6.1 Introduction

One of the attributes of hollow core slab construction is excellent fire resistance. More than 30 standard fire tests (ASTM E119) have been conducted on hollow core floor assemblies. The January 1994 issue of Underwriters Laboratories, Inc. *Fire Resistance Directory* includes more than 50 design numbers for hollow core slabs which qualify for ratings of 1, 2, 3, or 4 hours. Constructions which conform to these designs are assigned ratings by most US building codes.

As an alternative to UL ratings, model codes now include prescriptive requirements which can be used to establish fire endurance ratings. For each fire endurance rating, strand cover and equivalent thickness provisions are given. Use of such provisions eliminates the need for fire tests or UL ratings.

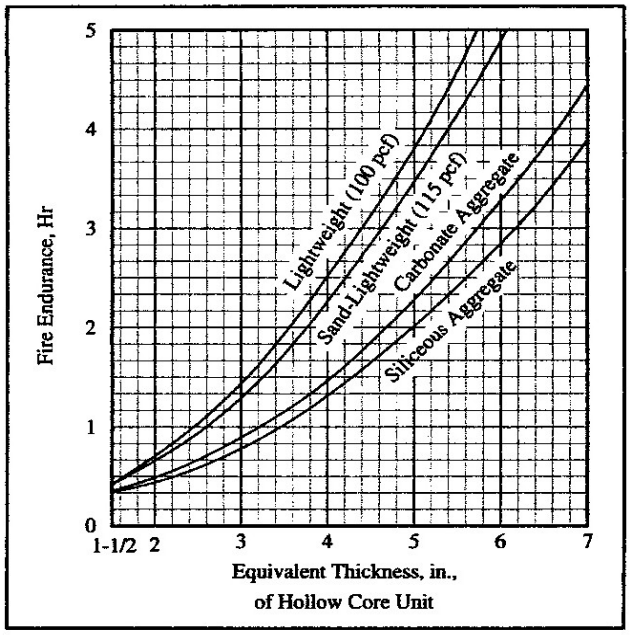
Most US building codes will also assign ratings to hollow core assemblies which do not conform with the UL designs if it can be shown by calculations made in accordance with procedures given in the PCI manual, *Design for Fire Resistance of Precast, Prestressed Concrete* (PCI MNL 124-89)[38] that they qualify for the required fire endurance. Readers can obtain more detailed information from that manual on fire resistance of hollow core slab assemblies as well as information on fire resistance of concrete beams, walls and protection of connections.

6.2 Heat Transmission Through Floors or Roofs

The standard fire test method, ASTM E119, limits the average temperature rise of the unexposed surface, i.e., the surface of floor or roof not exposed to fire, to 250° F (120° C) during a fire test. This criterion is often called the heat transmission end point.

For solid concrete slabs, the temperature rise of the unexposed surfaces depends mainly on the slab thickness and aggregate type. Figure 6.2 shows the relationship between slab thickness and fire endurance as determined by the heat transmission end point criterion.

Fig. 6.2 Fire endurance (heat transmission) of hollow core units



6.2.1 Equivalent Thickness

The information in Figure 6.2 is applicable to hollow core slabs by entering the graph with the "equivalent thickness" of the unit instead of the thickness. Equivalent thickness can be calculated by dividing the net area of the cross section of a hollow core unit by the width of the unit.

In Figure 6.2, concrete aggregates are designated as lightweight, sand-lightweight, carbonate or siliceous. Lightweight aggregates include expanded clay, shale, slate, and slag which produce concretes having unit weights between about 95 and 105 pcf (1520 – 1680 kg/m^3) without san replacement. Lightweight concretes in which sand is used as part or all of the fine aggregate and weigh less than 120 pcf (1920 kg/m^3) are designated as sand-

lightweight. For normal weight concrete, the type of coarse aggregate influences the fire endurance; the type of fine aggregate has only a minor effect. Carbonate aggregate includes limestone, dolomite and limerock, i.e., those consisting mainly of calcium or magnesium carbonate. Siliceous aggregates include quartzite, granite, basalt, and most hard rocks other than limestone or dolomite.

6.2.2 Toppings, Undercoatings, or Roof Insulation

All 8 inches (200 mm) deep hollow core units which are currently manufactured in North America qualify for at least a one-hour fire endurance as determined by heat transmission and some qualify for two hours or more. The addition of toppings, undercoatings, fire resistive ceilings, roof insulation, or filling the cores with dry aggregates will increase the heat transmission fire endurance. Figure 6.2.2.1 shows graphically the thickness of spray applied undercoating required for heat transmission fire endurances of 2, 3 and 4 hours. Figure 6.2.2.2 shows the thickness of sand-lightweight concrete, insulating concrete and high strength gypsum concrete overlays required for 2, 3 and 4 hours. Figure 6.2.2.3 shows data for 2 and 3 hour roofs with mineral board or glass fiber board insulation with 3-ply build-up roofing. Data shown in Figures 6.2.2.1, 6.2.2.2 and 6.2.2.3 apply directly to hollow core slabs made with siliceous aggregates and are conservative for slabs made with carbonate aggregates or with lightweight aggregates.

Example 6.2.1 Equivalent Thickness

Determine the thickness of topping required to provide a 3-hour fire endurance (heat transmission) for the generic hollow core slab shown in Figure 1.7.1. Both the slab and the topping are made with carbonate aggregate concrete.

Fig. 6.2.2.1 Hollow core units undercoated with spray applied materials (Heat transmission fire endurance)

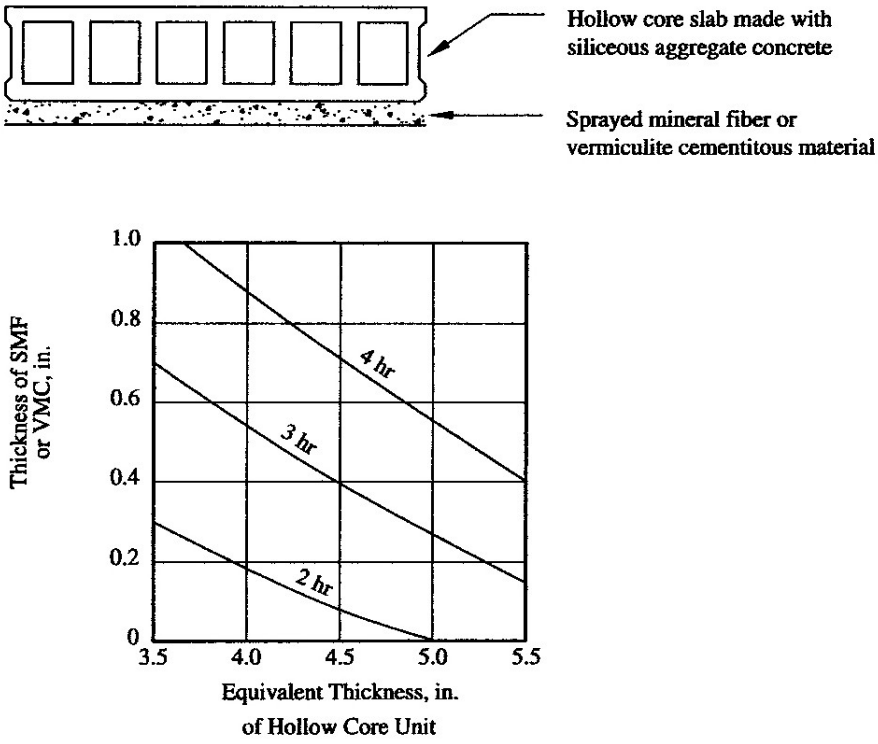


Figure 6.2.2.2
Floors with overlays of sand-lightweight concrete (120 pcf maximum), insulating concrete (35 pcf maximum), and high strength gypsum concrete

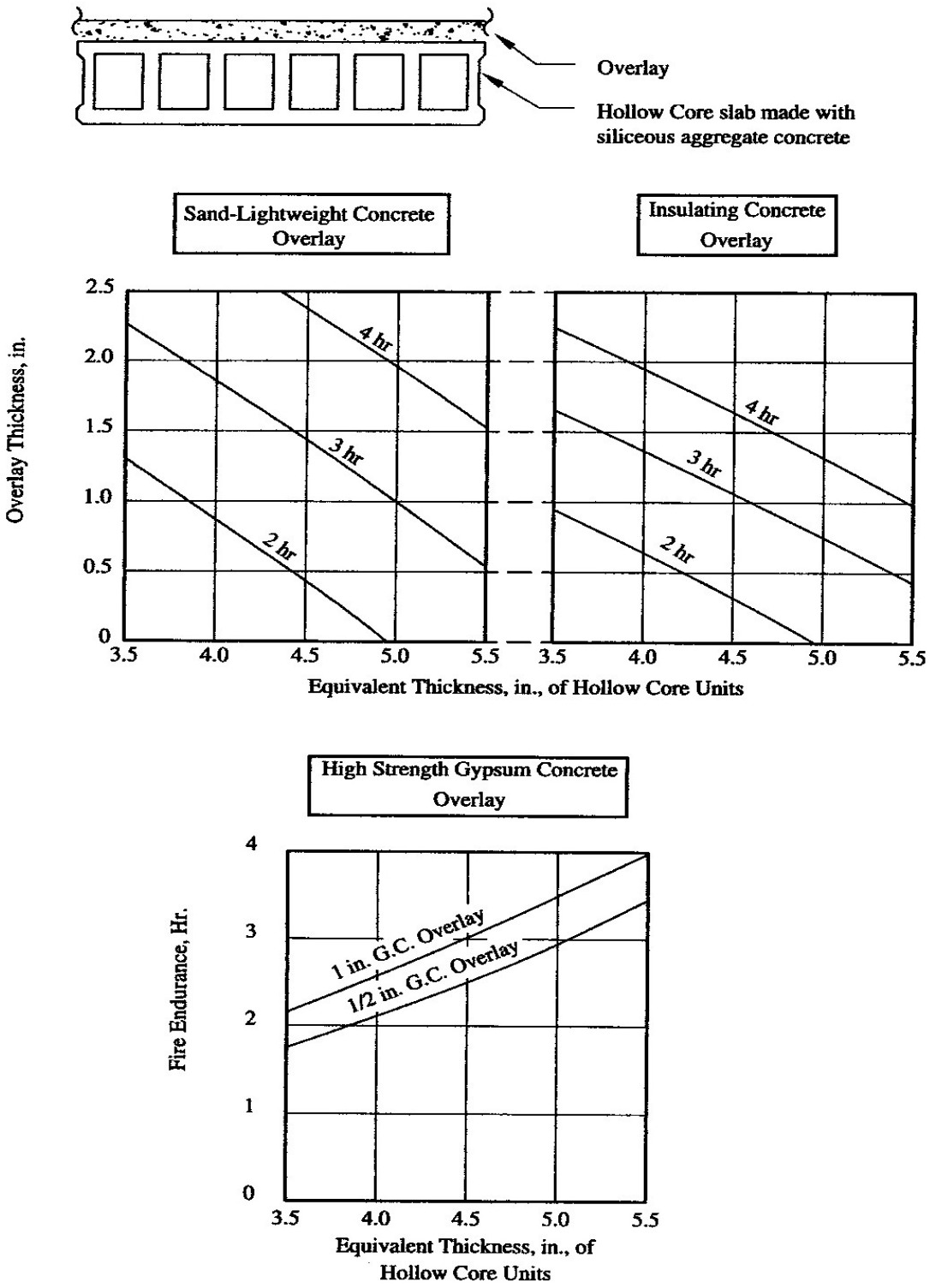


Figure 6.4.2 Examples of typical restrained and unrestrained construction classifications (from Appendix X3 of ASTM E119-88)

I. Wall Bearing:	
Single span and simply supported end spans of multiple bays[a]	
(1) Open-web steel joists or steel beams, supporting concrete slab, precast units or metal decking	unrestrained
(2) Concrete slabs, precast units or metal decking	unrestrained
Interior spans of multiple bays:	
(1) Open-web steel joists, steel beams or metal decking, supporting continuous concrete slab	restrained
(2) Open-web steel joists or steel beams, supporting precast units or metal decking	unrestrained
(3) Cast-in-place concrete slab systems	restrained
(4) Precast concrete where the potential thermal expansion is resisted by adjacent construction[b]	restrained
II. Steel Framing:	
(1) Steel beams welded, riveted, or bolted to the framing members	restrained
(2) All types of cast-in-place floor and roof systems (such as beam-and-slabs, flat slabs, pan joints, and waffle slabs) where the floor or roof system is secured to the framing members	restrained
(3) All types of prefabricated floor or roof systems where the structural members are secured to the framing members and the potential thermal expansion of the floor or roof system is resisted by the framing system or the adjoining floor or roof construction[b]	restrained
III. Concrete Framing:	
(1) Beams securely fastened to the framing members	restrained
(2) All types of cast-in-place floor or roof systems (such as beam-and-slabs, flat slabs, pan joists, and waffle slabs) where the floor system is cast with framing members	restrained
(3) Interior and exterior spans of precast systems with cast-in-place joints resulting in restraint equivalent to that which would exist in condition III(1)	restrained
(4) All types of prefabricated floor or roof systems where the structural members are secured to such systems and the potential thermal expansion of the floor or roof system is resisted by the framing system or the adjoining floor or roof construction[b]	restrained
IV. Wood Construction	
All Types	unrestrained

[a]Floor and roof systems can be considered restrained when they are tied into walls with or without tie beams, the walls being designed and detailed to resist thermal thrust from the floor or roof system.

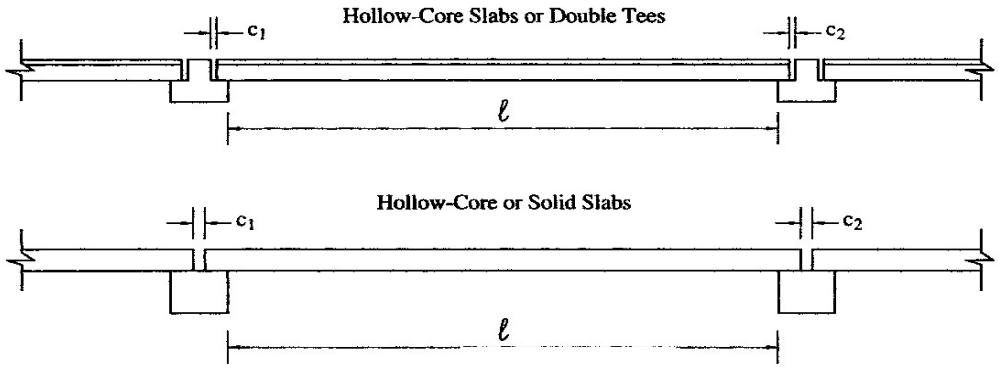
[b]For example, resistance to potential thermal expansion is considered to be achieved when:

(1) Continuous structural concrete topping is used.

(2) The space between the ends of precast units or between the ends of units and the vertical face of supports is filled with concrete or mortar.

(3) The space between the ends of precast units and the vertical faces of supports, or between the ends of solid or hollow core slab units does not exceed 0.25 percent of the length for normal weight concrete members or 0.1 percent of the length for structural lightweight concrete members.

Fig. 6.4.3. Typical examples of restrained floors or roofs of precast construction



To be considered as restrained:

$c_1 + c_2 < 0.0025\,\ell$ for normal weight concrete

$c_1 + c_2 < 0.0010\,\ell$ for lightweight concrete

Example: Determine maximum value of $c_1 + c_2$ for normal weight hollow core slabs with a clear span of 30 ft

Solution: $c_1 + c_2 = 0.0025(30 \times 12) = 0.90$ in