. 10—Small-Scale Fire Test Sample

Fig. 11—Small-Scale Horizontal Exposure Furnace
The sheathing materials and adhesives were to be evaluated to determine if these materials would also classify as "noncombustible" as defined in the Standard, UL 263.

The determinations of noncombustibility referred to above were based on ratings obtained according to the Standard, "Test Method for Fire-Hazard Classification of Building Materials," UL 723.

CONSTRUCTION OF SAMPLES FOR SMALL-SCALE FIRE TESTS

The small-scale, fire-test samples were all constructed as shown in Fig. 10. The 36 by 36 by 1½-in. concrete slabs were poured in galvanized steel forms. The aggregates used, the proportions, and the strengths of the concrete slabs were controlled as nearly as possible in order to closely duplicate the 1½-in. thick slab portion of the double-stemmed units used in the large-scale fire endurance test. The insulation materials were applied in varying thicknesses, as determined by the individual manufacturers, and in a manner and by methods judged to be representative of field construction. When applicable, sheathing material and adhesives were used in constructing the samples, and when used, were applied in the manner and rate-of-application tested in the determination of the noncombustible classification outlined above.

All samples were provided with a standard built-up roof covering of 3-ply, asphalt-saturated Type 15 rag felt and approximately 85 lb. per 100 sq. ft. of hot-mopping asphalt without gravel surfacing. This was the identical built-up roof covering used in the full scale assembly and as required in Standard UL 263 for roof assemblies.

The relative humidities of the concrete slabs were measured by moisture-sensitive electrical elements inserted in short lengths of pipe, which were installed at the time of casting. The humidities of the wet-pour type of insulation were also measured in this manner, the pipe installed during the pour.

METHOD

The small-scale furnace is shown in Figs. 11 and 12. The temperatures in the furnace chamber were measured by means of three symmetrically located thermocouples, placed 12 in. below the exposed surface.

The temperatures of the unexposed surface were measured by means of four thermocouples. Each thermocouple was covered by a 6 by 6-in. dry-asbestos pad. The thermocouples were located as shown in Fig. 10.

The temperatures on the concrete slab below the insulation material were measured by means of four thermocouples secured to the slab. These thermocouples were located as shown in Fig. 10.

During the tests of the small scale assemblies, no attempt was made to restrain the expansion of the assembly, no load was applied, and no deflection measurements were made.

Throughout the test, observations were made of the character of the fire and its control, the condition of the exposed and unexposed surfaces, and all developments pertinent to the temperature-transmission performance of the test assemblies.

RESULTS

Character and Distribution of Fire

The furnace fires for each of the tests were luminous and well-distributed, and the temperatures followed the Standard Time-Temperature Curve.

Correlation Tests—Prior to conducting the tests for submitters for listing purposes, four correlation
tests were conducted for the purpose of correlating the small-scale furnace to the full-scale furnace in regard to temperature transmission. It was determined that the correlation would be developed for an approximate 2-hr. temperature end point, and that this could be accomplished with four tests. More tests would be necessary if correlation of the furnaces at other temperature end points was desired.

Two of the test slabs were of sand-gravel concrete, while two were expanded-shale concrete, thus approximating the two types of aggregates used in the full-scale prestressed units. All four samples were constructed as closely as possible in the manner and with the same materials as used in the full scale assembly; that is, 2 in. of fiberboard insulation, adhesive, vapor barrier, and a standard built-up roof covering.

A comparison of the temperature end points between the sand-gravel concrete slabs and the expanded-shale concrete slabs did not indicate a discernible difference, however, because past test data has indicated that expanded-shale concrete is slightly more resistant to the transmission of heat, it was determined that the small-scale end point would be based on the sand-gravel slabs, and that subsequent small-scale listing tests would be conducted on sand-gravel concrete slabs. This would be consistent with the desires of the submitters to obtain listing for use with prestressed concrete units manufactured with both types of concrete.

The average temperature end point for the two sand-gravel concrete slabs was 142 min., where the temperature end point over the sand-gravel concrete units in the full scale test was 145 min., thus indicating an apparent difference between the two furnaces of 3 min. at this time. Accordingly, an apparent end point of 117 min. on the small-scale furnace would indicate a 120-min. end point on the full-scale furnace.
For work of this nature it was felt that a 10 min. margin beyond the classification period was necessary, and accordingly, for this investigation an end point of 127 min. was required.

Because of the proprietary nature, results of the small-scale fire tests are not included in this Report. However, the test data on their individual materials was provided to the submitters and is kept on file at the Laboratories.

CONCLUSIONS

The following conclusions represent the judgment of Underwriters' Laboratories, Inc., based upon the results of the examination and tests presented in this Report as they relate to established principles and previously recorded data.

FIRE-RESISTANCE PROPERTIES

It is judged that roof and ceiling assemblies, constructed of the materials and in the manner herein described, will afford 2-hr. protection against passage of flame and dangerous transmission of heat provided:
1. Bearing of the prestressed concrete units is 3 in. minimum.
2. The units are restrained at their ends.

Passage of flame through the unexposed surface of the test assembly did not occur during the 2-hr. fire-exposure period. Transmission of the heat through the assembly did not raise the temperature of the unexposed surface at any one point more than 325°F above the initial temperature and the average temperature did not exceed 250°F above the initial average temperature during the rating period. The assembly carried its rated live load during the fire-exposure test.


Since the double-stemmed prestressed concrete units were considered representative of both the double- and single-stemmed units, the designs promulgated will indicate both configurations.

Also, an additional design will be promulgated and classified as "combustible" in order to cover the assembly in which one or more of the materials used is defined as "combustible" in conformance with the Standard, "Fire Tests of Building Construction and Materials", UL263.

Based on the information developed through the small-scale fire-test investigations, it is judged that roof and ceiling assemblies, constructed of the materials, applied in the thicknesses indicated, and in the manner described in the following designs, will also afford 2-hr. protection against passage of flame and dangerous transmission of heat.

The designs promulgated will be illustrated in summary form in the Building Materials List as "Roof and Ceiling Design Nos. RC16–2 Hr, RC18–2 Hr, and RC19–2 Hr (combustible), and are illustrated herein.

PRACTICABILITY

The construction materials used in the test assemblies were readily installed by qualified workers with the tools and methods commonly used for construction work of a similar nature. However, the character of the materials and the installation procedures, as described in this Report and, in particular, the control of the end restraint and minimum bearing of the slabs on their supports, may be significant factors in the fire-resistance performance.
CONFORMITY

The full-scale fire 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.

The small scale tests were conducted as indicated in Test Record No. 2 with the furnace temperatures developed conforming to the Standard Time-Temperature Curve. The materials used in these constructions were each judged as to their conformance with the definitions of “noncombustible” as defined by the Standard. Those designs in which the constructions contained materials judged to be combustible in accordance with the Standard, UL263, were designated as “combustible.”

LISTING AND FOLLOW-UP PROGRAM

Prestressed (pretensioned) concrete units 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
ROOF AND CEILING DESIGN NO. RC16-2 HR
ROOF AND CEILING DESIGN NO. RC18-2 HR
ROOF AND CEILING DESIGN NO. RC19-2 HR†

†—This design is designated as “combustible.”

Mineral and fiber boards, adhesives and sheathing materials are now, or will be placed, under the Label Service of Underwriters’ Laboratories, Inc. and the cartons, containers or packages or rolls of the materials will be eligible to bear a label containing the appropriate above designs.

The perlite aggregate and vermiculite aggregate are now listed under Reexamination Service of Underwriters’ Laboratories, Inc.

RECOMMENDATION

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

We recommend promulgation of the following notice to subscribers and the action indicated thereby. These recommendations are based on test results. Additional submittals by other manufacturers are anticipated, and these will be evaluated on the same basis.

Listee’s name, City, State.
Roof and Ceiling Designs:
Design Nos. RC16-2 Hr, RC18-2 Hr, and RC19-2 Hr.

Address.
Label Service (or Reexamination Service)—See General Information card of above guide number.
See Guide No. 40 U18, for illustration of design numbers and fire-resistance classification.

Listing cards for the manufacturers of materials found acceptable for use in the above designs will be promulgated in the usual manner.
Part 2—Description of Numbered Items

Class D-2 Design
Design No. RC18-2 Hr

1. **Roof Covering**—Class A, B, or C built-up roof covering listed by Und. Lab., Inc., (Building Materials List, Guide No. 360 U18).

2. **Precast Concrete Units**—Double and single-stemmed units. Listed by Und. Lab., Inc., (Building Materials List, Guide No. 40 U18-17).

3. **Minimum Bearing**—3 in.


5. **Adhesive**—To be used with board insulation. Applied at rate specified in listing in ¼-in. wide ribbons, approx 6 in. o.c. beneath each layer of board. Listed by Und. Lab., Inc., (Building Materials List, Guide No. 40 U18.1%).

6. **Mineral and Fiber Boards**—Listed by Und. Lab., Inc., (Building Materials List, Guide No. 40 U18.12I). For thicknesses, see individual manufacturer's listing. To be applied in two or more layers with adhesive between each layer, and with adhesive to vapor barrier or concrete slab if vapor barrier is not used. Each layer of board to be offset in both directions from layer below a minimum of 6 in. in order to lap all joints.

Part 2—Description of Numbered Items

Class D-2 Design
Design No. RC18-2 Hr

1. **Roof Covering**—Class A, B, or C built-up roof covering listed by Und. Lab., Inc., (Building Materials List, Guide No. 360 U18).

2. **Precast Concrete Units**—Double and single-stemmed units. Listed by Und. Lab., Inc., (Building Materials List, Guide No. 40 U18-17).

3. **Minimum Bearing**—3 in.

4. **Insulating Concrete**—Various types of insulating concrete applied in the thicknesses indicated below.

   a. **Perlite Concrete**—Total thickness, minimum 2 in., maximum 6 in. 4 to 6 cu. ft. perlite concrete aggregate listed by Und. Lab., Inc., (Building Materials List, Guide No. 40 U18.16) to 94 lb. portland cement and 2 pt. of air-entraining agent.

   b. **Vermiculite Concrete**—Total thickness, minimum 2 in., maximum 6 in. 6 cu. ft. vermiculite plaster aggregate listed by Und. Lab., Inc., (Building Materials List, Guide No. 40 U18-
22) to 94 lb. portland cement and 0.125 lb. air-entraining agent.

Guide No. 40 U18
Roof and Ceiling Construction

Part 1-See Part 2 for Description of Numbered Items
Class D-2 Design
Design No. RC 19-2 (Combustible)

End Restraint

Part 2—Description of Numbered Items
Class D-2 Design
Design No. RC19-2 Hr (Combustible)


3. Minimum Bearing—3 in.

4. Insulating Material—Thicknesses, 2 in. minimum, 3½ in. maximum. Approximately equal weights of perlite concrete aggregate, listed by Und. Lab., Inc., (Building Materials List, Guide No. 40 U18-16), and asphalt meeting the following specifications:

- Softening point
  - 190-225°F (ASTM D36-26)
- Flash point (Cleveland Open Cup)
  - Minimum 437°F (ASTM D92-57)
  - Minimum 410°F (ASTM D93-61)

The resulting mixture is compacted to approx. 70 per cent of original volume and has a compacted density of 18 to 22 pcf.

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

Reviewed by:
R. L. Parks
Assoc. Managing Engineer
Fire Protection Dept.

The foregoing Recommendation has been accepted Aug. 10, 1966.

UNDERWRITERS' LABORATORIES, INC.

W. S. Austin
Vice President and Secretary

SUBMITTED:

Jack Bono
Managing Engineer
Fire Protection Dept.

RST:LP