(2) Flexure. Diaphragm flexure is resisted by members called chords. The chords are often at the edges of the diaphragm, but may be located elsewhere. The design force is obtained by dividing the diaphragm moment by the distance between the chords. The chords must be designed to resist direct tensile or compressive stresses, both in the members and in the splices at points of discontinuity. Usually, chords are easily developed. In a concrete frame, continuous reinforcing in the edge beam can be used. In a steel frame building, the spandrel beams can be used as chords if they have adequate capacity and adequate end connections where they would otherwise be interrupted by the columns; or special reinforcing can be placed in the slab. Chords need not actually be in the plane of the diaphragm as long as the chord forces can be developed between the diaphragm and the chord. For example, continuous chord reinforcing can be placed in walls or spandrels above or below the diaphragm. In masonry walls, the chord requirements tend to conflict with the control joint requirements. At bond beams, control joints will have to be dummy joints so that reinforcement can be continuous, and the marginal connections must be capable of resisting the flexural and shear stresses developed.

(3) Openings. A diaphragm with openings such as cut-out areas for stairs or elevators will be treated as a plate girder with holes in the web. The diaphragm will be reinforced so that forces developing on the sides of the opening can be developed back into the body of the diaphragm.

(4) L-and T-shaped buildings. L- and T-shaped buildings will have the flange (chord) stresses developed through or into the heel of the L or T. This is analogous to a girder with a deep haunch. Figure 7-51 illustrates the calculation of the chord forces at a re-entrant diaphragm corner. These chord forces need to be developed by an appropriate connection to the floor or roof framing, or by the addition of a drag strut, to develop resistance to the chord forces within the adjacent diaphragm.

d. Concrete Diaphragms.

(1) General design criteria. The criteria used to design concrete diaphragms will be ACI 318, as modified by FEMA 302. Concrete diaphragm webs will be designed as concrete slabs; the slab may be designed to support vertical loads between the framing members, or the slab itself may be supported by other vertical-load-carrying elements, such as precast concrete elements or steel decks. If shear is transferred from the diaphragm web to the framing members through steel deck fastenings, the design will conform to the requirements in Paragraph 7-7e(1)(a).

(2) Span and anchorage requirements. The following provisions are intended to prevent diaphragm buckling.

(a) General. Where reinforced concrete slabs are used as diaphragms to transfer lateral forces, the clear distance (L_V) between framing members or mechanical anchors shall not exceed 38 times the total thickness of the slab (t).

Drag struts are required at re-entrant building corners to develop tensile chord forces F_1 and F_2 into adjacent diaphragms.

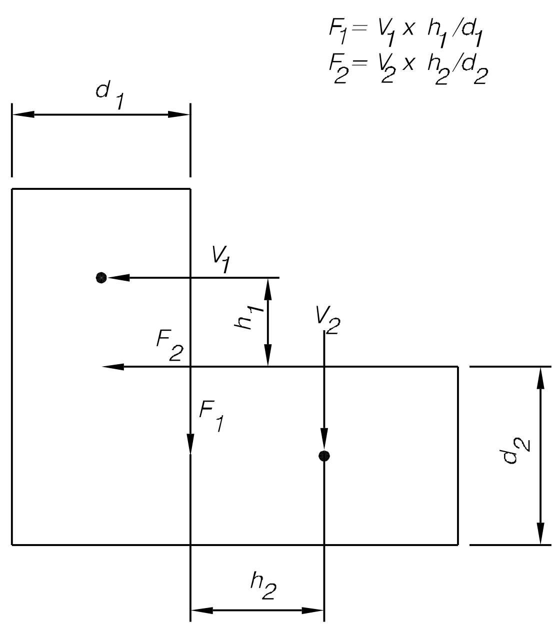


Figure 7-51 Drag struts at re-entrant building corners.

(b) Cast-in-place concrete slabs not monolithic with supporting framing. When concrete slabs used as diaphragms are not monolithic with the supporting framing members (e.g., slabs on steel beams), the slab will be anchored by mechanical means at intervals not exceeding 4 feet (1.2m) on center along the length of the supporting member. This anchorage is not a computed item, and should be similar to that shown in Figure 7-52, Detail A. For composite beams, anchorages provided in accordance with AISC provisions for composite construction will meet the requirements of this paragraph.

(c) Cast-in-place concrete diaphragms vertically supported by precast concrete slab units. If the slab is not supporting vertical loads but is supported by other vertical-load-carrying elements, mechanical anchorages will be provided at intervals not exceeding 38*t*; thus, the provisions above will be satisfied by defining L_V as the distance between the mechanical anchorages between the diaphragm slab and the vertical-load-carrying members. This mechanical anchorage can be provided by steel inserts or reinforcement, by bonded cast-in-place concrete lugs, or by bonded roughened surface, as shown in Figure 7-53. Positive anchorage between cast-in-place concrete and the precast deck must be provided to transmit the lateral forces generated from the weights of the precast units to the cast-in-place concrete diaphragm, and then to the main lateral-force-resisting system.

(d) Precast concrete slab units. If precast units are continuously bonded together as shown in Figure 7-54, they may be considered concrete diaphragms and designed accordingly, as previously described herein. Intermittently bonded precast units or precast units with grouted shear keys will not be used as a diaphragm. In areas with $S_{DS} \leq 0.25$g (Figure 7-55), there is an exception permitting the use of hollow-core planks with grouted shear keys and the use of connectors, in lieu of continuous bonding, for precast concrete members. The exception is permitted if the following considerations and requirements are satisfied:

1. Procedure conforms with PCI-MNL-120 seismic design requirements.

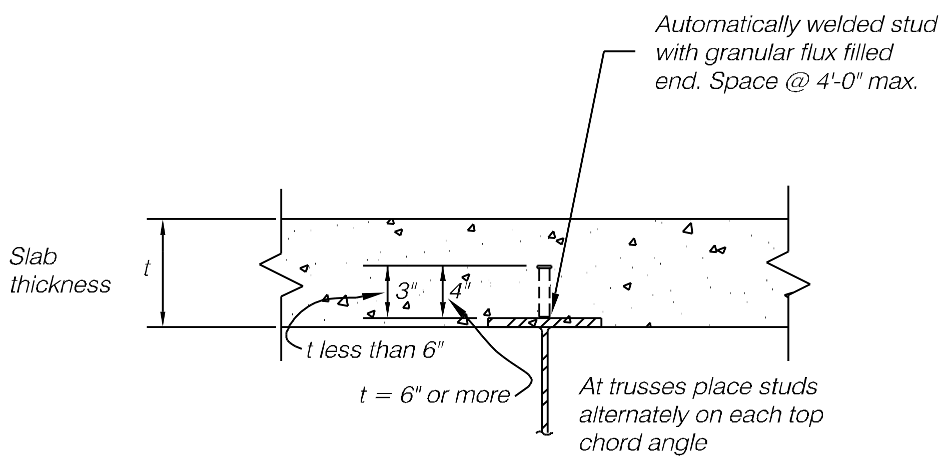
2. Shear forces for diaphragm action can be effectively transmitted through connectors. The shear is uniformly distributed throughout the depth or length of the diaphragm with reasonably spaced connectors, rather than with a few that will have localized concentration of shear stresses.

3. Connectors are designed for 0.6*R* times the prescribed shear force.

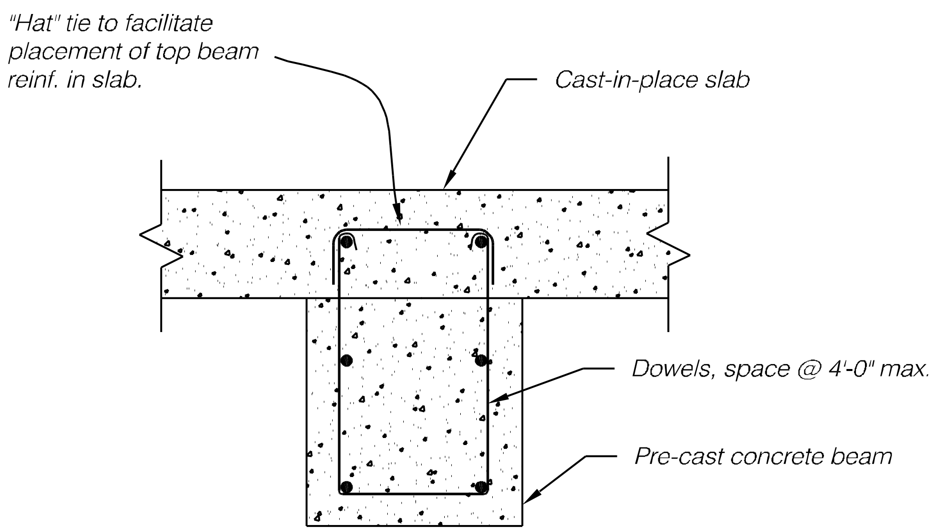
4. Detailed structural calculations are made including the localized effects in concrete slabs attributed from these connectors.

5. Sufficient details of connectors and embedded anchorage are provided to preclude construction deficiency.

(e) Metal-formed deck, Where metal deck is used as a form, the slab shall be governed by the requirements of Paragraph (b) above. Refer to Paragraph 7-7e, where the deck is used structurally.



DETAIL A

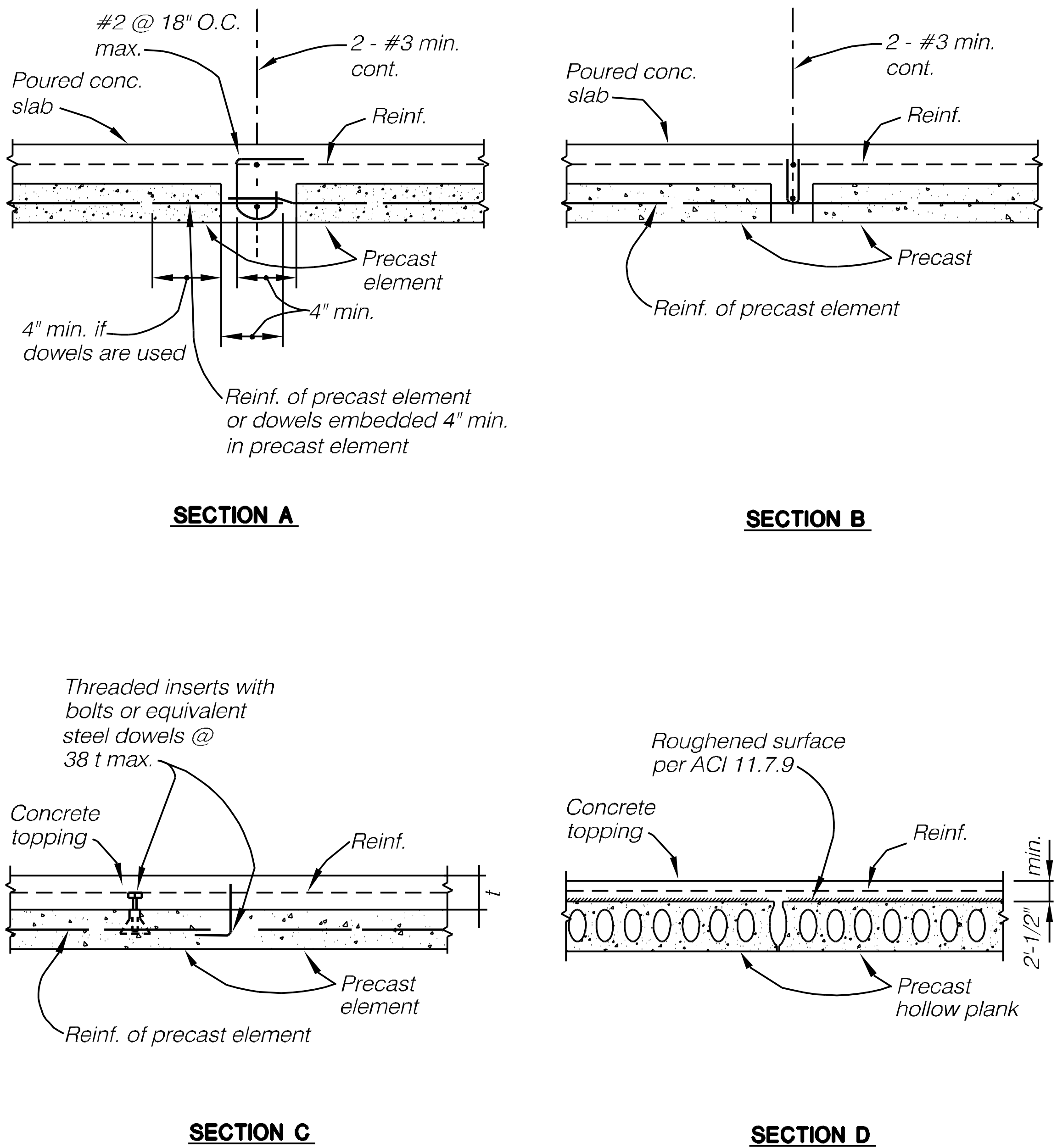


1 inch = 25mm
1 foot = 0.3m

DETAIL B

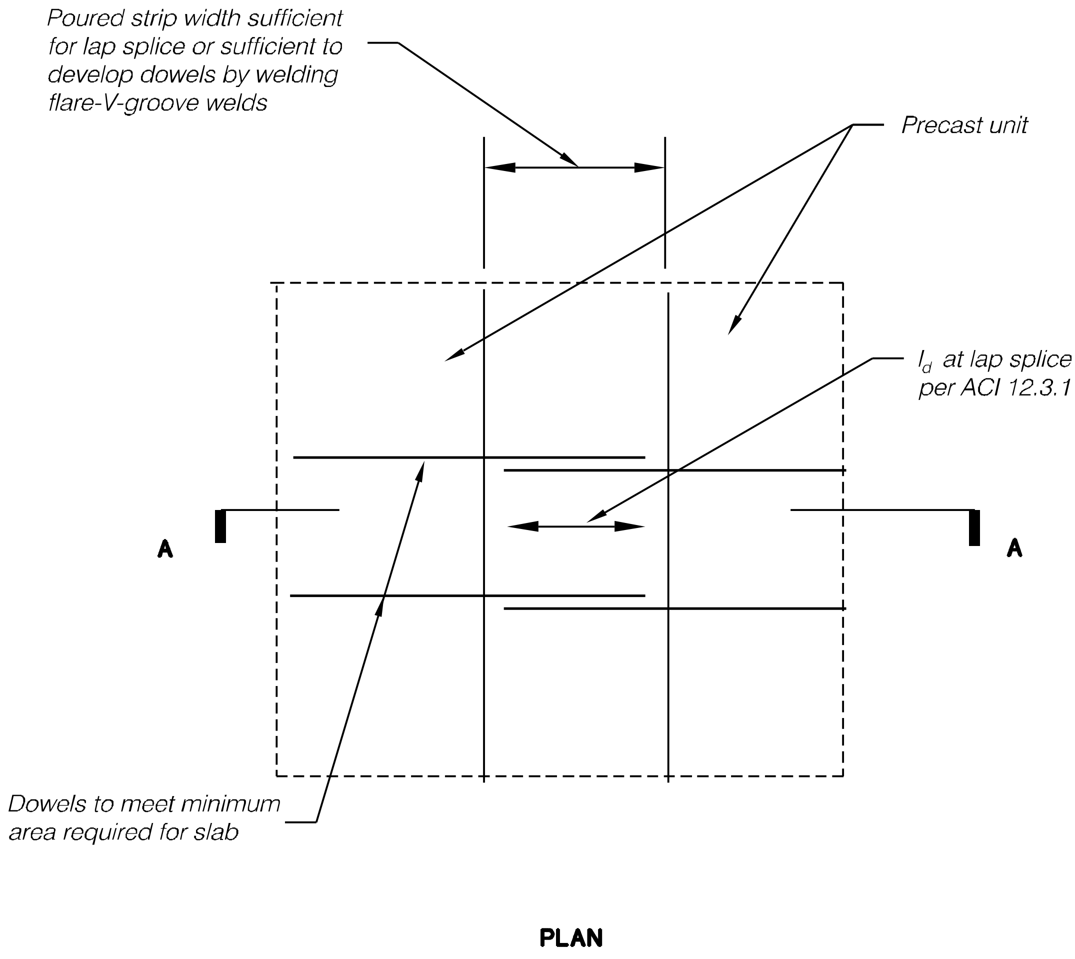
Slabs Not Monolithic with Supporting Framing

Figure7-52 Anchorage of cast-in-place concrete slab



1 inch = 25mm
#2 bar ≈ 5M bar
#3 bar ≈ 10M

Figure 7-53 Attachment of superimposed diaphragm slab to precast slab units.



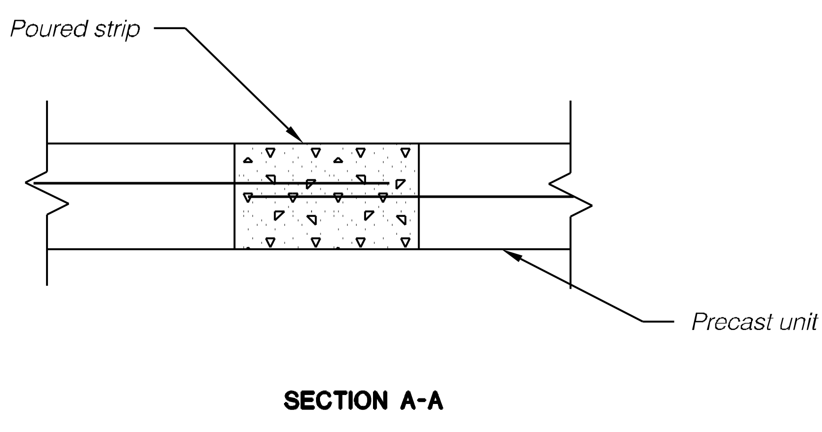


Figure7-54 Precast concrete diaphragms using precast units.

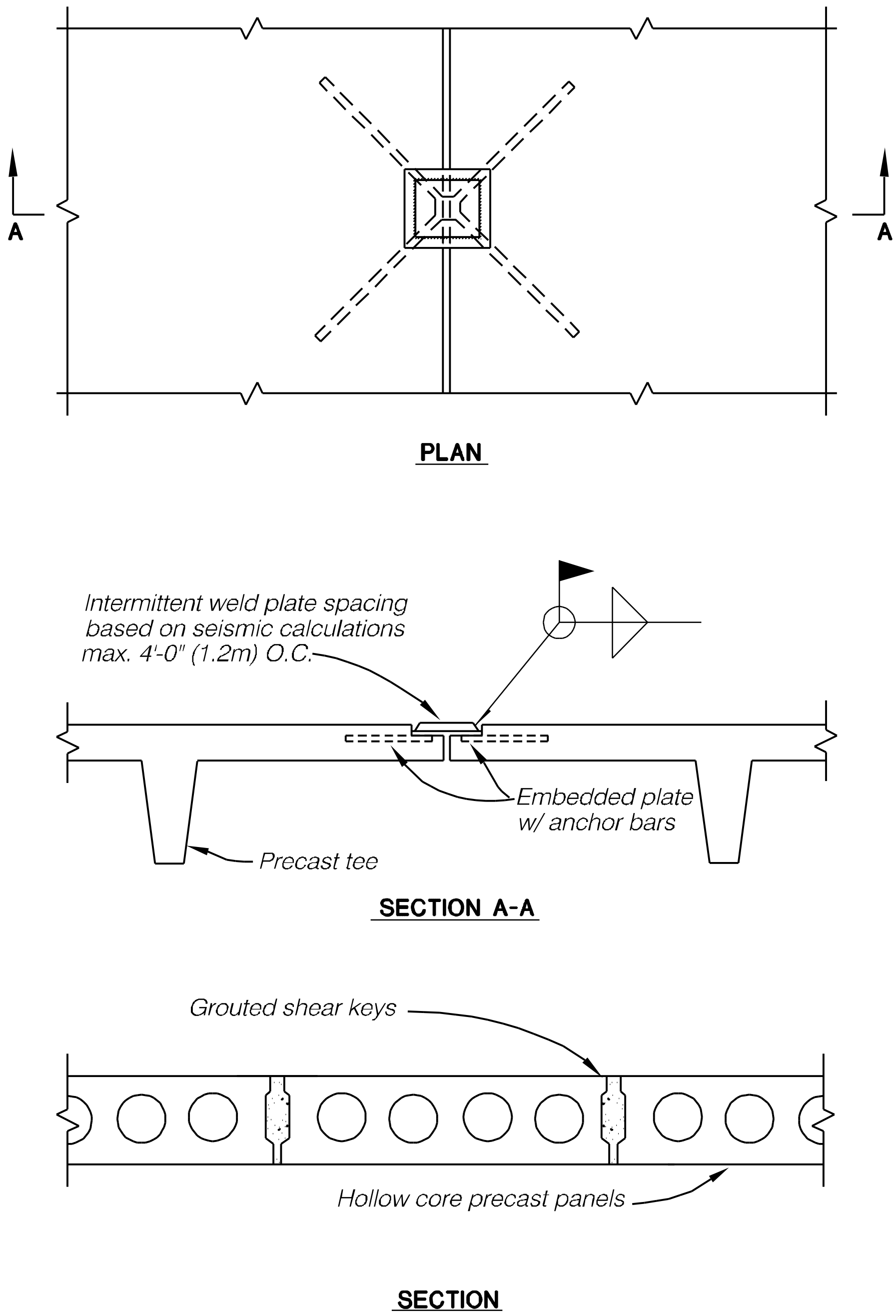


Figure 7-55 Concrete diaphragms using precast units-details permitted for Seismic Design Categories A and B

(3) Special reinforcements. Special diagonal reinforcement will be placed on corners of diaphragms, as indicated in Figure 7-56. Typical chord reinforcement and connection details are shown in Figure 7-57.

(4) Acceptance criteria.

(a) Reinforced concrete diaphragms for Performance Objective 1*A* shall be designed with the response reduction factor, *R,* in Table 7-1, based on the building's structural systems.

(b) For enhanced performance objectives, reinforced concrete diaphragms shall be considered as force-controlled rigid elements, and the demand / capacity ratio in shear shall not exceed 1.25.

e. Steel Deck Diaphragms.

(1) General design criteria. The following criteria will be used to design steel deck diaphragms. The three general categories of steel deck diaphragms are Type A, Type B, and decks with concrete fill. Design data from industry sources such as the Steel Deck Institute and the Research Reports of the International Conference of Building Officials may be used subject to the approval of the Agency Proponent.

(a) Typical deck units and fastenings. Deck units will be composed of a single fluted sheet or a combination of two or more sheets fastened together with welds. The special attachments used for field attachment of steel decks are shown in Figure 7-58. In addition to those shown, standard fillet (1/8-inch by 1-inch) (3mm by 25 mm) and butt welds are also used. The depth of deck units will not be less than 1½ inches (38mm).

(b) Connections at ends and at supporting beams. Refer to Type A and Type B details, Paragraphs 7-7e(2) and 7-7e(3).

(c) Connections at marginal supports. Marginal welds for all types of steel deck diaphragms will be spaced as follows:

for puddle welds

$$a_w = \frac{35{,}000\left(t_1 + t_2^{'}\right)}{q_{ave}} \qquad (7\text{-}12)$$

metric equivalent:

$$a_w = \frac{200{,}000\left(t_1 + t_2^{'}\right)}{q_{ave}} \qquad (7\text{-}12m)$$

for fillet welds and seam welds

$$a_w = \frac{1200\ell_w^{'}}{q_{ave}} \qquad (7\text{-}13)$$

metric equivalent:

$$a_w = \frac{6850\ell_w^{'}}{q_{ave}} \qquad (7\text{-}13m)$$

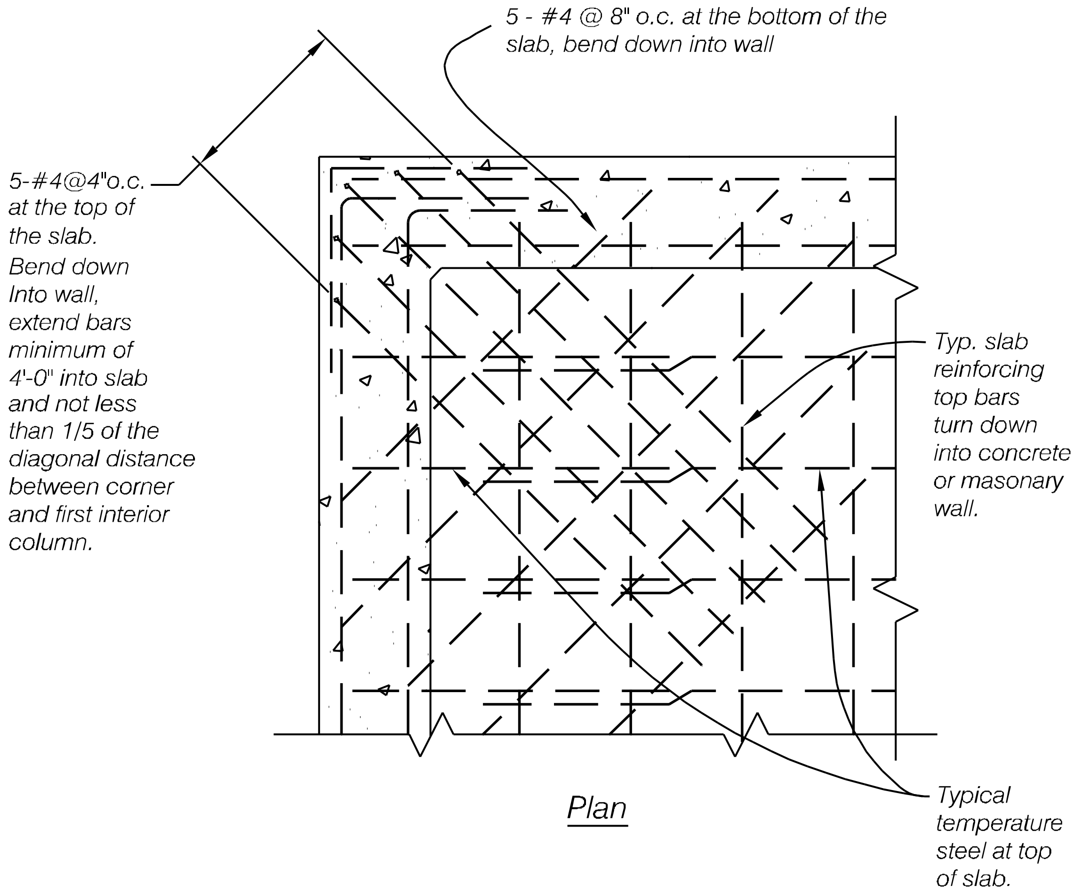
where:

a_w = spacing of marginal welds in feet (m).

t_1 = thickness of flat sheet elements in inches (mm) (22-gauge minimum).

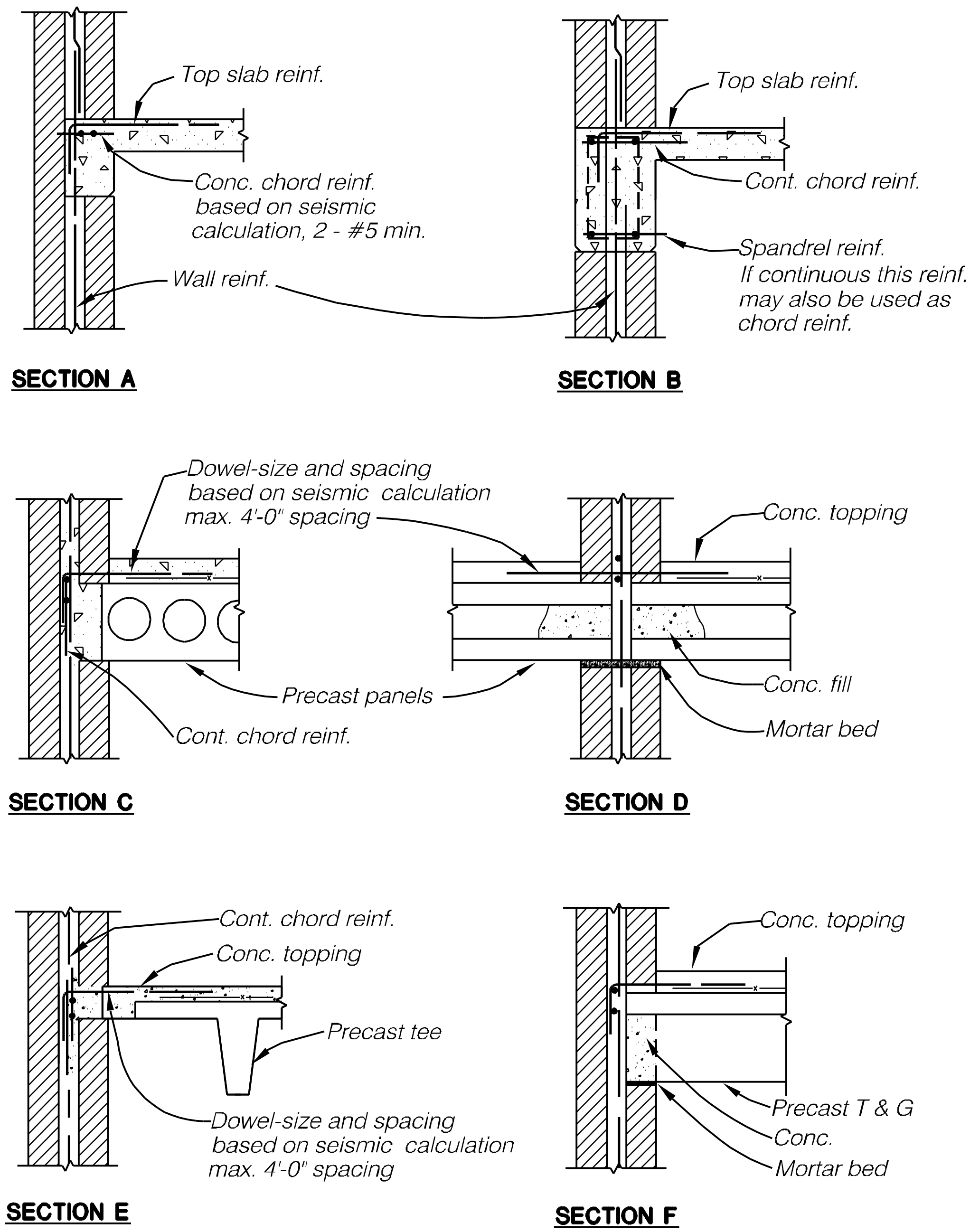
t'_2 = effective thickness of fluted elements in inches (mm).

q_{ave} = average shear in diaphragm over length L_1, in pounds per foot (N/m).



#4 bar ≈ 10M bar
1 inch = 25mm

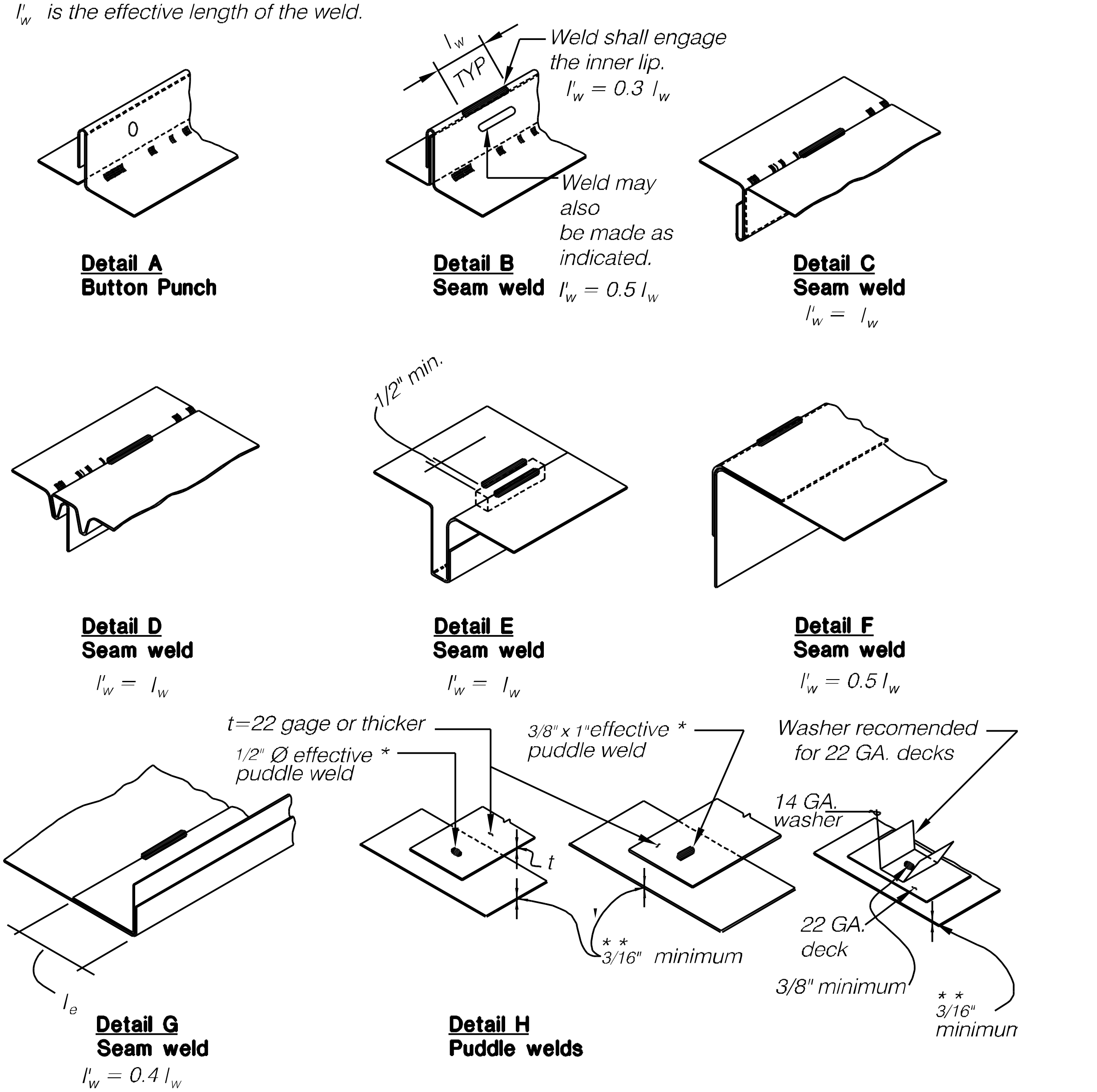
Figure 7-56 Corner of monolithic concrete diagragm.



1 foot = 0.3m
#5 bar = 15M bar

Figure 7-57 Concrete diaphragms - typical connection details.

NOTE: Maximum spacing of seam welds or button punches 3'-0". Minimum lenghth of seam welds - 1" for determining shears on diaphragms. Minimum spacing of seam welds or button punches - 1'-0". Maximum length of seam welds - 2". l'_w is the effective length of the weld.



*NOTE:
Effective size of Puddle weld indicates size of fusion area of weld metal on framing members.

**NOTE:Minimum thickness may be waived by design agency based on manufacturers standard products.

Figure 7-58 Steel deck diaphragms - Typical details of fastenings

1 inch = 25mm
1 foot = 0.3m