9.3.6.6 Treatment of Joints Between Wall Panels

Joints between wall panels should be detailed so that passage of flame or hot gases is prevented, and transmission of heat does not exceed the limits specified in ASTM E 119. Concrete wall panels expand when heated, so the joints tend to close during fire exposure. Non-combustible materials that are flexible, such as ceramic fiber blankets, provide thermal, flame, and smoke barriers, and, when used in conjunction with caulking materials can provide the necessary weather-tightness while permitting normal volume change movements. Joints that do not move can be filled with mortar. For a more detailed discussion and additional information, refer to PCI MNL-124. [1]

The IBC addresses joints in exterior walls in various sections of the code:

- In Section 713, joints are specified to have the same fire-resistance rating as the wall. Walls that are permitted to have unprotected openings are noted as an exception to this requirement.
- Table 704.8 is used to determine if unprotected openings are allowed as well as designating the percentage of unprotected openings allowed.
- Section 704.13 also addresses joints and has the same exception as Section 713.
- Section 721.2.1.3 addresses joints in precast walls. This section requires that unprotected joints be included as openings in the calculation of opening percentages for comparison to the allowed opening percentage of Table 704.8.
Where no openings are permitted, the fire resistance required for the wall should be provided at the joints.

Table 9.3.6.7 is based on results of fire tests of panels with butt joints. [8] The tabulated values apply to one-stage butt joints and are conservative for two-stage and ship-lap joints. [1]

Joints between adjacent precast floor or roof elements may be ignored in calculating the slab thickness provided that a concrete topping at least 1½ in. thick is used. Where no concrete topping is used, joints should be grouted to a depth of at least one-third the slab thickness at the joint, or the joints made fire-resistive in a manner acceptable to the authority having jurisdiction. No joint treatment is required in pre-topped double tee parking structures.

9.3.7 Fire Endurance by Rational Design

It was noted above that many fire tests and related research studies have been directed toward an understanding of the structural behavior of prestressed concrete subjected to fire. The information gained from that work has led to the development of calculation procedures that can be used in lieu of fire tests. The purpose of this section is to introduce these calculation procedures.

Because the method of support is the most important factor affecting structural behavior of flexural elements during a fire, the discussion that follows deals with three conditions of support: simply supported members, continuous slabs and beams, and members which are restrained from thermal expansion. For additional examples and more detailed information, refer to PCI MNL-124. [1]

The fire endurance of concrete walls, as determined by fire tests, is normally governed by the ASTM criteria for temperature rise of the unexposed surface rather than by structural behavior during fire tests. This is probably due to the low level of stresses, even in concrete bearing walls, and the fact that reinforcement generally does not perform a primary structural function. In most cases, the amount of cover protection required by code exceeds that required for fire protection so there is, in effect, reserve structural fire endurance within the concrete wall.

9.3.7.1 Simply Supported Members

To understand the effects of fire, let us assume that a simply supported prestressed concrete slab is exposed to fire from below, that the ends of the slab are free to rotate, and that expansion can occur without restriction. Also, assume that the

![Figure 9.3.7.1 Moment diagrams for simply supported beam or slab.](image)

**Table 9.3.6.7** Protection of joints between wall panels utilizing ceramic fiber felt

<table>
<thead>
<tr>
<th>Panel equivalent thicknessa (in.)</th>
<th>Thickness of ceramic fiber felt (in.) required for fire resistance ratings and joint widthsb shown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint width = 3⁄8 in.</td>
<td></td>
</tr>
<tr>
<td>1 hr</td>
<td>¼</td>
</tr>
<tr>
<td>2 hr</td>
<td>¼</td>
</tr>
<tr>
<td>3 hr</td>
<td>¼</td>
</tr>
<tr>
<td>4 hr</td>
<td>¼</td>
</tr>
<tr>
<td>Joint width = 1 in.</td>
<td></td>
</tr>
<tr>
<td>1 hr</td>
<td>0</td>
</tr>
<tr>
<td>2 hr</td>
<td>0</td>
</tr>
<tr>
<td>3 hr</td>
<td>0</td>
</tr>
<tr>
<td>4 hr</td>
<td>0</td>
</tr>
</tbody>
</table>

N.A. = Not applicable.

a. Interpolation may be used for joint width between 3⁄8 in. and 1 in. The tabulated values apply to one-stage butt joints and are conservative for two-stage and ship-lap joints.

b. Panel equivalent thicknesses are for carbonate concrete. For siliceous aggregate concrete change "4, 5, 6, and 7" to "4.3, 5.3, 6.5, and 7.5." For sand-lightweight concrete change "4, 5, 6, and 7" to "3.3, 4.1, 4.9, and 5.7."
fines an equivalent opening factor, \( F_{eo} \), to be:

\[
F_{eo} = \frac{(T_u + 460)^4}{(T_e + 460)^4} \quad \ldots 8.3
\]

where

- \( T_u \) = average temperature in deg. F of the unexposed wall surface at the time required fire-resistive rating is reached under test conditions
- \( T_e \) = 1638°F for a 3/4-hr fire-resistance rating
  1700°F for a 1-hr fire-resistance rating
  1850°F for a 2-hr fire resistance rating

The equivalent opening factor is then applied in a formula to determine the corrected area of openings:

\[
A_c = A + A_f F_{eo} \quad \ldots 8.4
\]

where

- \( A_c \) = corrected area of unprotected openings including actual and equivalent openings
- \( A \) = actual area of unprotected openings
- \( A_f \) = area of exterior surface of the exposing building face exclusive of openings, on which the temperature limitation of the standard fire test is exceeded.

Fig. 8.3 shows the relationship between \( F_{eo} \) (as defined in the National Building Code of Canada) and panel thickness for three types of concrete. To illustrate the use of Fig. 8.3, suppose that for a particular building face, a 2-hr fire resistance rating is required and the area of unprotected openings permitted is 57%. Suppose also that the actual area of unprotected openings is 49% and that the window wall panels are made of carbonate aggregate concrete (referred to as Type N in NBCC). Determine the minimum thickness of the panel. In this case \( A_e = 57\% \), \( A = 49\% \), \( A_f = 100 - 49 = 51\% \), so

\[
F_{eo} = \frac{A_e - A}{A_f} = \frac{57 - 49}{51} = 0.16
\]

From Fig. 8.3, for \( F_{eo} = 0.16 \) at 2 hr, the minimum panel thickness is 2.1 in. Thus if the panel is 2.1 in. thick or thicker, the code requirements will be satisfied.

### 8.6 TREATMENT OF JOINTS

Joints between wall panels should be detailed so that passage of flame or hot gases is prevented, and transmission of heat does not exceed the limits specified in ASTM E1119. Concrete wall panels expand when heated, so the joints tend to close during fire exposure. Noncombustible materials that are flexible, such as ceramic fiber blankets or asbestos rope, provide thermal, flame, and smoke barriers, and when used in conjunction with caulking materials they can provide the necessary weathertightness while permitting normal volume change movements. Joints that do not provide movement can be filled with mortar.

Joints between wall panels are similar to openings. Most building codes do not require openings to be protected against fire if the openings constitute only a small percentage of the wall area and if the spatial separation is greater than some minimum distance. In those cases, protection of joints would not be required.

In other cases, openings must be protected, but most codes permit a lesser degree of protection. For example, the Uniform Building Code requires that when openings are permitted and must be protected, the "openings shall be protected by a fire assembly having a three-fourths-hour fire-protection rating." Where no openings are permitted, the fire resistance required for the wall should be provided at the joints.

Fire tests of wall panel joints\(^{(77)}\) showed that the fire endurance, as determined by a temperature rise of 325°F over the joint, is influenced by joint type, joint treatment (materials), joint width, and panel thickness. By providing the proper thickness of insulating materials within the joint, it is possible to attain fire endurance essentially as long as those of the panels. Results of the fire tests, shown in Figs. 8.4-8.7, can be used to determine the thicknesses of materials needed to provide the necessary fire endurance.

Fig. 8.4 shows the fire endurance of one-stage butt-joints and two-stage shiplap joints in which the treatment consisted of sealants and polyethylene backup strips.

Fig. 8.5 summaries fire test data on one-stage butt-joints in the form of a design aid that can be used to estimate the thickness of ceramic fiber blanket required for a particular joint width and fire endurance.

Fig. 8.6 shows data for two-stage cavity joints incorporating ceramic fiber blankets, and Fig. 8.7 shows similar data for two-stage shiplap joints.
Fig. 8.4  Fire endurance of one-stage butt joints and two-stage shiplap joints where the joint treatment consisted of sealant and backup rods.

Fig. 8.5  Design aid for use in estimating thickness of ceramic fiber blanket required in one-stage butt joints for various fire endurances.
Fig. 8.6  Fire endurance of two-stage cavity joints treated with 1-1/4-in. thickness of ceramic fiber blankets, backup rods, and sealants.

Fig. 8.7  Fire endurance of two-stage shiplap joints treated with 1-1/2-in thickness of ceramic fiber blankets, backup rods, and sealants.
8.7 DETAILING PRECAUTIONS

One of the purposes of code provisions for fire resistive construction is to limit the involvement of a fire to the room or compartment where the fire originates. Thus the floors, walls, and roof surrounding the compartment must serve as fire barriers.

Most codes require that fire walls start at the foundation and extend continuously through all stories to and above the roof, except where the roof is of fire resistive construction, in which case the wall must be tightly fitted against the underside of the roof. If the roof and walls are of combustible construction, fire walls must extend not only through the roof, but must extend through the sides of the building beyond the eaves or other combustible projections.

When protected openings are required in walls, coverings for such openings must be fire resistive. Most codes require that fire doors have fire resistive classifications of three-fourths of the classification required of the wall. Glazed openings in fire doors or fire windows are limited in area by code provisions, and the glass must be reinforced with wire mesh. Fire dampers must be used in ducts unless fire tests show that they are not needed.

8.7.1 Fire Stopping Between Floors and Wall Panels

When precast concrete wall panels are designed and installed in such a manner that no space exists between the wall panel and floor, a fire below the floor cannot pass through the joint between the floor and wall. However, some curtain wall panels are designed in such a manner that a space exists between the floor and wall. This space is referred to as a "safe-off" area. Fig. 8.8 shows two methods of fire stopping such safe-off areas. Safing insulation is available in the form of mineral fiber mats of varying dimensions and densities. Care must be taken during installation to be sure that the entire safe-off area is sealed. The safing insulation provides an adequate firestop and accommodates differential movement between the wall panel and floor.

![Diagram of safing insulation and curtain wall panel](image)

Fig. 8.8 Two methods of installing safing insulation between floor slab and wall panels. The sketch shows safing supported on a metal plate, while the safing in the photo is supported by impaling pins (not shown). (Photo courtesy: U.S. Gypsum Co.)