Seismic Detailing Provisions

BNBC

Why is seismic detailing needed

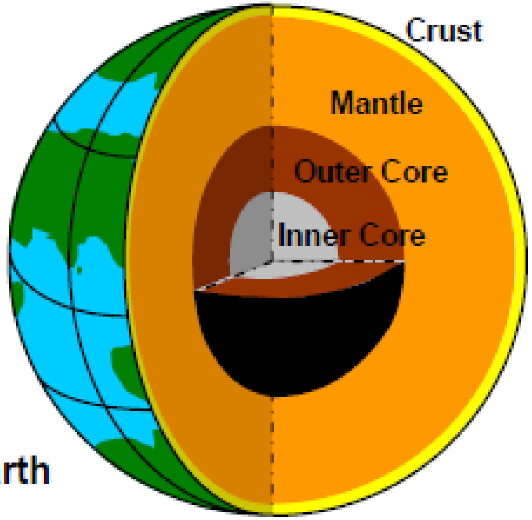


Figure 1:
Inside the Earth

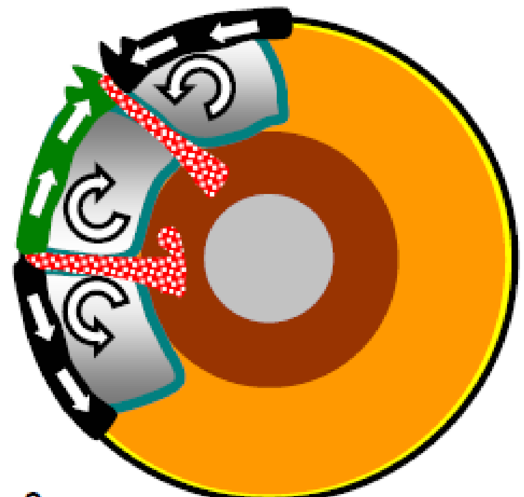


Figure 2:
Local Convective Currents in the Mantle

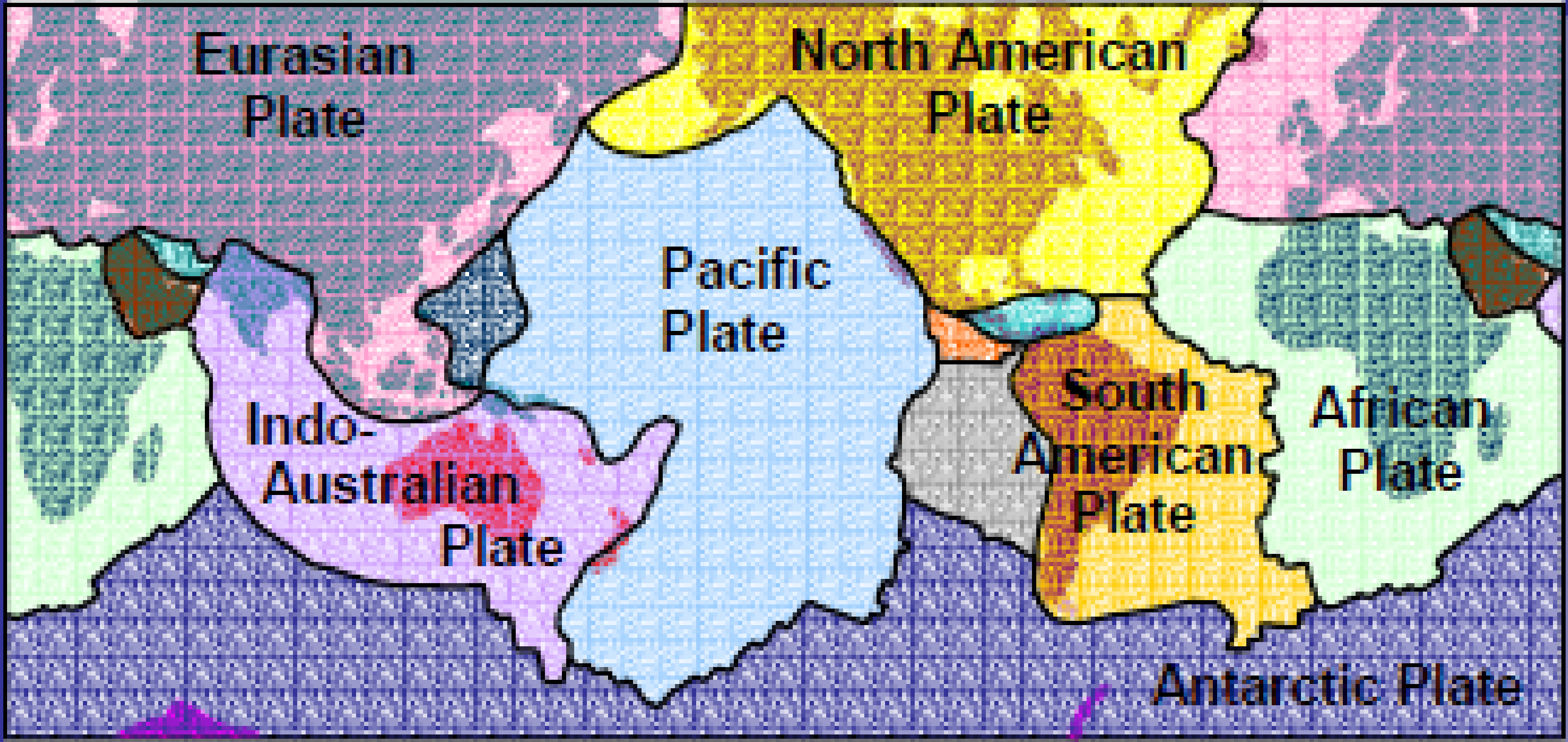


Figure 3:
Major Tectonic Plates on the Earth's surface

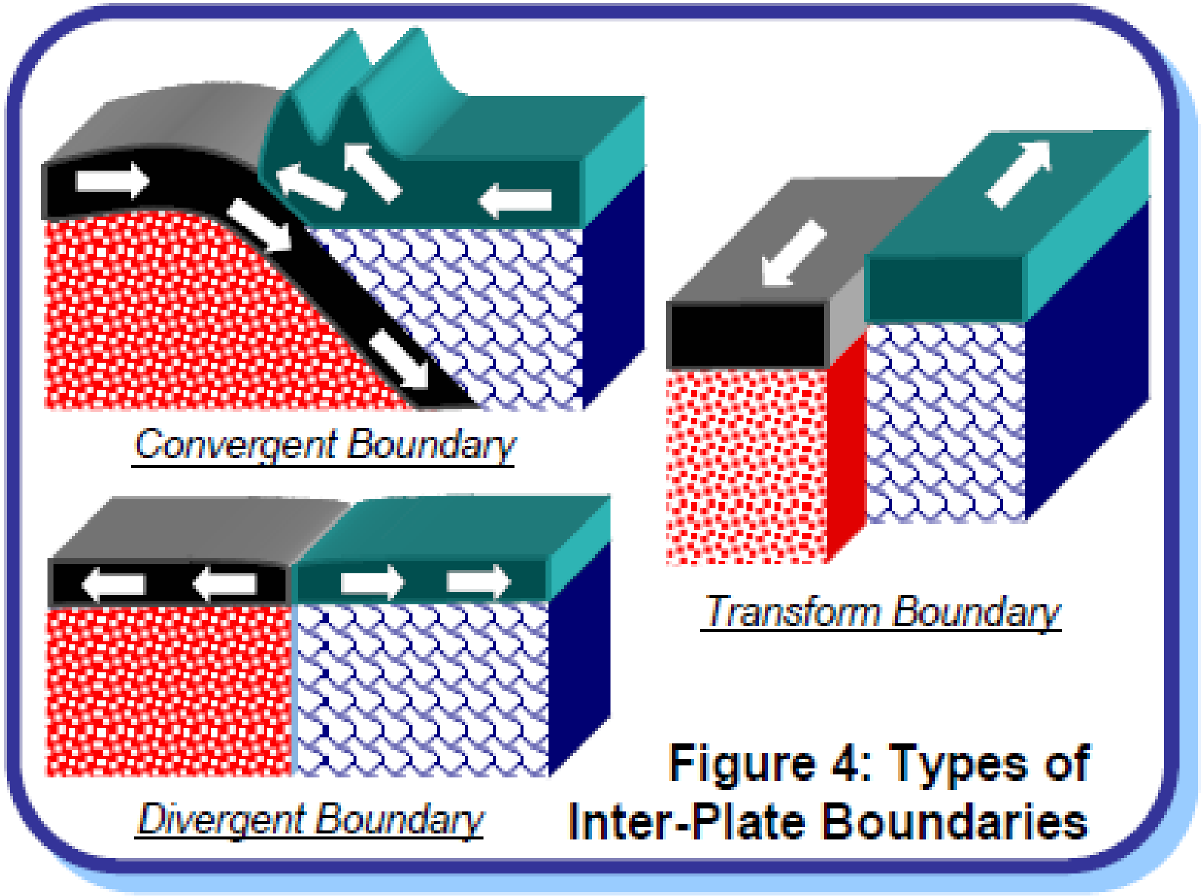


Figure 4: Types of Inter-Plate Boundaries

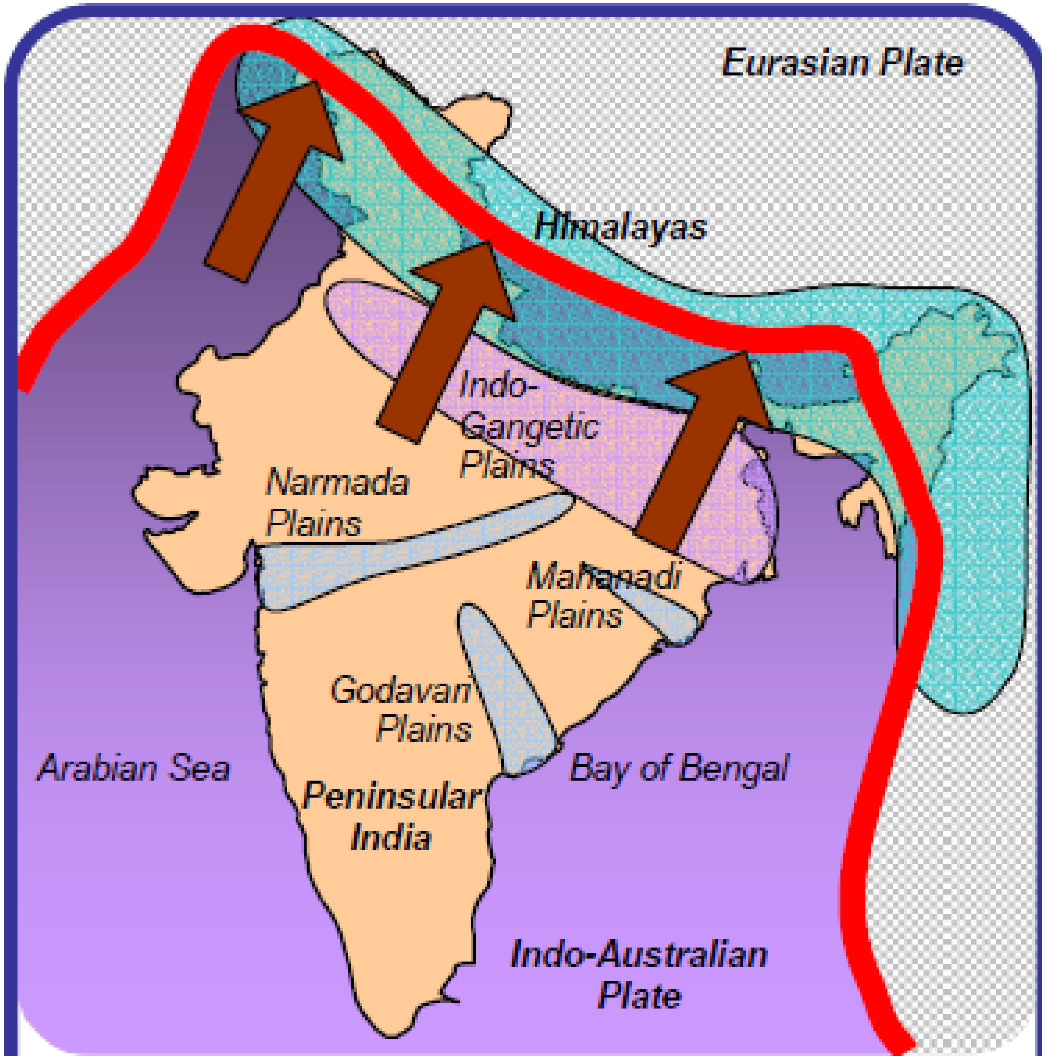
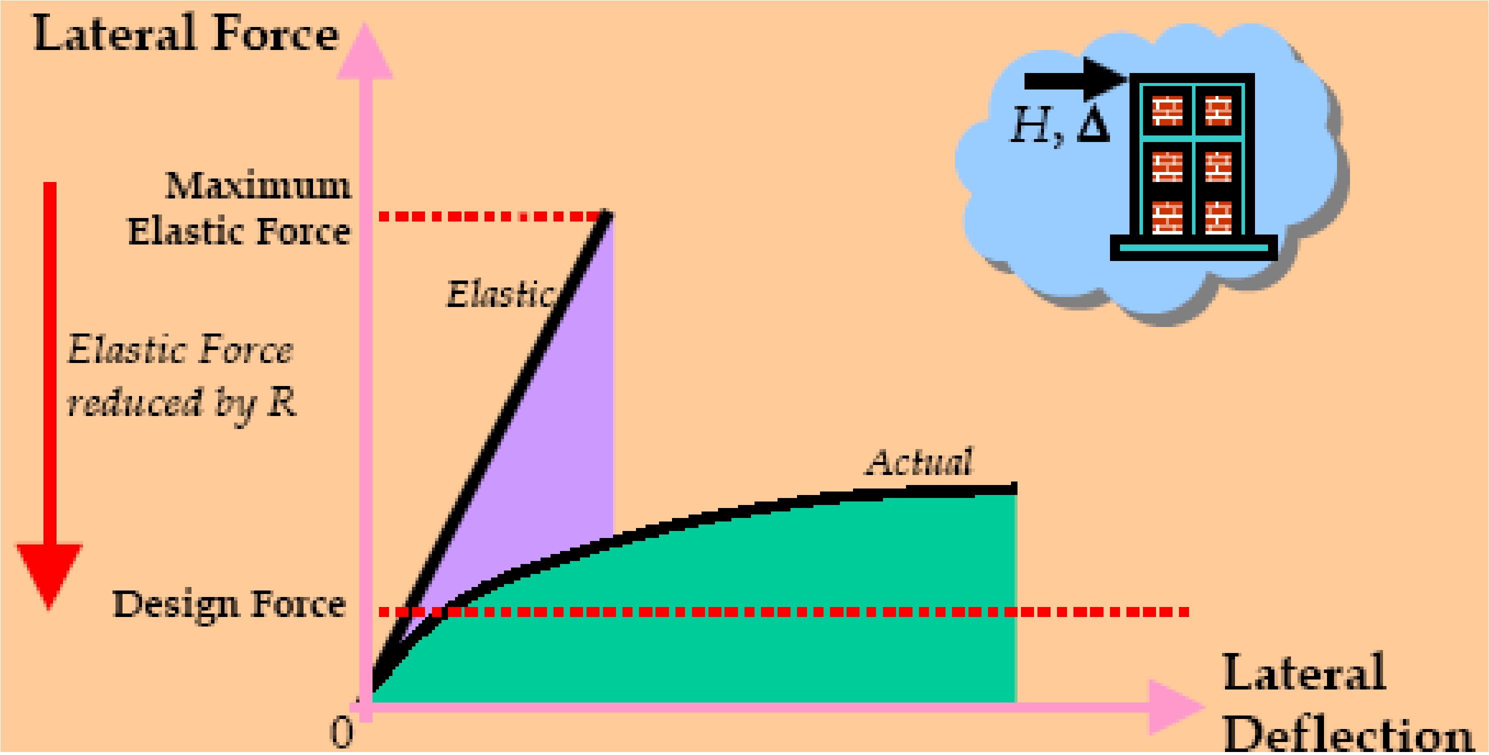


Figure 1: Geographical Layout and Tectonic Plate Boundaries at India

Table 1: Some Past Earthquakes in India

Date	Event	Time	Magnitude	Max. Intensity	Deaths
16 June 1819	Cutch	11:00	8.3	VIII	1,500
12 June 1897	Assam	17:11	8.7	XII	1,500
8 Feb. 1900	Coimbatore	03:11	6.0	X	Nil
4 Apr. 1905	Kangra	06:20	8.6	X	19,000
15 Jan. 1934	Bihar-Nepal	14:13	8.4	X	11,000
31 May 1935	Quetta	03:03	7.6	X	30,000
15 Aug. 1950	Assam	19:31	8.5	X	1,530
21 Jul. 1956	Anjar	21:02	7.0	IX	115
10 Dec. 1967	Koyna	04:30	6.5	VIII	200
23 Mar. 1970	Bharuch	20:56	5.4	VII	30
21 Aug. 1988	Bihar-Nepal	04:39	6.6	IX	1,004
20 Oct. 1991	Uttarkashi	02:53	6.6	IX	768
30 Sep. 1993	Killari (Latur)	03:53	6.4	IX	7,928
22 May 1997	Jabalpur	04:22	6.0	VIII	38
29 Mar. 1999	Chamoli	12:35	6.6	VIII	63
26 Jan. 2001	Bhuj	08:46	7.7	X	13,805
26 Dec. 2004	Sumatra	06:28	9.3	VII	10,749

Philosophy of Earthquake Engineering



Earthquake Design Philosophy

The earthquake design philosophy may be summarized as follows (Figure 1):

(a) Under minor but frequent shaking, the main members of the building that carry vertical and horizontal forces should not be damaged; however building parts that do not carry load may sustain repairable damage.

(b) Under moderate but occasional shaking, the main members may sustain repairable damage, while the other parts of the building may be damaged such that they may even have to be replaced after the earthquake; and

(c) Under strong but rare shaking, the main members may sustain severe (even irreparable) damage, but the building should not collapse.

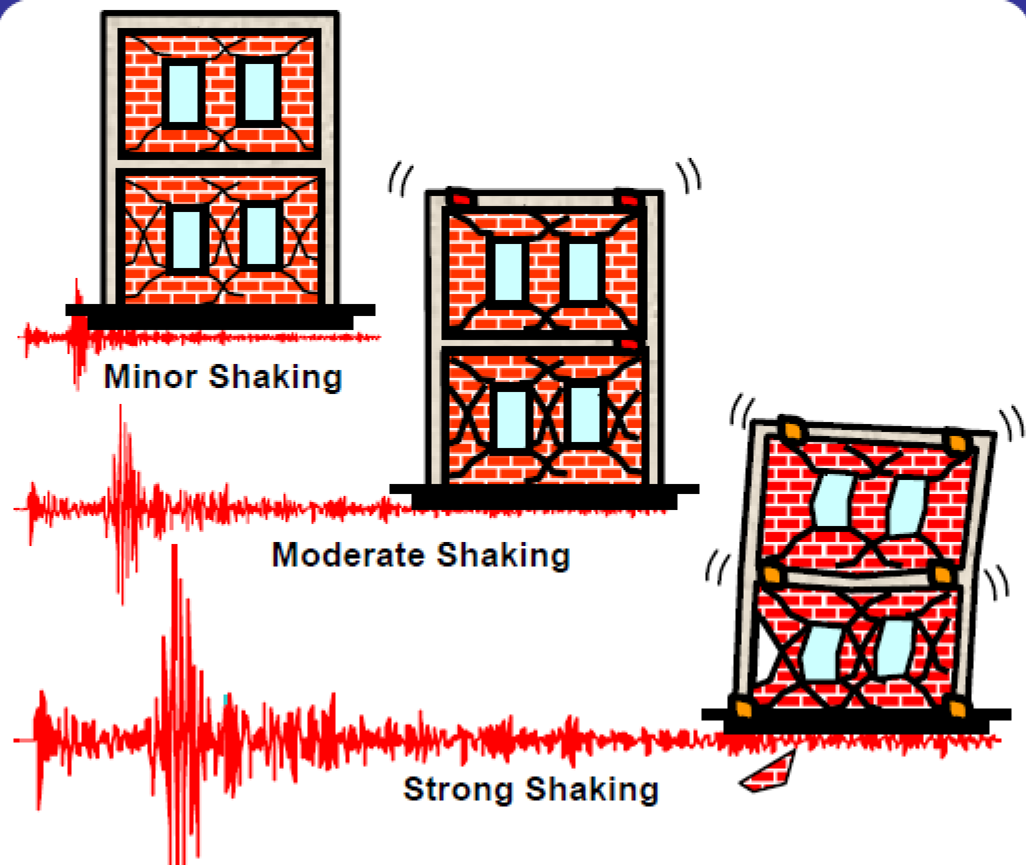


Figure 1: Performance objectives under different intensities of earthquake shaking – *seeking low repairable damage under minor shaking and collapse-prevention under strong shaking.*

$$F = ma$$

$$V = \frac{ZIC}{R} W$$

Maximum Elastic Acceleration

Reduction to account for ductility and overstrength

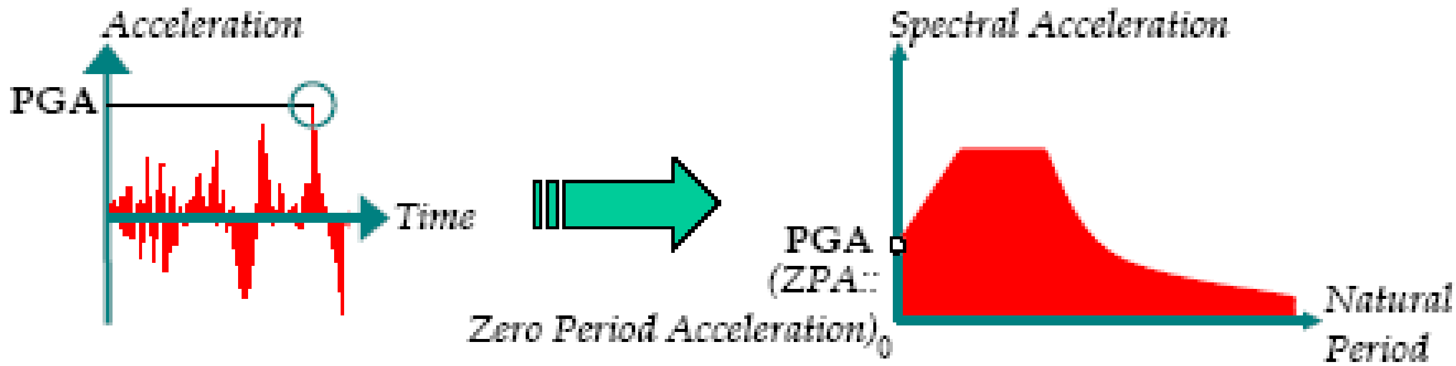
Equivalent Static Load Method

$$V = \frac{ZIC}{R}W$$

- Z= Seismic zone coefficient
- I=Importance factor
- R= Response modification coefficient
- C= Numerical coefficient $$C = \frac{1.25S}{T^{2/3}}$$
- S= Site coefficient
- T= Fundamental period of vibration, sec

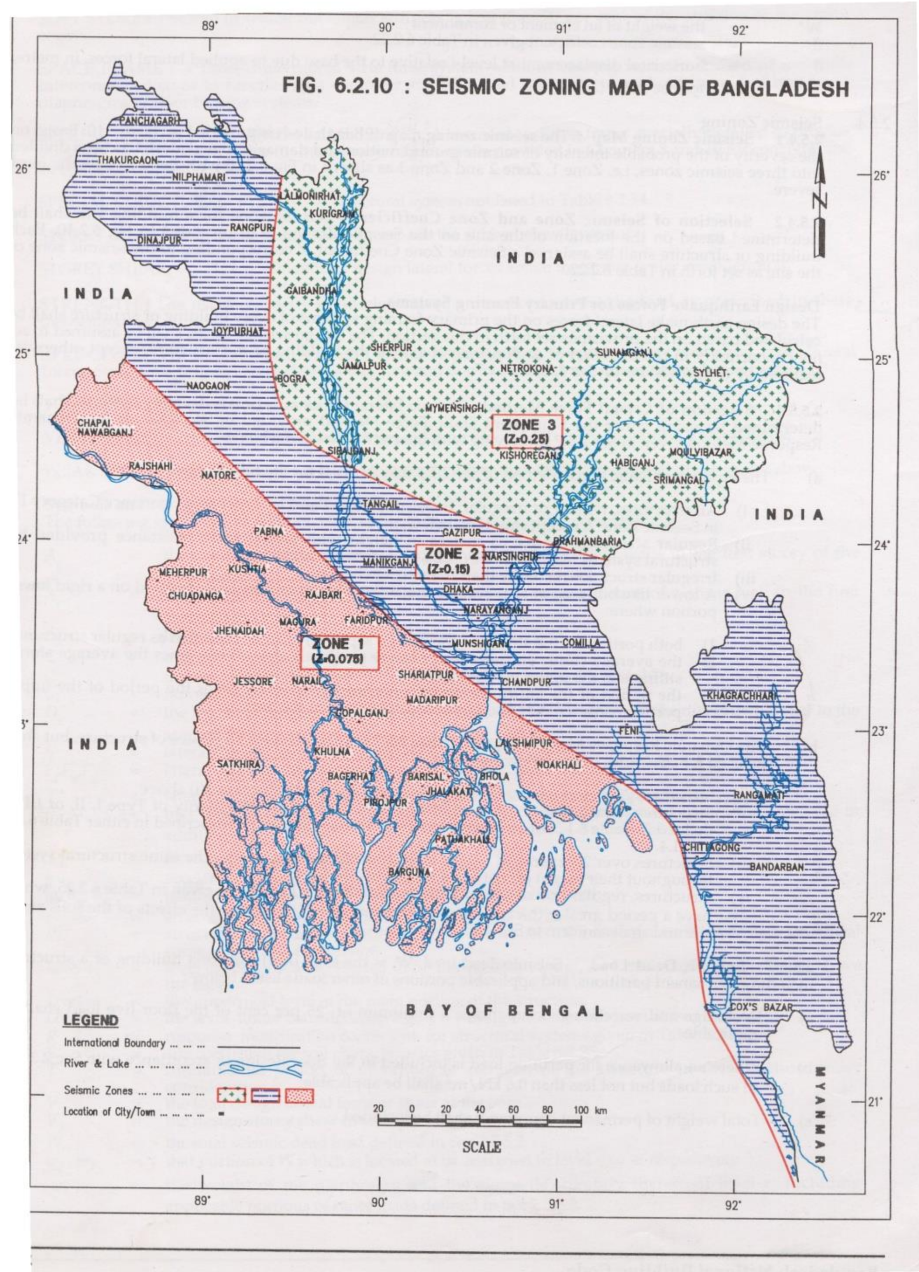
Z coefficient

✓ Reflects ***Peak Ground Acceleration (PGA)***
of the region during
Maximum Credible Earthquake (MCE)



Seismic Zoning Map

Fig. 2.5.1: Seismic Zoning Map of Bangladesh



Design Earthquake Force, BNBC 2014

Spectral Acceleration

$$S_a = \frac{2}{3}\frac{ZI}{R}C_s$$

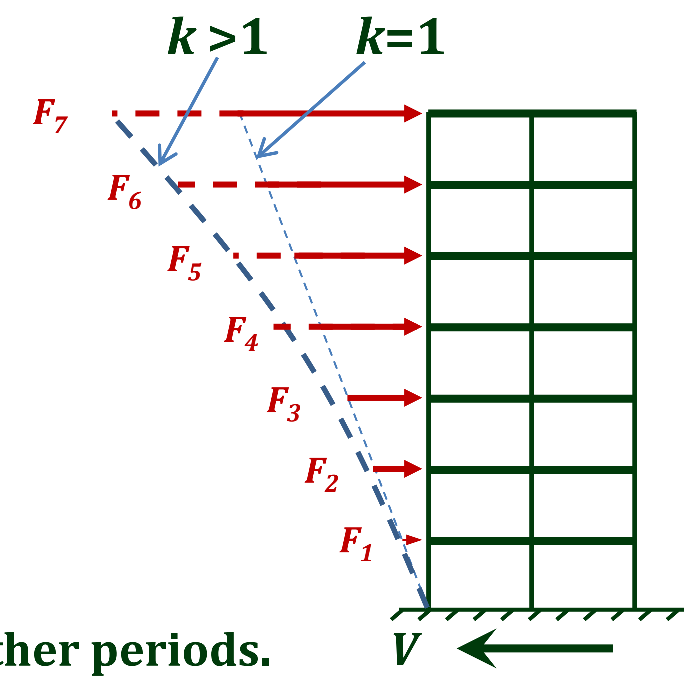
Base shear

$$V = S_a W$$

Vertical Distribution of base shear

$$F_x = V\frac{w_x h_x^{\ k}}{\sum_{i=1}^{n} w_i h_i^{\ k}}$$

k = 1 for structure period ≤ 0.5
= 2 for structure period ≥ 2.5s
= linear interpolation between 1 and 2 for other periods.



Equivalent Static Analysis: BNBC 2015

Site dependent soil factor and other parameters defining elastic response spectrum

Soil type	S	T_B (s)	T_C (s)	T_D (s)
SA	1.0	0.15	0.40	2.0
SB	1.2	0.15	0.50	2.0
SC	1.15	0.20	0.60	2.0
SD	1.35	0.20	0.80	2.0
SE	1.4	0.15	0.50	2.0

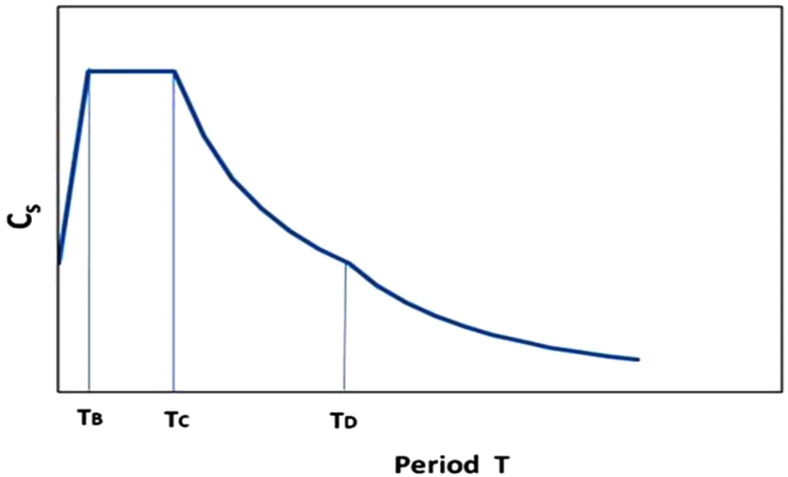
$$C_s = S\left(1 + \frac{T}{T_B}(2.5\eta - 1)\right) \quad \text{for} \quad 0 \le T \le T_B$$

$$C_s = 2.5S\eta \quad \text{for} \quad T_B \le T \le T_C$$

$$C_s = 2.5S\eta\left(\frac{T_C}{T}\right) \quad \text{for} \quad T_C \le T \le T_D$$

$$C_s = 2.5S\eta\left(\frac{T_C T_D}{T^2}\right) \quad \text{for} \quad T_D \le T \le 4 \text{ sec}$$

Normalized acceleration response spectrum, C_s



$$\eta = \sqrt{10/(5+\xi)} \ge 0.55$$

Here ξ is structural damping expressed as a percentage of critical damping.

Requirements for Intermediate Moment Frames

Reinforcement Requirements

- Reinforcement details in a frame member shall satisfy 8.3.10.4 below if the factored compressive axial load for the member does not exceed $0.1f_c'A_g$. If the factored compressive axial load is larger, frame reinforcement details shall satisfy 8.3.10.5 below unless the member has spiral reinforcement according to Eq (6.3.6). If a two-way slab system without beams is treated as part of a frame resisting earthquake effect, reinforcement details in any span resisting moments caused by lateral force shall satisfy 8.3.10.6 below.

Shear requirements

- Design shear strength of beams, columns, and two-way slabs resisting earthquake effect shall not be less than either (a) the sum of the shear associated with development of nominal moment strengths of the member at each restrained end of the clear span and the shear calculated for factored gravity loads, or (b) the maximum shear obtained from design load combinations which include earthquake effect.

Requirements for Intermediate Moment Frames: **Beams**

a) The positive moment strength at the face of the joint shall not be less than one-third the negative moment strength provided at that face (Fig.8.3.12). Neither the negative nor positive moment strength at any section along the length of the member shall be less than one-fifth of the maximum moment strength provided at the face of either joint.

b) At both ends of the member, stirrups shall be provided over lengths equal to twice the member depth measured from the face of the supporting member toward midspan (Fig.8.3.13). The first stirrup shall be located not more than 50 mm from the face of the supporting member. Maximum stirrup spacing shall not exceed (a)*d/4* , (b) 8 times the diameter of the smallest longitudinal bar enclosed, (c) 24 times the diameter of the stirrup bar, and (d) 300 mm.

c) Stirrups shall be placed at not more than d/2 throughout the length of the member.

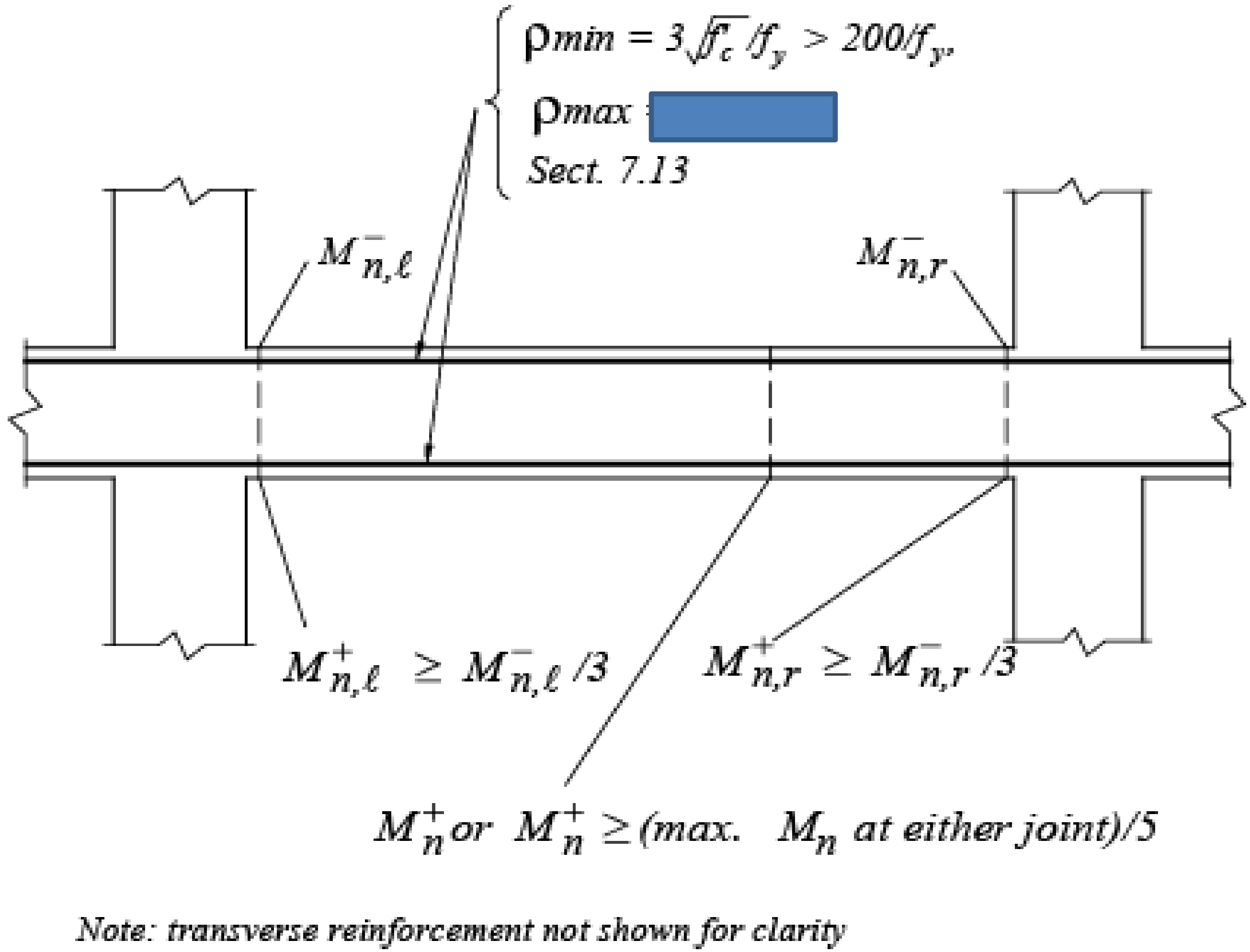


Fig.8.3.12 Flexural Requirements for Beams

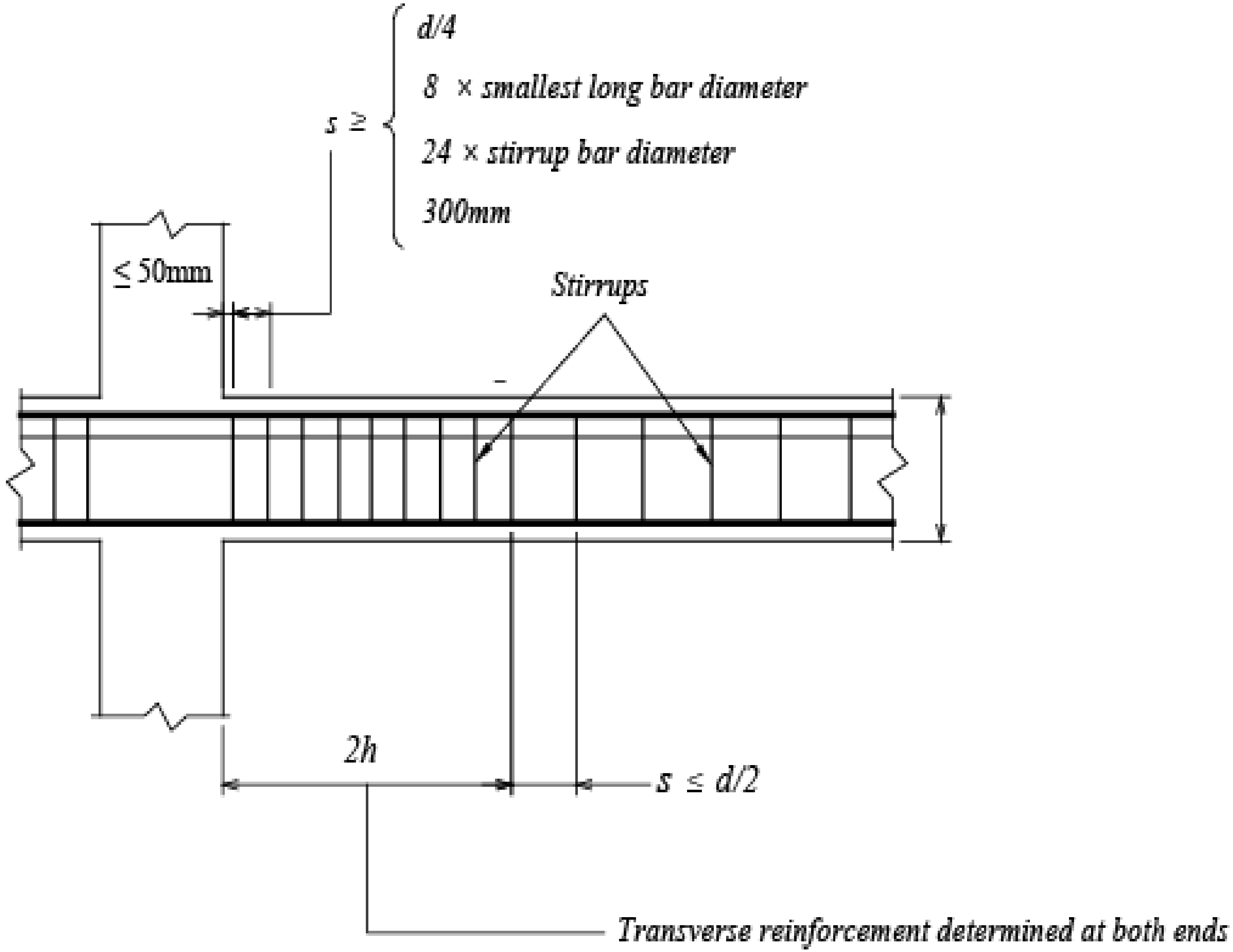


Fig.8.3.13 Transverse reinforcement Requirements for Beams

Requirements for Intermediate Moment Frames: **Columns**

a) Maximum tie spacing shall not exceed s_o over a length l_0 measured from the joint face. The spacing s_o shall not exceed (i) 8 times the diameter of the smallest longitudinal bar enclosed, (ii) 24 times the diameter of the tie bar, (iii) one-half of the smallest cross-sectional dimension of the frame member, and (iv) 300 mm. The length l_0 shall not be less than (i) one-sixth of the clear span of the member, (ii) maximum cross-sectional dimension of the member, and (iii) 450 mm.

b) The first tie shall be located not more than $s_0/2$ from the joint face.

c) Joint reinforcement shall conform to 6.4.9.

d) Tie spacing shall not exceed $2s_0$ throughout the length of the member.

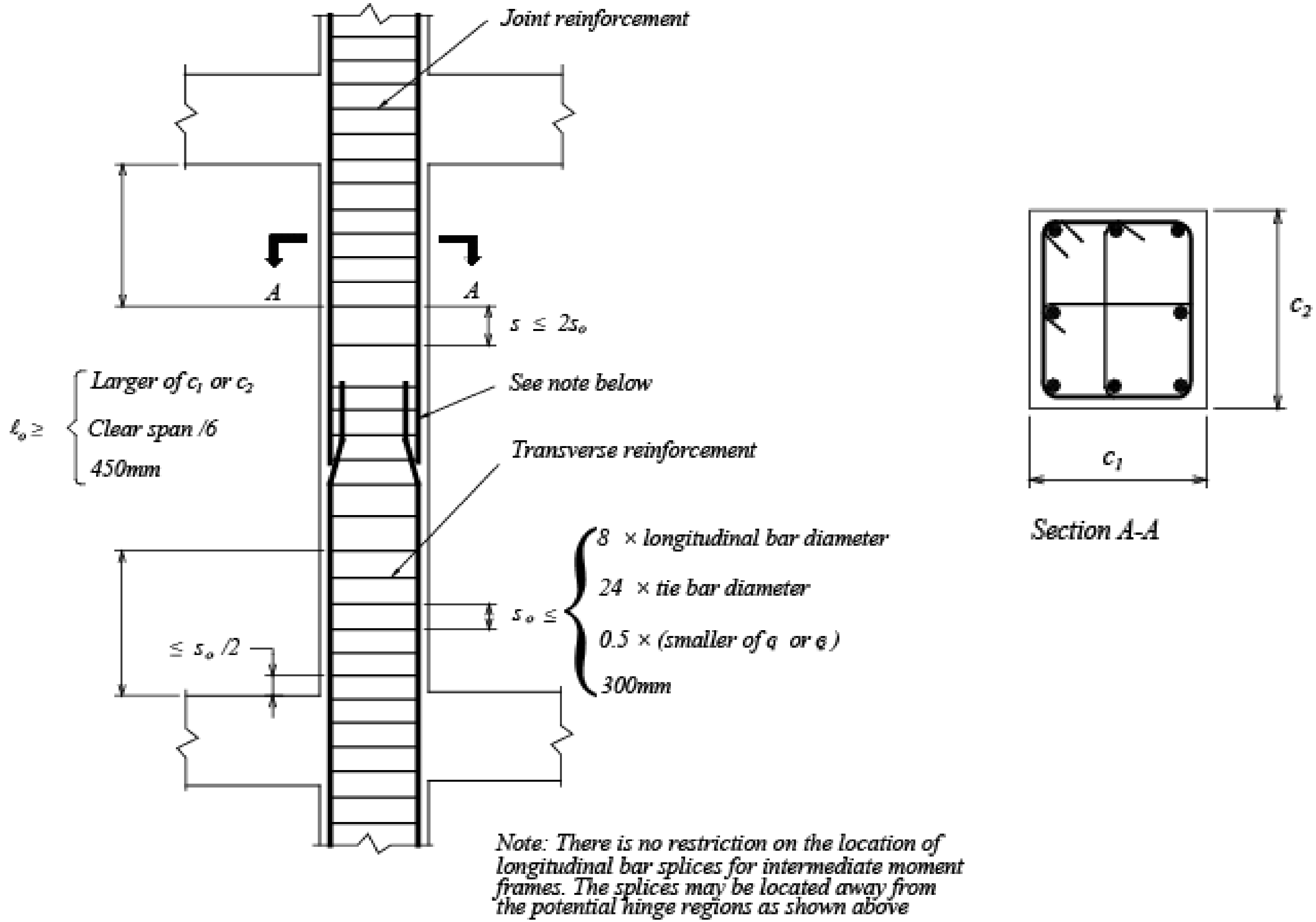
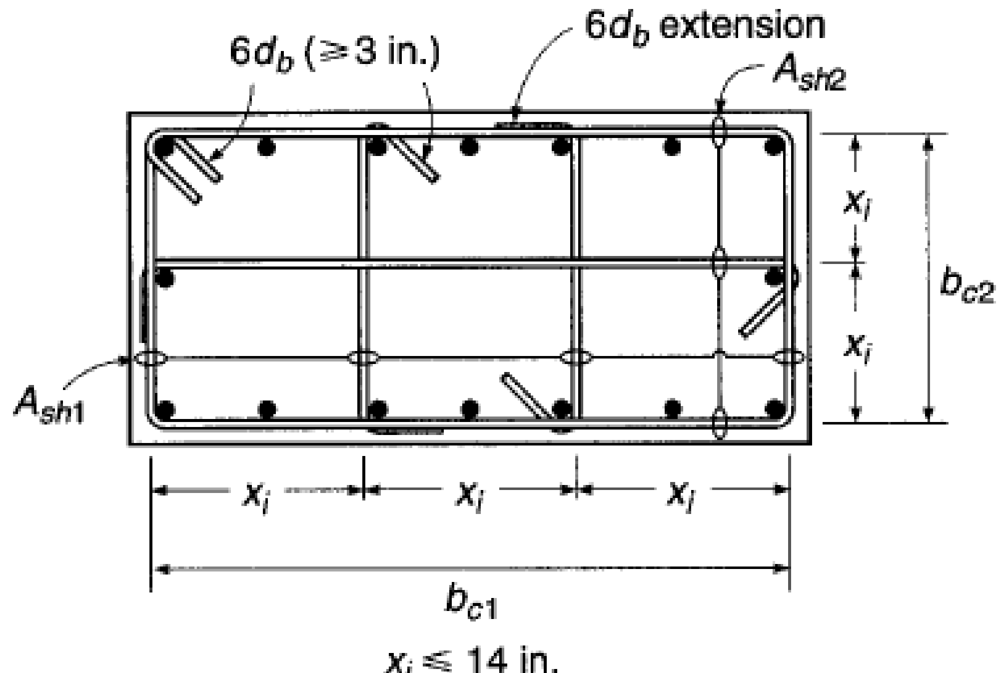


Fig.8.3.14 Transverse Reinforcement Requirements for Columns

Seismic hook

FIGURE 20.12
Example of transverse reinforcement in columns; consecutive crossties engaging the same longitudinal bars must have 90° hooks on opposite sides of columns. (*Adapted from Ref. 20.9.*)



Requirements for Intermediate Moment Frames:
Two-way Slabs without Beams

a) The factored slab moment at the supports relating to earthquake effect shall be determined for load combinations specified in Chapter 2, Loads. All reinforcement provided to resist the portion of slab moment balanced by support moment shall be placed within the column strip defined in 6.5.2.1 (Fig.8.3.15).

b) The fractional part of the column strip moment shall be resisted by reinforcement placed within the effective width (Fig.8.3.15) specified in 6.5.5.3.2.

c) Not less than one-half of the total reinforcement in the column strip at the support shall be placed within the effective slab width (Fig.8.3.15) specified in 6.5.5.3.2.

d) Not less than one-quarter of the top steel at the support in the column strip shall be continuous throughout the span (Fig.8.3.16).

e) Continuous bottom reinforcement in the column strip shall be not less than one-third of the top reinforcement at the support in the column strip.

f) Not less than one-half of all bottom reinforcement at midspan shall be continuous and shall develop its yield strength at the face of support (Fig.8.3.17).

g) At discontinuous edges of the slab all top and bottom reinforcement at the support shall be developed at the face of the support (Fig.8.3.16 and Fig.8.3.17).

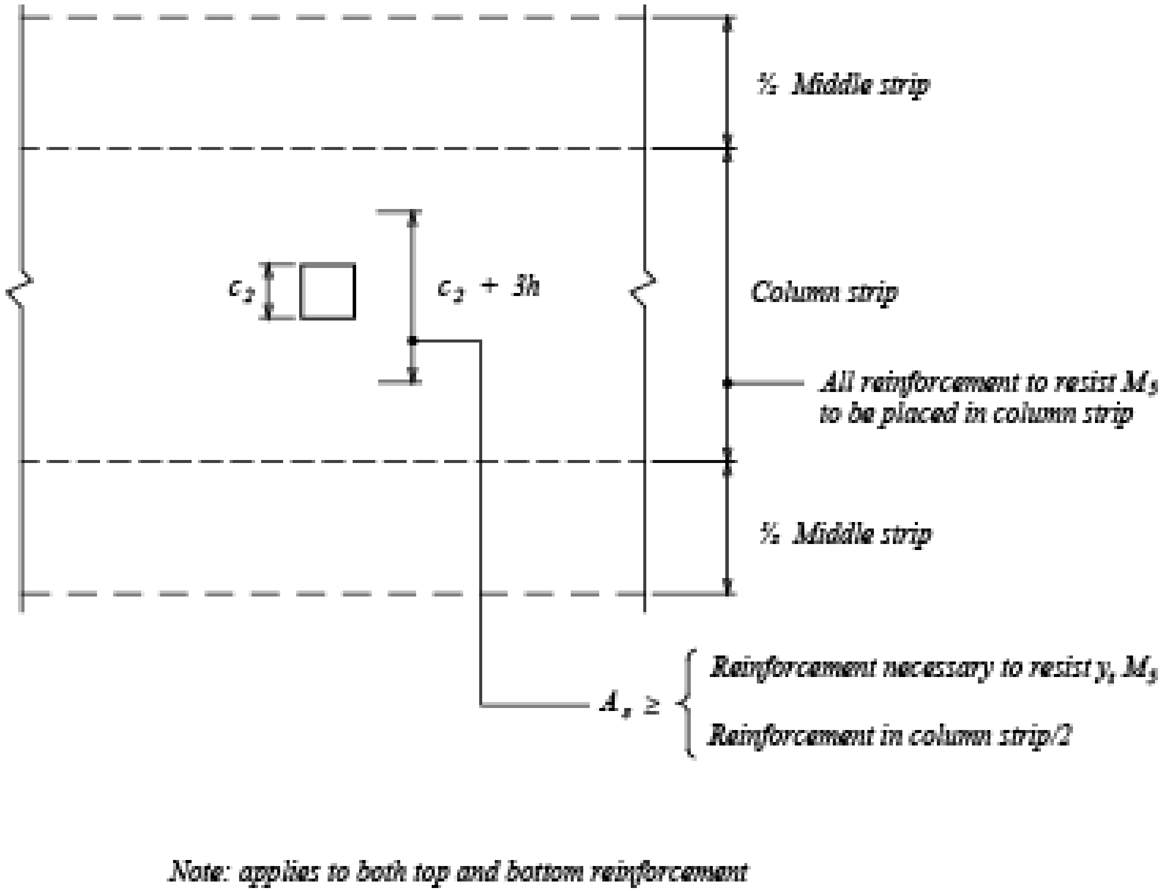


Fig.8.3.15 Reinforcement Details at Support of Two-way Slabs without beams

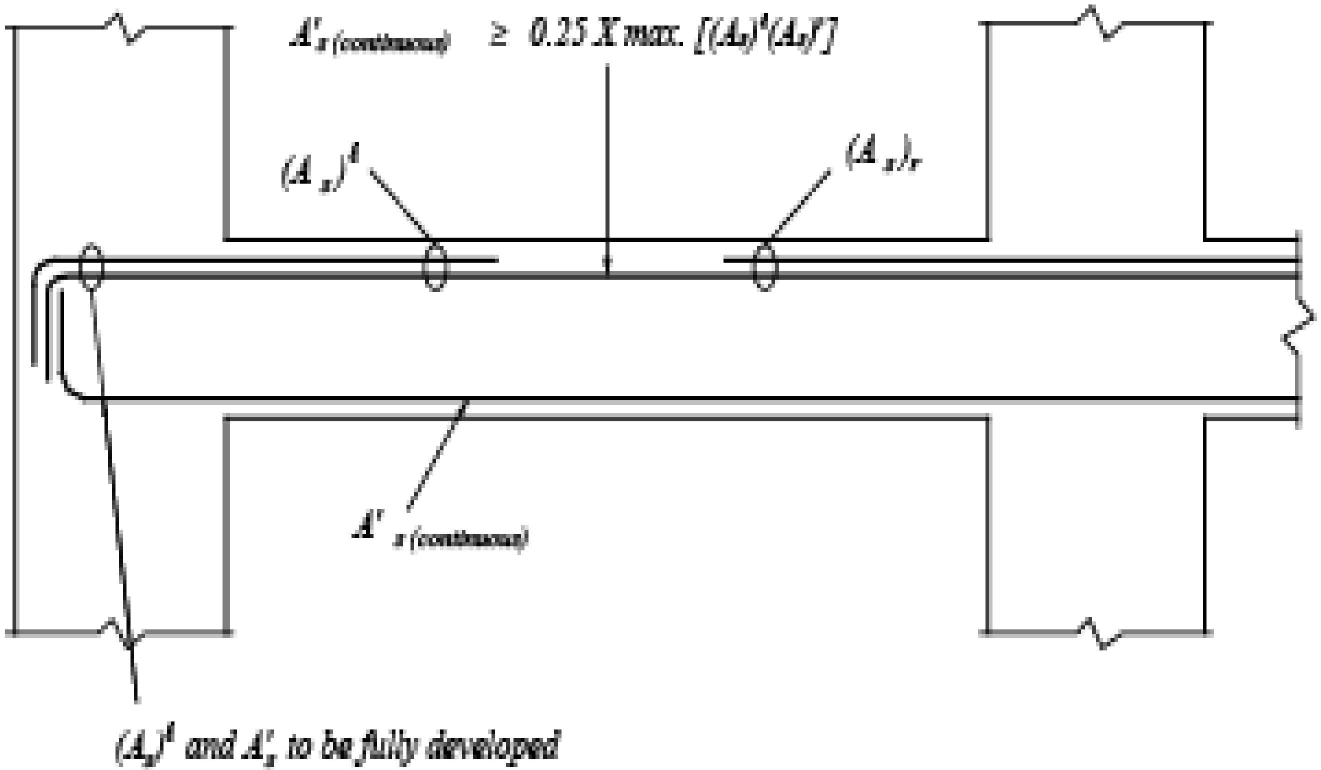


Fig.8.3.16 Reinforcement Details in Two-way Slabs without beams: Column Strip

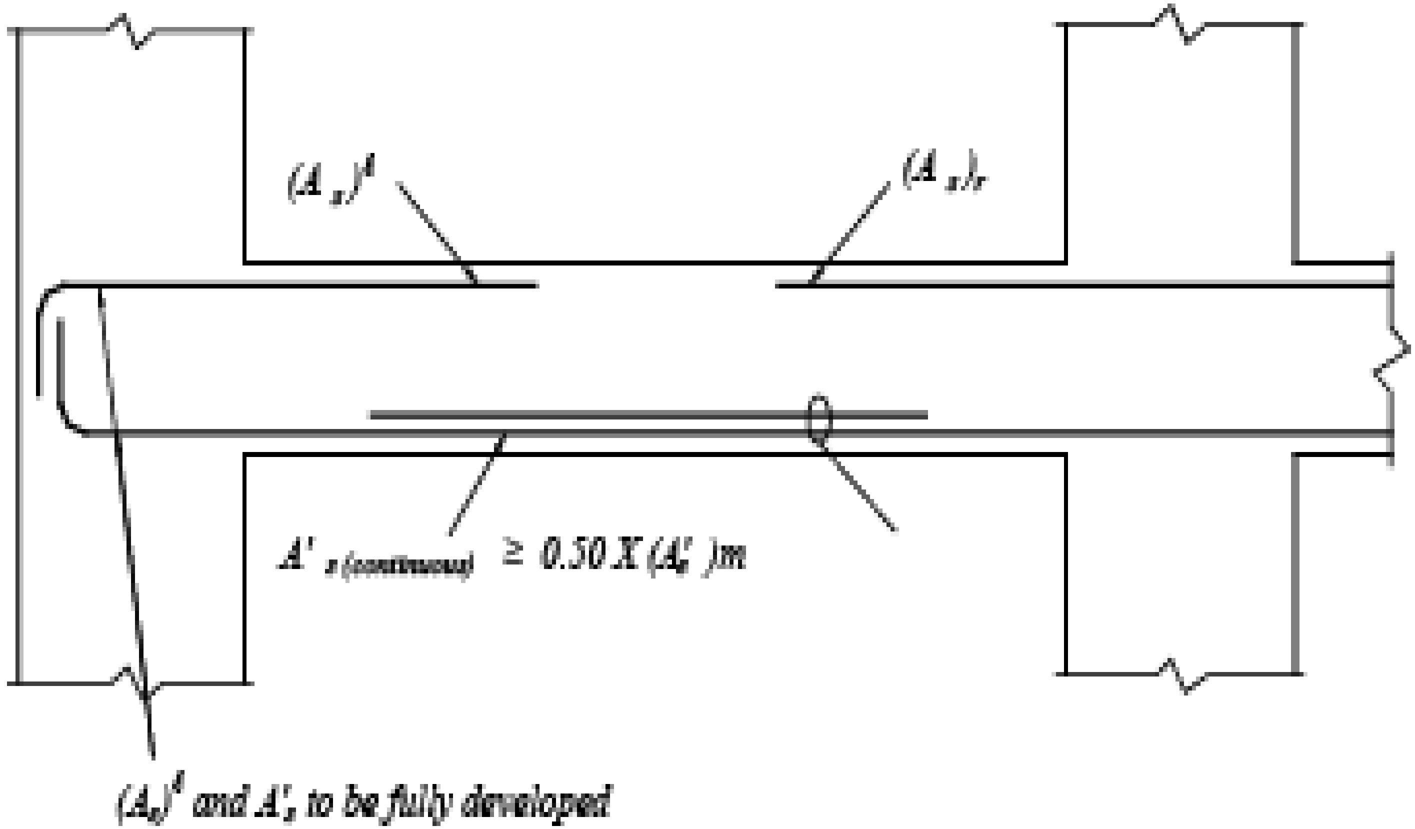


Fig.8.3.17 Reinforcement Details in Two-way Slabs without beams: Middle Strip

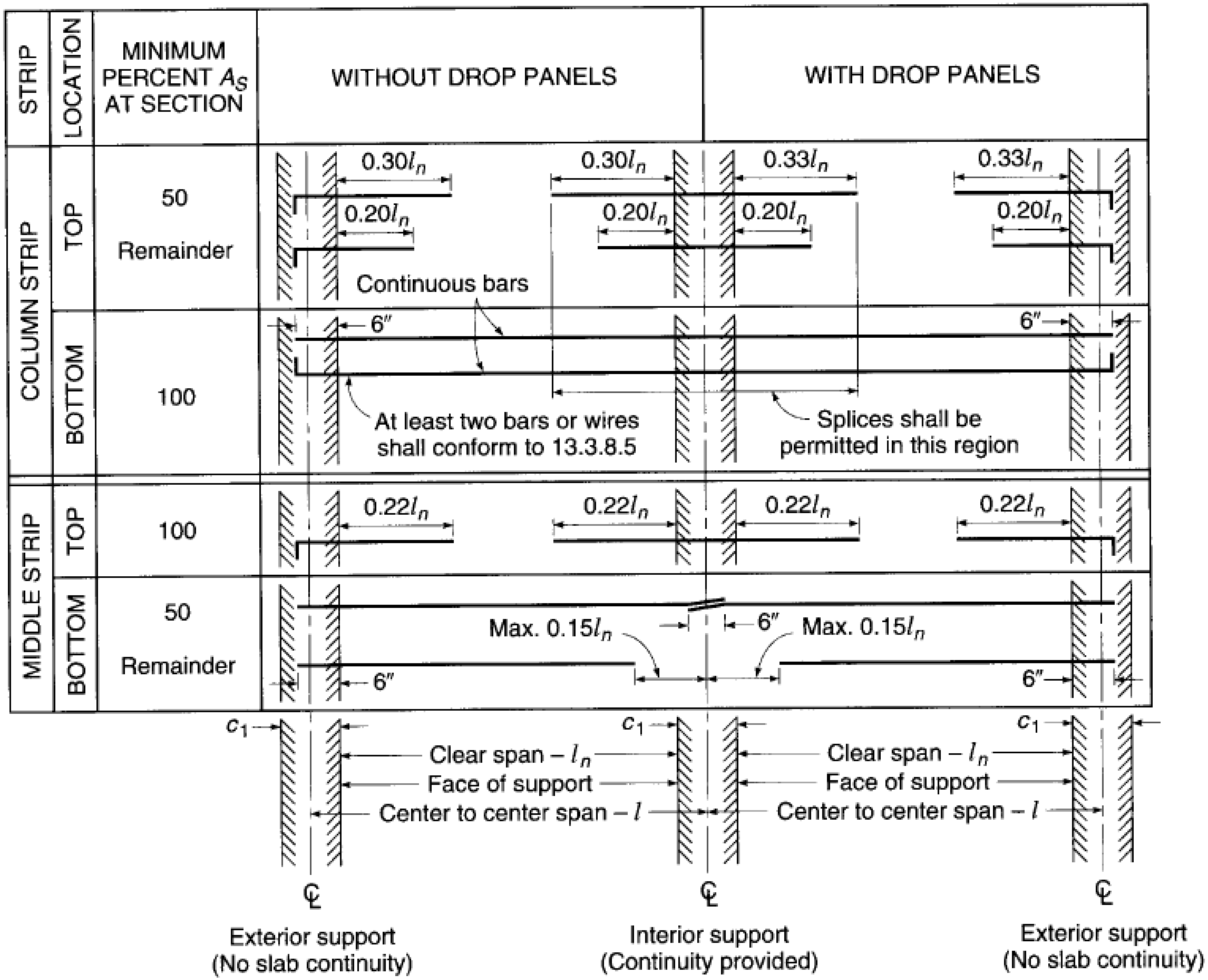


FIGURE 13.14
Minimum length of slab reinforcement in a slab without beams.

For two-way slabs without beams, ACI Code 21.3.6 requires design for earthquake effects using Eqs. (20.4) and (20.5). Under these loading conditions, the reinforcement provided to resist the unbalanced moment transferred between the slab and the column M_s (M_u in Section 13.11) must be placed within the column strip. Reinforcement to resist the fraction of the unbalanced moment M_s defined by Eq. (13.16*a*), $M_{ub} = \gamma_f M_u = \gamma_f M_s$, but not less than one-half of the reinforcement in the column strip at the support, must be concentrated near the column. This reinforcement is placed within an effective slab width located between lines $1.5h$ on either side of the column or column capital, where h is the total thickness of the slab or drop panel.

To ensure ductile behavior throughout two-way slabs without beams, at least one-quarter of the top reinforcement at the support in column strips must be continuous throughout the span, as must bottom reinforcement equal to at least one-third of the top reinforcement at the support in column strips. A minimum of one-half of all bottom reinforcement at midspan in both column and middle strips must be continuous and develop its yield strength at the face of the support. For discontinuous edges of the slab, both the top and bottom reinforcement must be developed at the face of the support. Finally, at critical sections for two-way shear at columns (Section 13.10a), V_u may not exceed $0.4\phi V_c$. The latter provision may be waived if the requirements of ACI Code 21.13.6 for slab-column connections in members not designated as part of the seismic-force-resisting system are met (see Section 20.5b).