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EVALUATION REPORT

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ONE- AND TWO-HOUR FIRE-RESISTIVE CONCRETE ROOF DIAPHRAGMS WITH AND WITHOUT INSULPERM INSULATION

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1.0 SUBJECT

One- and Two-hour Fire-resistive Concrete Roof Diaphragms with and without Insulperm insulation.

2.0 DESCRIPTION

2.1 Roof Diaphragms:

The roof diaphragm construction consists of nominal $7/8$ -, $1^{5/16}$ -, $1^{1/2}$ -, 2- or 3-inch-deep, high-strength steel decking welded to the supporting framing and covered with a Zonolite concrete slurry, leveled to a $1/8$ -inch (3.2 mm) minimum thickness over the flutes. Zonolite Insulperm board is firmly seated and leveled on the slurry surface before initial set occurs, with board slots at right angles to the deck span, end joints staggered, and all joints butted snugly. A 2-inch (51 mm) minimum thickness of Zonolite concrete is laid immediately and screeded to a level, even surface to receive built-up roofing. A maximum of four hours is permitted for each construction sequence, with all slurry and Insulperm board covered the same day. The 2-inch-thick (51 mm) slab is considered a protective slab and is not mechanically attached to the supporting or perimeter framing to resist lateral loading. The minimum 2-inch-thick (51 mm) fill of Zonolite concrete may be poured in one operation directly over the deck, without Insulperm insulation.

2.2 Materials:

2.2.1 Steel Decking: The decking is minimum No. 26 gage, cold-rolled single-fluted, nominal $7/8$ -, $1^{5/16}$ -, $1^{1/2}$ -, 2- or 3-inch-deep, 24- to 36-inch-wide (610 to 914 mm) steel decking having a 4-inch to 12-inch (102 to 305 mm) pitch. The $7/8$ - and $1^{5/16}$ -inch-deep (22 and 33 mm) decks must conform to ASTM A 446 Grade E requirements, with a minimum yield strength of 80 ksi (551 MPa) for thicknesses of 0.04 inch (1.02 mm) or less, and must conform to ASTM A 446, Grade C, requirements, with a minimum yield strength of 40 ksi (276 MPa) for thicknesses greater than 0.04 inch (1.02 mm). Minimum No. 26 gage [0.016 inch (0.41 mm)], $1^{1/2}$ -, 2- and 3-inch-deep (38, 51, and 76 mm) decks must conform to ASTM A 446 Grade A requirements with a minimum yield strength of 33 ksi (227 MPa). Decking must be galvanized to conform with ASTM A 525 requirements, with a minimum G-60 coating.

2.2.2 Welding Electrodes: Filler metal is 70-ksi-tensile-strength (482 MPa) filler metal complying with the applicable AWS standards for the welding process.

2.2.3 Fastening Accessories: Fastening accessories consist of weld washers, which are $1^{5/16}$ -inch (23.8 mm) square No. 14 gage steel washers, with berit-up edges on two opposite sides and a $3/8$ -inch-diameter (9.5 mm) hole at the center to receive a puddle weld.

2.2.4 Zonolite Concrete: Zono concrete consists of a 1:6 mix by volume of portland cement to Zonolite vermiculite concrete aggregate and sufficient water to provide a wet density of 44 to 60 pcf (705 to 961 kg/m³). The concrete must have a minimum oven-dry weight of 22 pcf (352 kg/m³), and a minimum unit compressive strength of 140 psi (965 kPa) when tested in accordance with ASTM C 495.

2.2.5 Insulperm Insulation Board: Insulperm insulation board is a polystyrene foam board manufactured by Premier Industries. Each board is 2 feet (610 mm) wide by 4 feet (1219 mm) long, with thicknesses from $3/4$ to 8 inches (19.1 to 203 mm) in $1/4$ -inch (6.4 mm) increments. Board density must be 1.1 pcf (16 kg/m³), maximum. Each board contains 30 slotted holes, $1/8$ inch (3.2 mm) wide by $2^{1/4}$ inches (57 mm) long and 1-inch (25.4 mm) diameter 30 keying holes, or 30 hole combination slot openings. Holes and slots are on a regular pattern, for mechanical bonding of Zonolite concrete to the board. See Figures 1 and 2.

2.2.6 Deck Welding: All deck welding must be accomplished under special inspection as required by Section 1701.2 of the UBC. Welding must comply with ANSI/AWS D1.3. Weld patterns at supporting framing must be one of the following:

Type 2: One weld washer fastener at each lap, and at two intermediate flutes.

Type 3: One weld washer fastener at each lap, and in all other flutes.

Weld patterns are identified by two numbers, the first referring to end support framing locations, and the second referring to interior support framing locations.

2.3 Diaphragm Shear and Flexibility:

2.3.1 Zonolite ZIC: The maximum allowable diaphragm shear and flexibility for the No. 26 and No. 24 gage steel decking are subject to the following conditions:

1. Allowable diaphragm shear values (q) are shown in Table 1.
2. The flexibility factor (F) for both weld patterns is shown in Table 1.
3. Weld washer spacing to chords, struts or other shear transfer framing members parallel to the deck flutes

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is based on a maximum shear transfer of 600 pounds (2.67 kN) per washer.

4. The shear transfer between the diaphragm and an interior tie or strut line perpendicular to deck corrugations must not exceed the shear values, q_{max} , per Table 1. Two lines of weld patterns may be used to develop the total shear transfer.
5. Where individual panels are cut longitudinally, the partial panel must be connected in a manner to fully transfer the shear at that point to adjacent full panels.
6. The diaphragm flexibility limitations are set forth in Table 2.
7. Values as set forth above are not subject to increase for duration of load.
8. For additional diaphragm assemblies with Zonolite concrete, see Evaluation Reports ER-2078 and ER-2757.
9. For steel decks not referenced, the diaphragm shears and flexibility factors must be based on bare decks, computed in accordance with accepted principles.

2.3.2 Zonolite Restrained B-Deck: The Zonolite restrained B-deck system consists of No. 18 to No. 22 gage Type B deck with a No. 16 or No. 18 gage restraining element at diaphragm perimeters. The steel deck is $1\frac{1}{2}$ inches (38 mm) deep with a 6-inch (152 mm) flute pitch and 36-inch-wide (914 mm) panels as recognized in Evaluation Reports ER-2078, ER-2757 and ER-4176. Zonolite concrete is prepared in accordance with Section 2.2.4 of this report. The deck must be welded to supports in compliance with the applicable evaluation report for the steel deck. Panels seams must be connected using top seam arc welds or button punches. The Zonolite concrete slurry is placed and followed by the Insulperm insulation board, and a top layer of Zonolite concrete in accordance with Section 2.1 of this report, with Insulperm insulation from $\frac{3}{4}$ to 4 inches (19.1 to 102 mm) thick. Diaphragm shears and flexibility factors must comply with the ICBO ES evaluation report for the steel deck. For deck assemblies where the Insulperm insulation is from 4 to 8 inches (102 to 203 mm) thick, diaphragm shears must be reduced to 85 percent and flexibility factors are doubled. See Figure 3.

2.4 Fire-resistive Roof Construction:

2.4.1 General: The fire-resistive assemblies described in this section must be constructed with Zonolite concrete recognized in this evaluation report, except the concrete must have a minimum compressive strength of 125 psi (861 kPa). Additionally, for assemblies that are required to have welded-wire mesh, the reinforcing mesh must be minimum 2-inch (51 mm) hexagonal mesh woven from No. 19 gage [0.041 inch (1.04 mm)] galvanized wire with an additional No. 16 gage [0.062 inch (1.6 mm)] galvanized wire spaced $3\frac{1}{2}$ inches (89 mm) apart. When the fire-rated assembly is a roof-ceiling assembly, the roof covering material must be a compatible, fire-retardant, built-up roofing complying with the code. Where the insulation board thickness is from 4 to 8 inches (102 mm to 203 mm), the built-up roof covering must be Class A, B, or C. All fire-rated assemblies described in this report must have a minimum weld pattern at the supporting frame consisting of $\frac{3}{8}$ -inch (9.5 mm) arc-spot (puddle) welds with weld washers spaced a maximum of 13 inches on center.

2.4.2 Zonolite ZIC Two-hour Unrestrained: The roof diaphragm construction consists of nominal $\frac{7}{8}$ -, $1\frac{5}{16}$ -, $1\frac{1}{2}$ -, 2- or 3-inch-deep, high-strength steel decking welded to the supporting framing and covered with a Zonolite concrete slurry, leveled to a $\frac{1}{8}$ -inch (3.2 mm) minimum thickness over the flutes. Zonolite Insulperm board is firmly seated and leveled on the slurry surface before initial set occurs, with board slots at right angles to the deck span, end joints staggered and all joints butted snugly. A 2-inch (51 mm) minimum thickness of Zonolite concrete must be laid immediately and

screeded to a level, even surface to receive built-up roofing. A maximum of four hours is permitted for each construction sequence, with all slurry and Insulperm board covered the same day. The 2-inch-thick (51 mm) slab is considered a protective slab and is not mechanically attached to the supporting or perimeter framing to resist lateral loading. Beams or open web steel joists must be of two-hour fire-resistive construction. The roof deck units loadings are limited to non-composite design, governed by allowable steel deck unit stresses and deflection limitations. Allowable spans are set forth in Table 3.

2.4.3 Zonolite ZIC Two-hour Restrained: The roof construction consists of Zonolite concrete recognized in this evaluation report, poured to a minimum thickness of $2\frac{1}{4}$ inches (57 mm) above the top flutes of the galvanized steel decking; which is supported by independently fire-protected steel framing. The underside of the steel deck is permitted to be unprotected. The vermiculite slab must be reinforced with mesh placed over the top of the metal deck prior to concrete placement.

2.4.4 Zonolite ZIC One-hour Unrestrained: The assembly is constructed in the same manner as the two-hour unrestrained roof construction described in Section 2.4.3, except that the slab reinforcement may be omitted, structural requirements permitting.

2.4.5 Zonolite ZIC One-hour Restrained: The assembly is constructed in the same manner as the two-hour restrained roof construction described in Section 2.4.3, except that slab reinforcement may be omitted, provided allowable loads do not exceed 75 percent of maximum allowable loads.

2.4.6 Additional Fire-resistive Constructions: Zonolite concrete is permitted to be used in prestressed fire-resistive concrete as set forth in Chapters 7 and 8 of the PCI manual "Design for Fire Resistance of Precast Prestressed Concrete," recognized in Evaluation Report ER-3264.

2.5 Special Inspection:

2.5.1 Zonolite ZIC Concrete: Special inspection is required under Sections 1701.5.1 and 1701.5.2 of the UBC. Inspector duties include observing mix verification, reinforcement type and placement, placement of foam plastic, concrete preparation and placement; conducting field tests; and obtaining samples.

2.5.2 Welding: Special inspection is required under Section 1701.5.2 of the UBC. The welder must first demonstrate ability to produce the prescribed weld to the welding inspector's satisfaction. Section 6 of the Structural Welding Code-Sheet Steel, ANSI/AWS D1. 3-81, contains qualification procedures. Other inspector duties include verifying steel and welding materials, and observing welding preparation and procedures.

2.6 Identification:

The Zonolite vermiculite aggregate is provided in bags, and the Insulperm boards are bundled into units 30 inches (76 mm) in height. Both products carry labels noting the product name, the manufacturer's name and address, and the name of the quality control agency (Underwriters Laboratories Inc.).

3.0 EVIDENCE SUBMITTED

Data in accordance with the ICBO ES Acceptance Criteria for Steel Decks (AC43), dated July 1996, and reports of fire tests conducted in accordance with UBC Standard 7-1.

4.0 FINDINGS

That the fire-resistive concrete diaphragms described in this report comply with the 1997 *Uniform Building Code*[™], subject to the following conditions:

- 4.1 The allowable diaphragm shears do not exceed those set forth in this report, with no increase for short-term loadings.

- 4.2 The allowable spans for vertical loads are based on the steel deck properties alone.
- 4.3 Special inspection is provided for concrete and welding in accordance with Section 1701.2 of the code.

- 4.4 Fire-resistive roof assemblies are assumed to be unrestrained unless evidence substantiating adequate thermal restraint is submitted to and approved by the building official.

This report is subject to re-examination in one year.

TABLE 1—ALLOWABLE DIAPHRAGM VALUES (q) AND FLEXIBILITY FACTOR (F) FOR ZONOLITE® INSULPERM® ROOF DECKS ON HIGH-STRENGTH STEEL DECK

NOMINAL GAGE	THICKNESS (Inch)	DEPTH (Inches)	WELD ¹ PATTERN	FLANGE OR WEB SLOTS ²	MAXIMUM SPAN (feet)	q (plf)	F
24	0.0239 $\leq t$	1 ⁵ / ₁₆	3-3	No	8	570	4.5
		1 ⁵ / ₁₆	2-2	No	8	410	4.5
		1 ⁵ / ₁₆	2-2	Yes	8	410	13.5
26	0.0179	1 ⁵ / ₁₆	3-3	No	8	570	9.0
		1 ⁵ / ₁₆	2-2	No	8	250	9.0
		1 ⁵ / ₁₆	2-2	Yes	8	250	13.5
16 18 20 22 24 26	0.0598 0.0478 0.0359 0.0299 0.0239 0.0179 0.0179 $\leq t$ 0.0179 $< t < 0.239$ 0.0239 $\leq t$	—	—	Yes	8	1,130	4.5
		1 ⁵ / ₁₆	3-3	Yes	8	960	4.5
		1 ⁵ / ₁₆	3-3	Yes	8	790	4.5
		1 ⁵ / ₁₆	3-3	Yes	8	730	4.5
		1 ⁵ / ₁₆	3-3	Yes	8	660	4.5
		1 ⁵ / ₁₆	3-3	Yes	8	570	4.5
		7/8	3-3	Yes	4	820	4.5
		7/8	2-2	Yes	4	250	13.5
		7/8	2-2	Yes	4	410	13.5

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 plf = 14.6 N/m.

¹Weld patterns are identified by two numbers, the first referring to end support framing locations and the second to interior support framing locations (See Section 2.2.6).

²Flange or web slots must be minimum 1 percent nominal open area.

TABLE 2—DIAPHRAGM FLEXIBILITY LIMITATION^{1,2,3}

FLEXIBILITY CATEGORY	F	MAXIMUM SPAN IN FEET FOR MASONRY OR CONCRETE WALLS	SPAN-DEPTH LIMITATION			
			Rotation Not Considered in Diaphragm		Rotation Considered in Diaphragm	
			Masonry or Concrete Walls ⁴	Flexible Walls ⁴	Masonry or Concrete Walls	Flexible Walls ⁴
Semiflexible	10-70	400	2 ¹ / ₂ :1 or as required for deflection	4:1	As required for deflection	2 ¹ / ₂ :1
Semirigid	1-10	No limitation	3:1 or as required for deflection	5:1	As required for deflection	3:1

For SI: 1 foot = 304.8 mm, 1 lbf/foot = 14.6 N/m.

¹Roof diaphragms are to be investigated regarding their flexibility and recommended span-depth limitations. Refer to above tables for determination of value of F .

²Roof diaphragms supporting masonry or concrete walls are to have their deflections limited to the following amount:

$$\Delta_{wall} = \frac{H^2 f_c}{0.01Et}$$

where:

H = Unsupported height of wall, in feet.

t = Thickness of wall, in inches.

E = Modulus of elasticity of wall material for deflection determination, in pounds per square inch.

f_c = Allowable compressive strength of wall material in flexure, in pounds per square inch. For concrete, $f_c = 0.45f'_c$. For masonry, $f_c = F_b = 0.33f'_m$.

³The total deflection, Δ , of the diaphragm may be computed from the equation:

$$\Delta = \Delta f + \Delta w$$

where:

Δf = Flexural deflection of the diaphragm determined in the same manner as the deflection of beams.

Δw = The web deflection may be determined by the equation:

$$\Delta w = \frac{q_{avg} L_1 F}{10^6}$$

where:

L_1 = Distance in feet between vertical resisting element (such as shear wall) and the point to which the deflection is to be determined.

q_{avg} = Average shear in diaphragm in pounds per foot over length L_1 .

F = Flexibility factor: The average microinches a diaphragm web will deflect in a span of 1 foot under a shear of 1 pound per foot. To determine actual diaphragm deflection in inches, multiply F by the length of the diaphragm in feet and by the lateral load in pounds per foot of diaphragm acting normal to the direction of the span considered and divide by 1,000,000.

⁴When applying these limitations to cantilevered diaphragms, the allowable span-depth ratio will be half that shown.

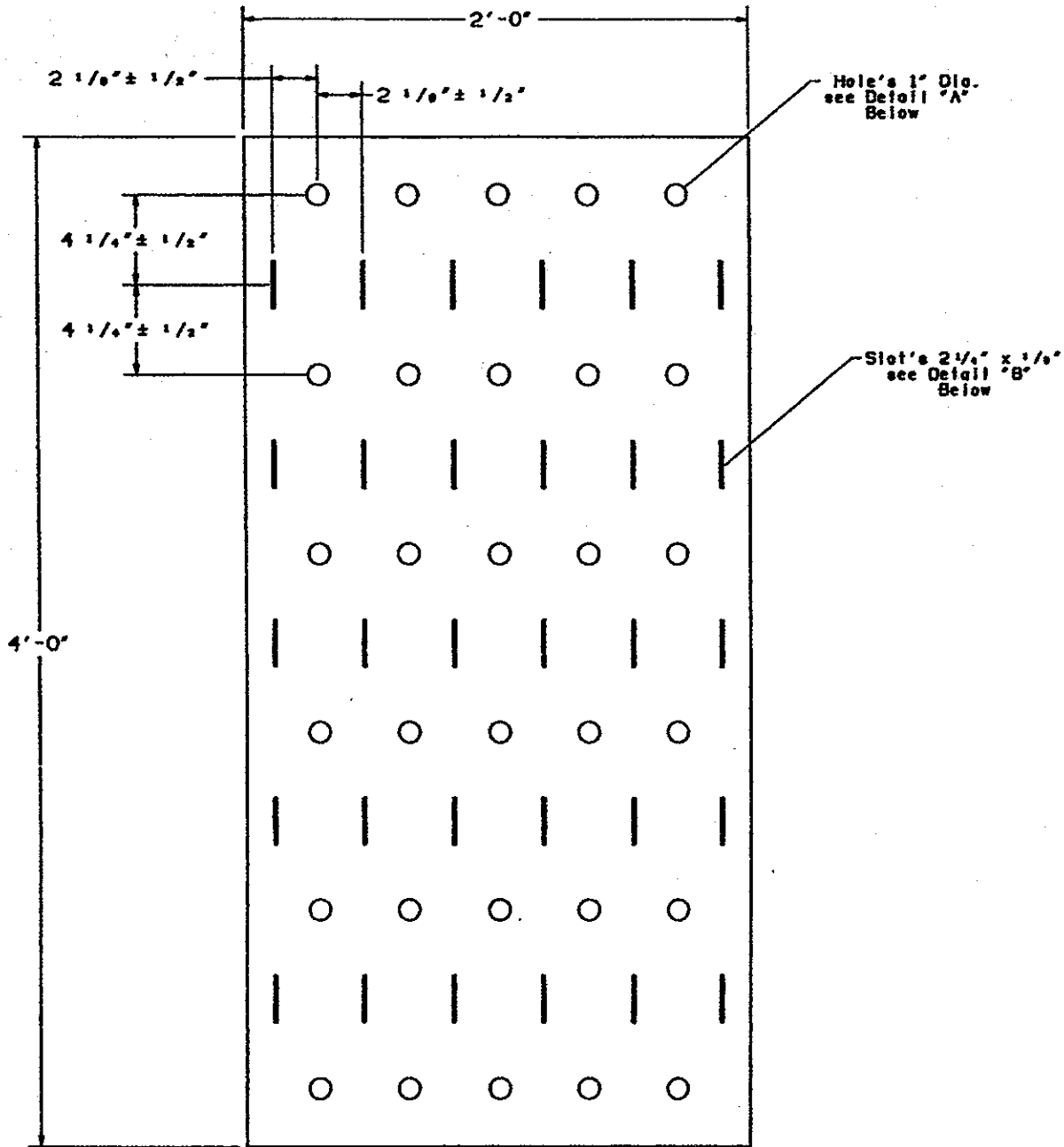
TABLE 3—MAXIMUM SPANS FOR ZONOLITE FIRE-RESISTIVE ASSEMBLIES

DECK DEPTH (Inches)	MINIMUM GAGE	MAXIMUM CLEAR SPAN (feet-inches)
7/8, 1 ⁵ / ₁₆ , 1 ¹ / ₂ , 2, 3	26	6-0
7/8, 1 ⁵ / ₁₆ , 1 ¹ / ₂ , 2, 3	24	7-8 ³ / ₈ ¹
1 ¹ / ₂ , 2, 3	22	9-8 ³ / ₈ ²

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

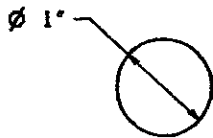
¹Span may be increased to 8 feet 0 inch if assembly is restrained.

²Span may be increased to 10 feet 0 inch if assembly is restrained and three continuous spans are in place. Loading is based on noncomposite conditions considering allowable steel stresses and deflections using steel properties only.



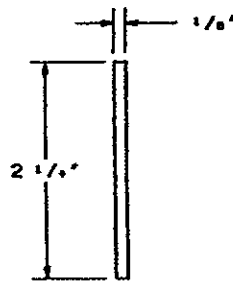
PLAN VIEW

Tolerances : Pos. Dimensions Equal to or Greater than 1 inch, Tolerance Shall Be $\pm \frac{1}{2}$ "



DETAIL VIEW "A" HOLE

Scale: Half Size

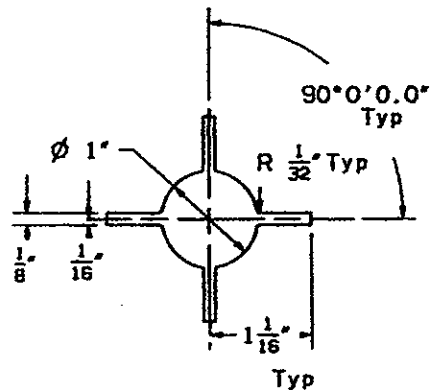
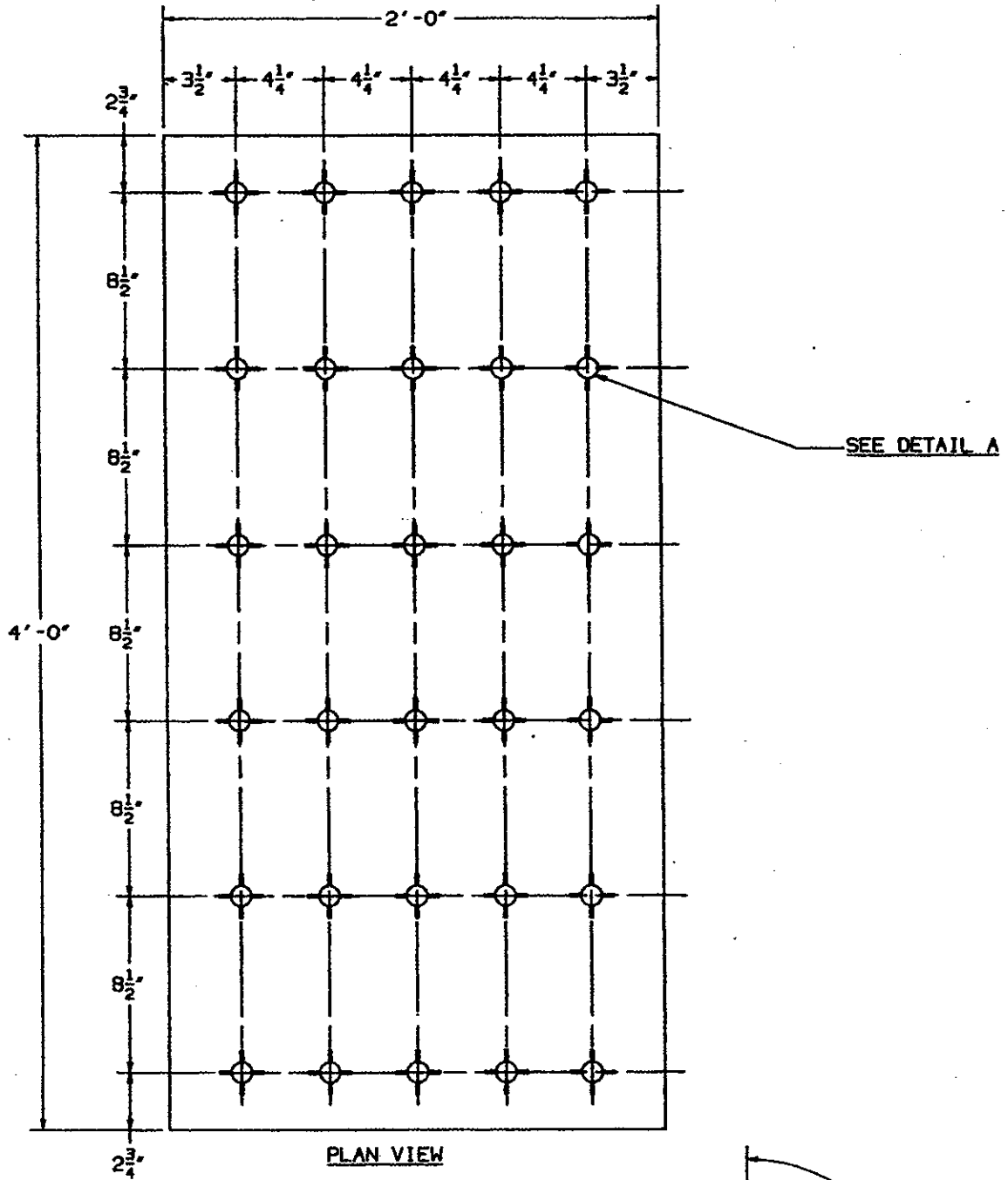


DETAIL VIEW "B" HOLE

Scale: Half Size

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

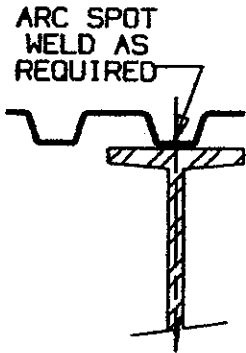
FIGURE 1—INSULPERM® BOARD PERFORATIONS



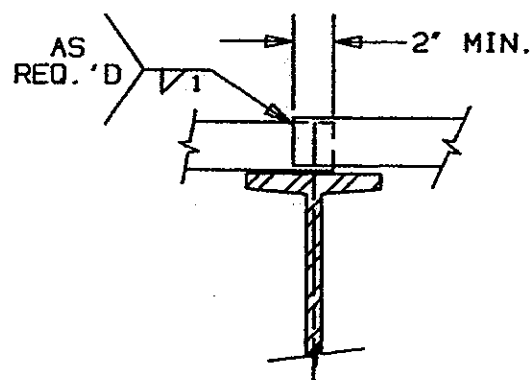
DETAIL VIEW A
Scale: Half Size

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

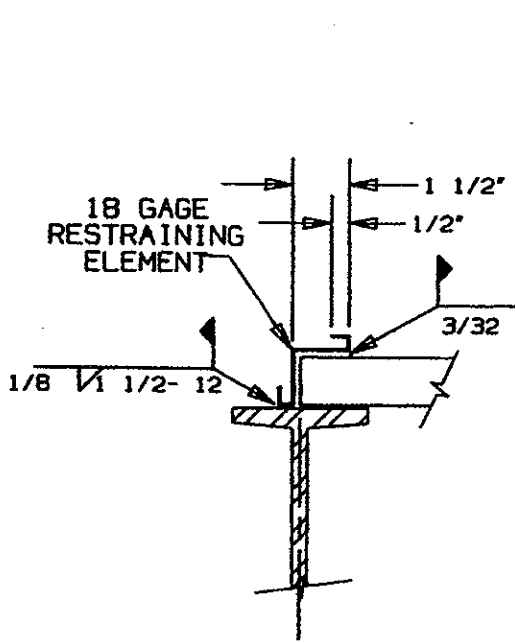
FIGURE 2—INSULPERM BOARD



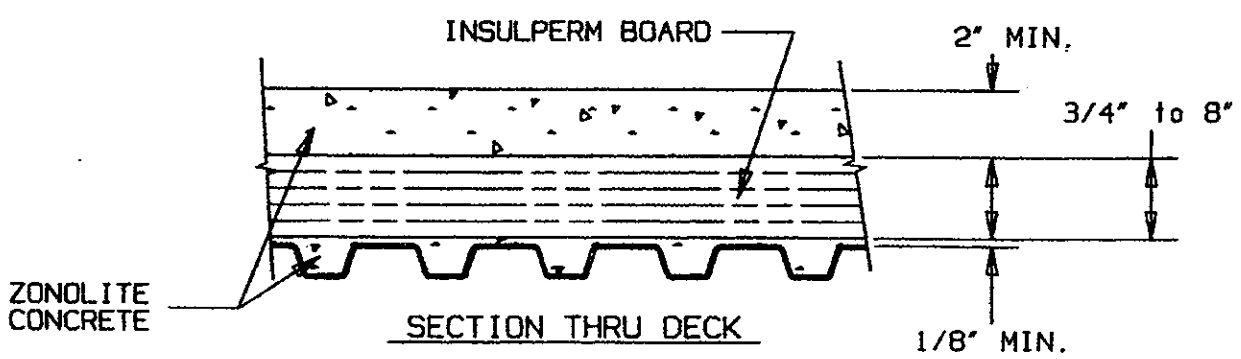
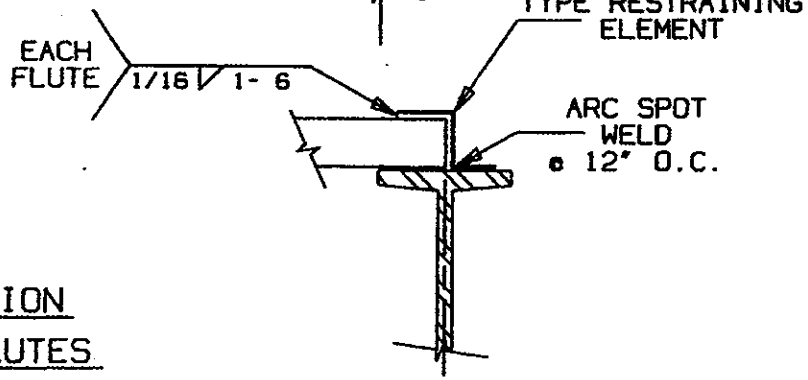
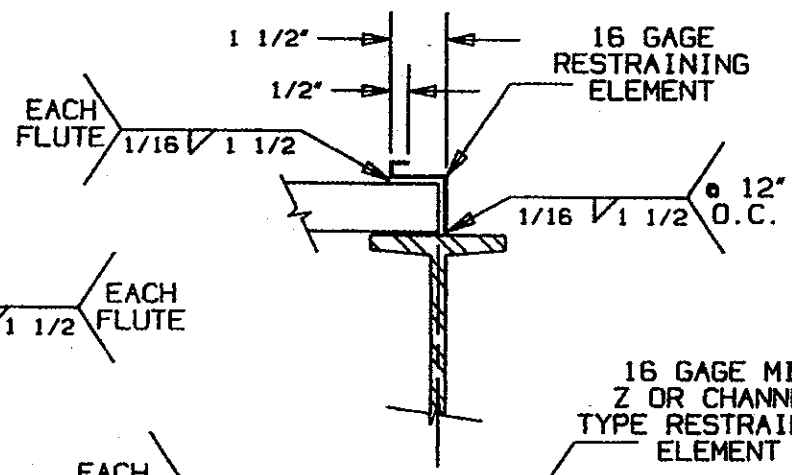
ATTACHMENT
PARALLEL TO FLUTES



END LAP



RESTRAINT CONNECTION
PERPENDICULAR TO FLUTES



For SI: 1 inch = 25.4 mm.

FIGURE 3—RESTRAINED "B" DECK AND INSULPERM® DETAILS