Importance of Earthquake-Related Detailing in Construction:

Experiences from the Mandalay Earthquake in Myanmar

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27th June 2025

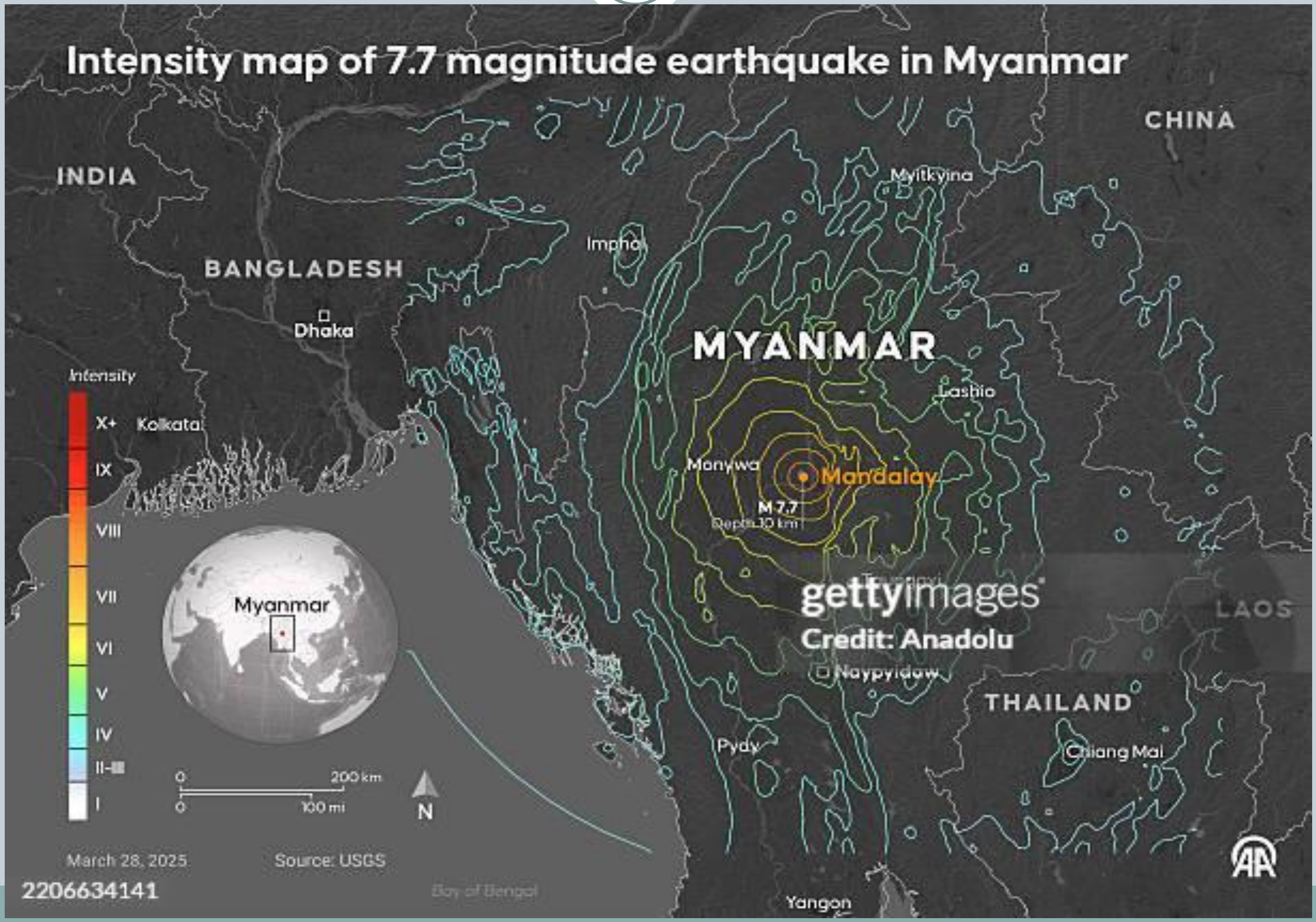
Bangkok, Thailabnd

Background

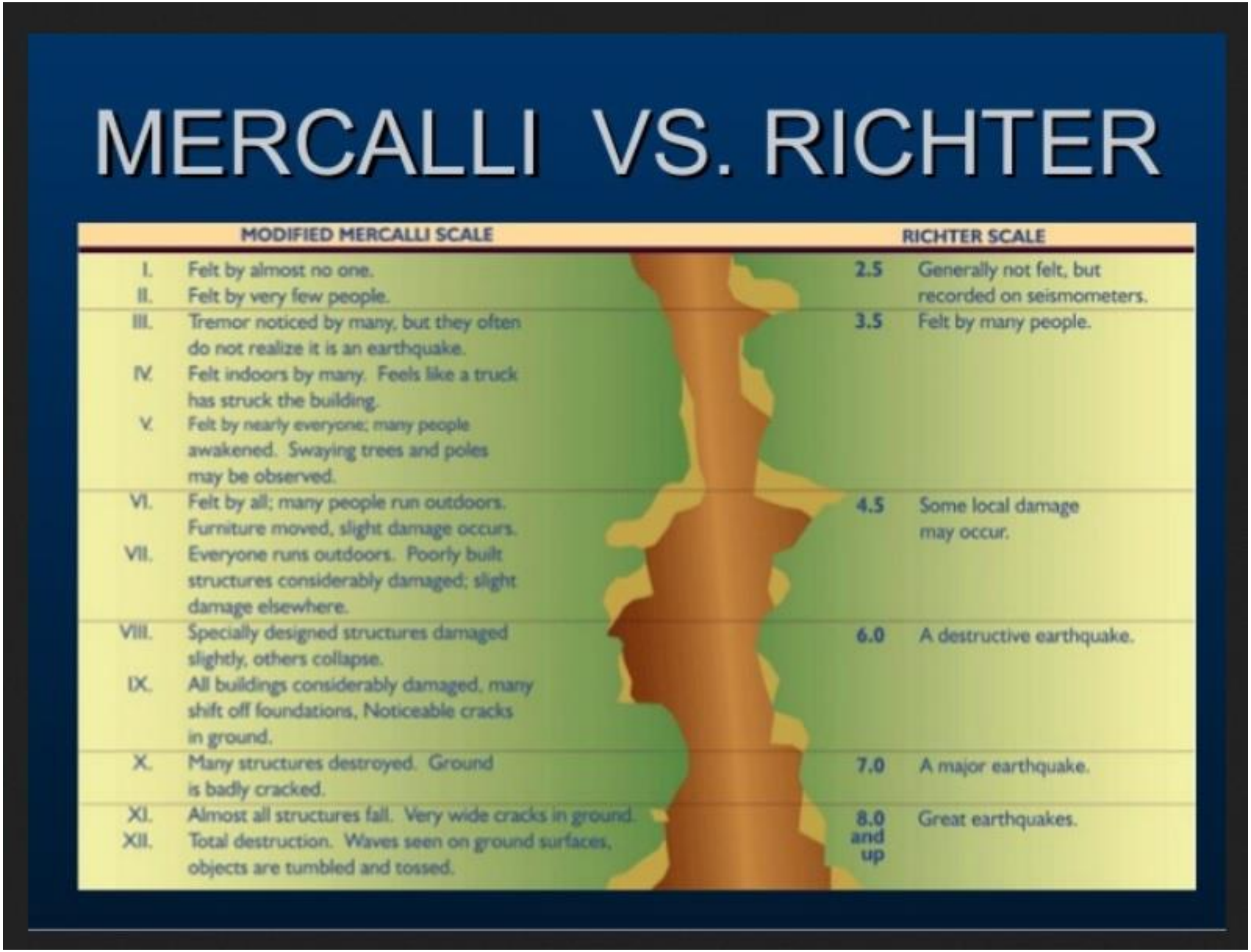
- 28 March 2025 at 12:50:52 MMT (06:20:52 UTC), a Magnitue 7.7 earthquake struck the Sagaing Region of Myanmar, with an epicenter close to Mandalay, the country's second-largest city.
- It was the most powerful earthquake to strike Myanmar since 1912, and the second deadliest in Myanmar's modern history, surpassed only by upper estimates of the 1930 Bago earthquake.
- The earthquake caused extensive damage in Myanmar and significant damage in neighboring Thailand. Hundreds of homes were also damaged in Yunnan, China, while more than 400 apartments were affected in Ho Chi Minh City, Vietnam. (Ref . : Wikipedia.)

the Sagaing Fault, a major transform fault within Myanmar, a significant source of seismic activity.

The Sunda megathrust, a major fault line, runs along Myanmar's western coast, capable of generating large earthquakes caused by subduction of the Indian plate beneath the Burma plate.



MODIFIED MERCALLI INTENSITY SCALE (MMI) AFTER USGS		
Intensity	**Shaking**	**Description/Damage**
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.



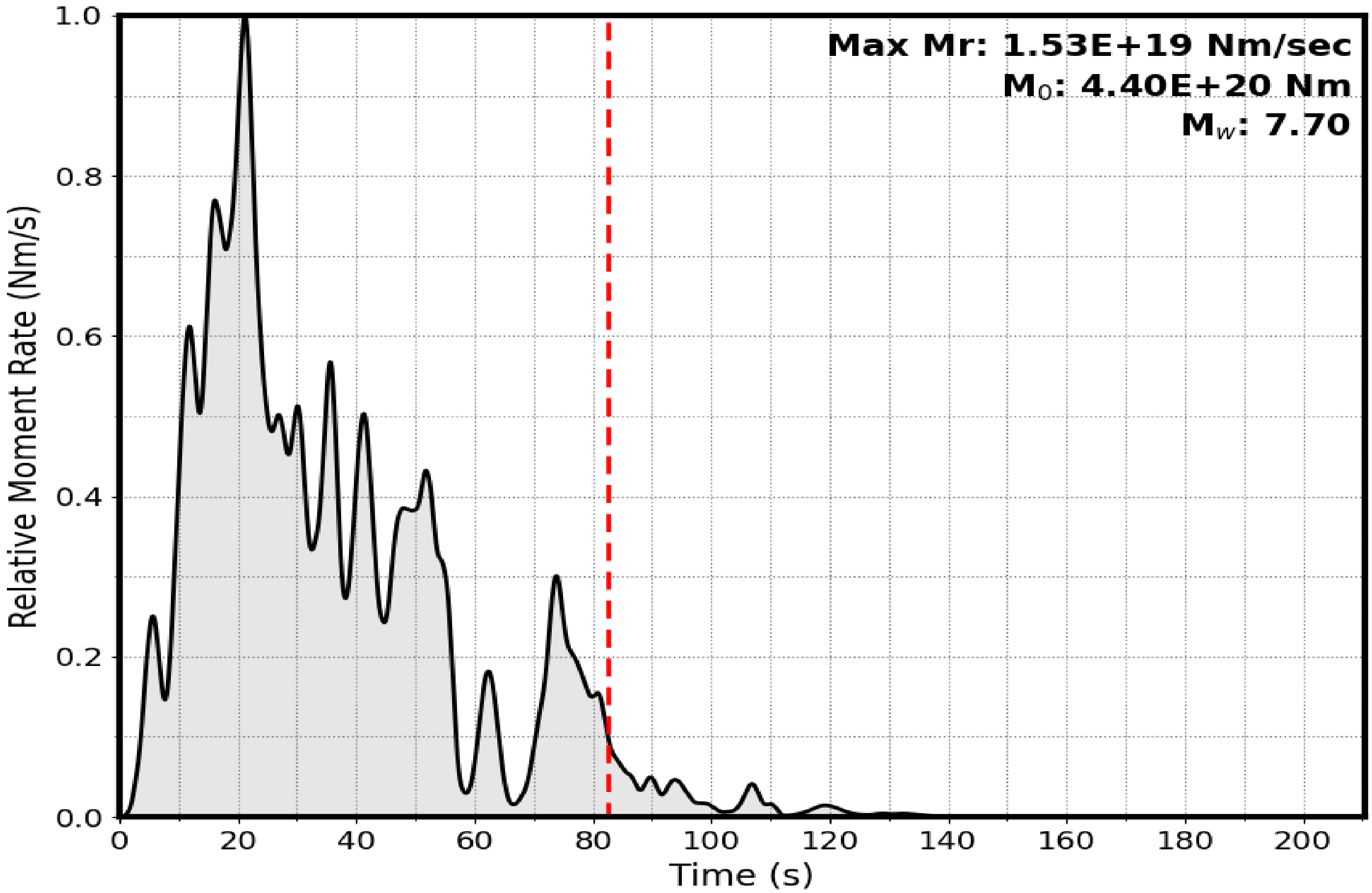
MERCALLI VS. RICHTER

MODIFIED MERCALLI SCALE		RICHTER SCALE	
I. II.	Felt by almost no one. Felt by very few people.	2.5	Generally not felt, but recorded on seismometers.
III. IV. V.	Tremor noticed by many, but they often do not realize it is an earthquake. Felt indoors by many. Feels like a truck has struck the building. Felt by nearly everyone; many people awakened. Swaying trees and poles may be observed.	3.5	Felt by many people.
VI. VII.	Felt by all; many people run outdoors. Furniture moved, slight damage occurs. Everyone runs outdoors. Poorly built structures considerably damaged; slight damage elsewhere.	4.5	Some local damage may occur.
VIII. IX.	Specially designed structures damaged slightly, others collapse. All buildings considerably damaged, many shift off foundations, Noticeable cracks in ground.	6.0	A destructive earthquake.
X.	Many structures destroyed. Ground is badly cracked.	7.0	A major earthquake.
XI. XII.	Almost all structures fall. Very wide cracks in ground. Total destruction. Waves seen on ground surfaces, objects are tumbled and tossed.	8.0 and up	Great earthquakes.

Overview of Mandalay Earthquake

- • Date: March 28, 2025, 12:50:52 Local Time
- • Magnitude: 7.7
- • Epicenter: Near Mandalay, 22.011°N 95.936°E
- 10.0 km depth
- • Effects: Significant structural damage, casualties, and disruptions.

Moment Magnitude



Introduction

- • Earthquake-related detailing refers to construction practices that improve seismic resilience.
- • Essential in regions prone to seismic activity like Myanmar.
- • Prevents catastrophic failure of buildings during earthquakes.

Types of Damage Observed

- • Collapse of bridges and buildings
- • Cracks in reinforced concrete frames
- • Failure of structural elements
- • Poor performance of unreinforced masonry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Earthquake induced Lateral Force

Root Causes of Damage

- • Inadequate detailing in construction
- • Lack of ductile reinforcement
- • Poor quality control
- • Ignoring code provisions
- • Informal construction practices

Failure of Column in Shear

Improper confinement of longitudinal bars led to shear failure column during earthquake

Open Ground Storey

Upper storey stiffened by brick walls and less stiffer ground floor

Failure of columns because of poor energy dissipation capacity

Failure of building due to weak column strong beam

Failure of column due to captive effect

Failure of steel frame due to warping torsion

What is Earthquake-Related Detailing?

- • Ductile design
- • Proper stirrup spacing
- • Beam-column joint reinforcement
- • Confinement reinforcement in columns
- • Ensures energy dissipation during quakes
- • Captive effect due to Architectural Requirements

Splice Zone in RC Structure
For Seismic Consideration

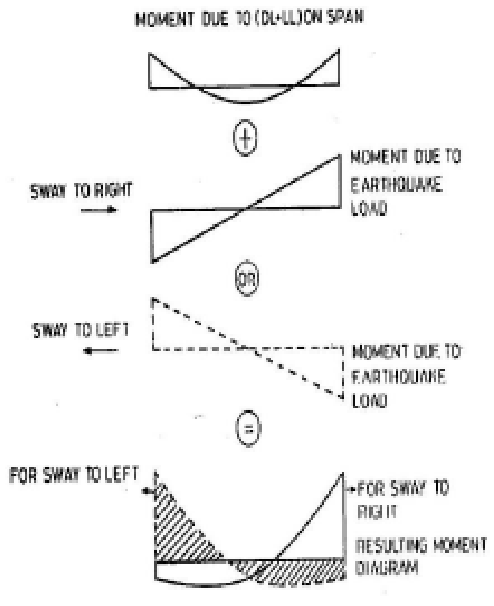


Figure C3 – Reversal of moments due to earthquake loading

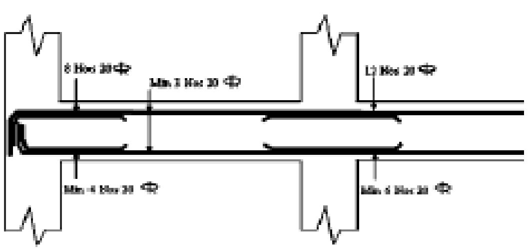


Fig. C4 – Longitudinal reinforcement at the joints in a beam

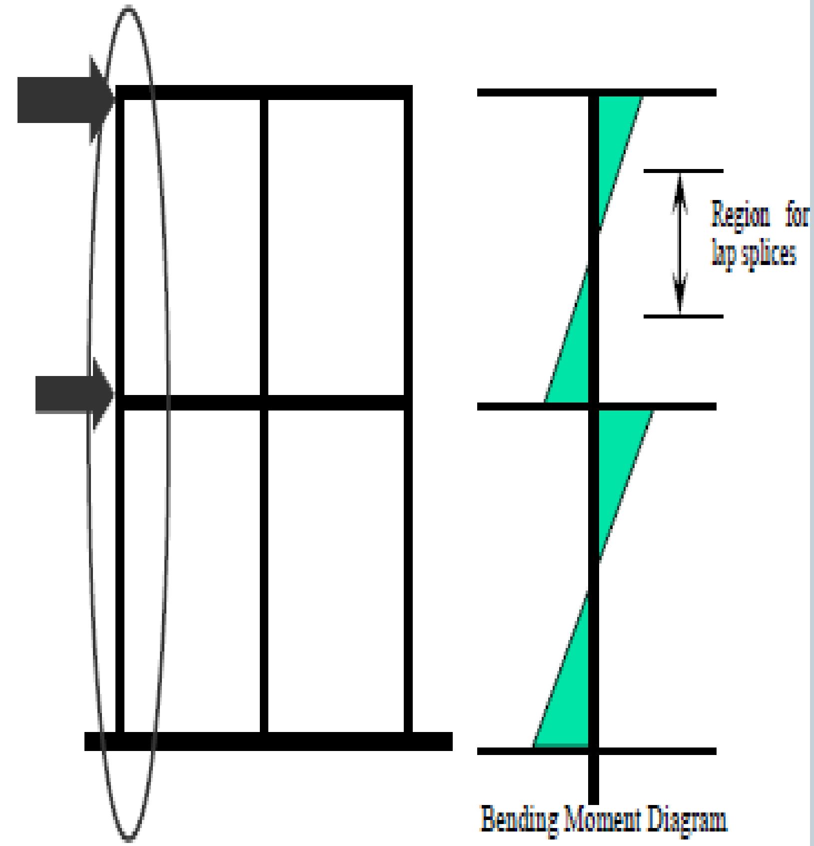


Fig. C7 – Region for lap splices

B. ORDINARY & SEISMIC DETAILINGS OF R. C. STRUCTURES

(1) General

Seismic zones

According to UBC (Uniform Building Code),

Seismic Zones are 0, 1 (Low) ; 2A, 2B (Moderate) ; 3, 4 (High Seismic Risk).

Yangon is considered as in equivalent Zone 2A UBC (Myanmar Zone II/III)

Mandalay is considered as in equivalent Zone 4 UBC (Myanmar Zone V)

[***Note*** *: Myanmar Zones are : I, II, III, IV and V – see the Seismic Zone map*]

Moment-Resisting Frames and Detailing Requirements

(i) Ordinary Moment-Resisting Frames (OMRF) for Zones 0 and 1 (UBC) — require no seismic detailing; ordinary detailing is sufficient

(ii) Intermediate Moment-Resisting Frames (IMRF) for Zones 2A and 2B (UBC) — require detailing for IMRF

(iii) Special Moment-Resisting Frames (SMRF) for Zones 3 and 4 (UBC) — require detailing for SMRF

Note : ***Dual system and other framing systems are not included in this discussion. Dual system means (shear wall / braced frame) + (OMRF / IMRF / SMRF) acting together.***

(2) Ordinary Moment-Resisting Frame Detailing

Slabs

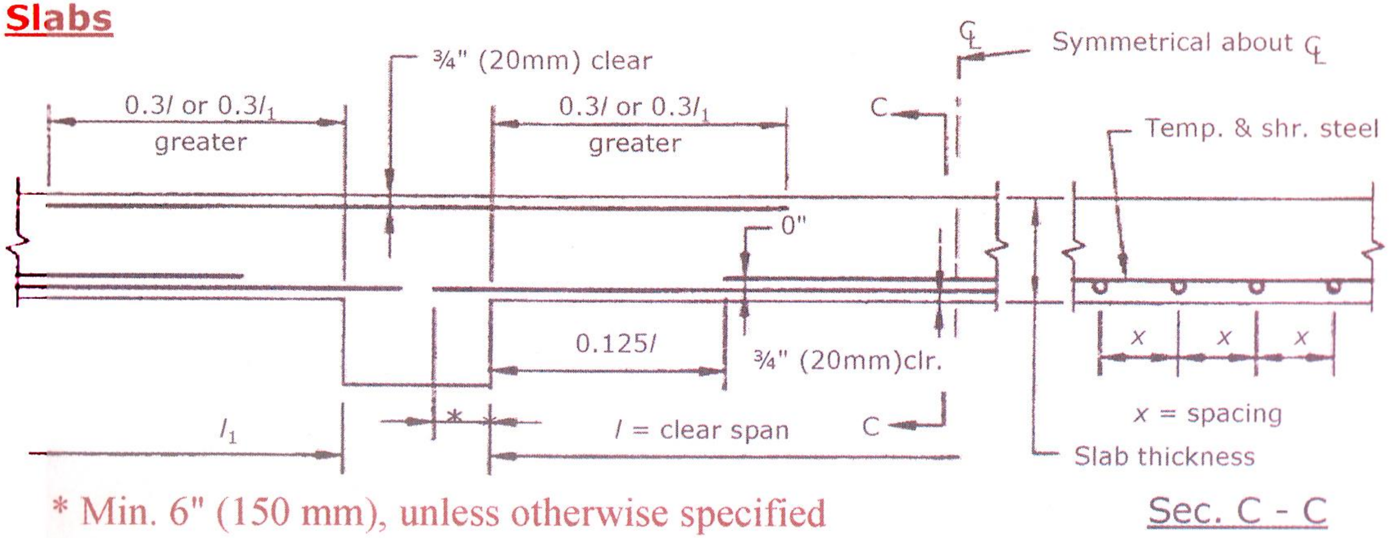


Fig. Interior span, continuous one-way slab

For slabs,

Maximum spacing

= 3h (or) 18″ (one-way slab – for main steel)

= 2h (or) 18″ (two-way slab – for main steel)

= 5h (or) 18″ (for temp. & shr. steel)

Note : $A_{s,min}$ for slab = 0.002 bh for fy = 40/50 ksi (= temp. & shr. steel)

= 0.0018 bh for f_y = 60 ksi (= temp. & shr. steel)

Reference : U Nyi Hla Nge

(2) Ordinary Moment-Resisting Frame Detailing *contd.*

Beams

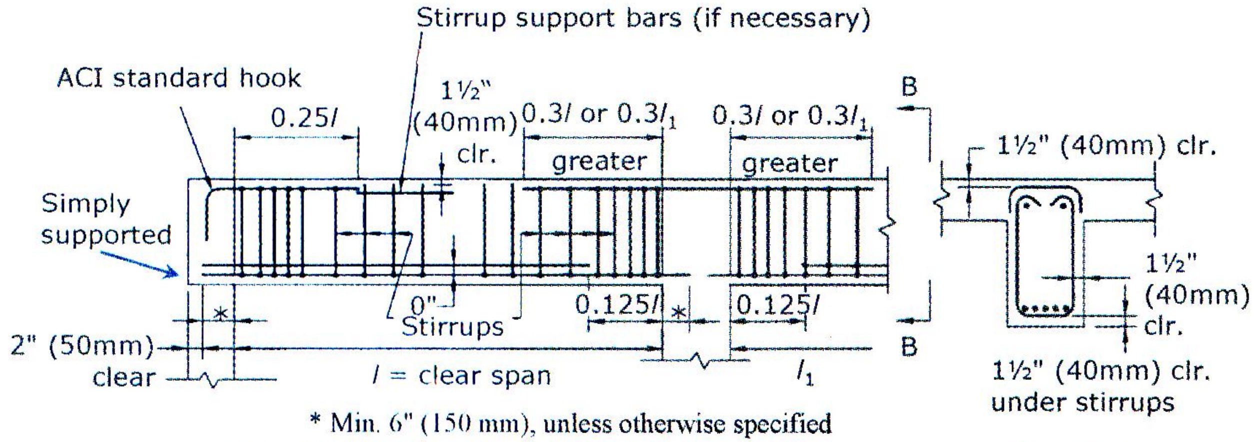


Fig. Non-perimeter beam with closed stirrups Sec. B - B

Note : if the end of exterior-span beam is monolithic with R. C. column or shear wall, assume the same as interior-span beam.

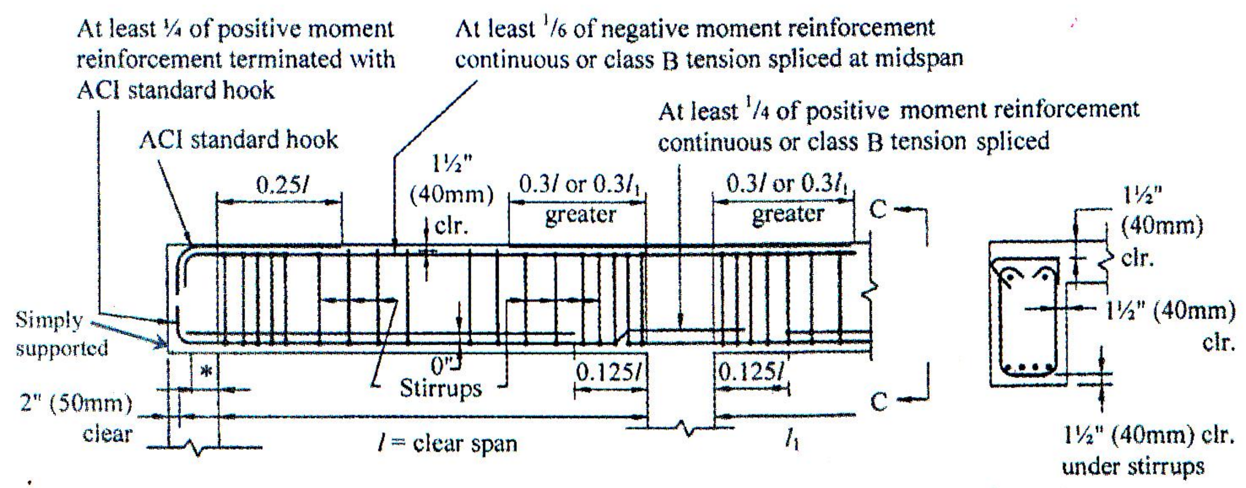


Fig. Perimeter beam Sec. C - C

For *beams*,
max. spacing of stirrups
is the *smallest* of

(1) $s_{max} = \dfrac{A_v f_y}{0.75\sqrt{f_c'}\, b_w} \le \dfrac{A_v f_y}{50\, b_w}$

(2) $s_{max} = \dfrac{d}{2}$

$\left(= \dfrac{d}{4} \text{ if } V_s > 4\sqrt{f_c'}\, b_w d \right)$

(3) $s_{max} = 24$ in.

$(= 12 \text{ in. if } V_s > 4\sqrt{f_c'}\, b_w d)$

(4) $s_{max} = \dfrac{P_h}{8}$ or 12 in.

(closed stirrups for torsion case) where P_h is perimeter of centreline of stirrups.

Note:

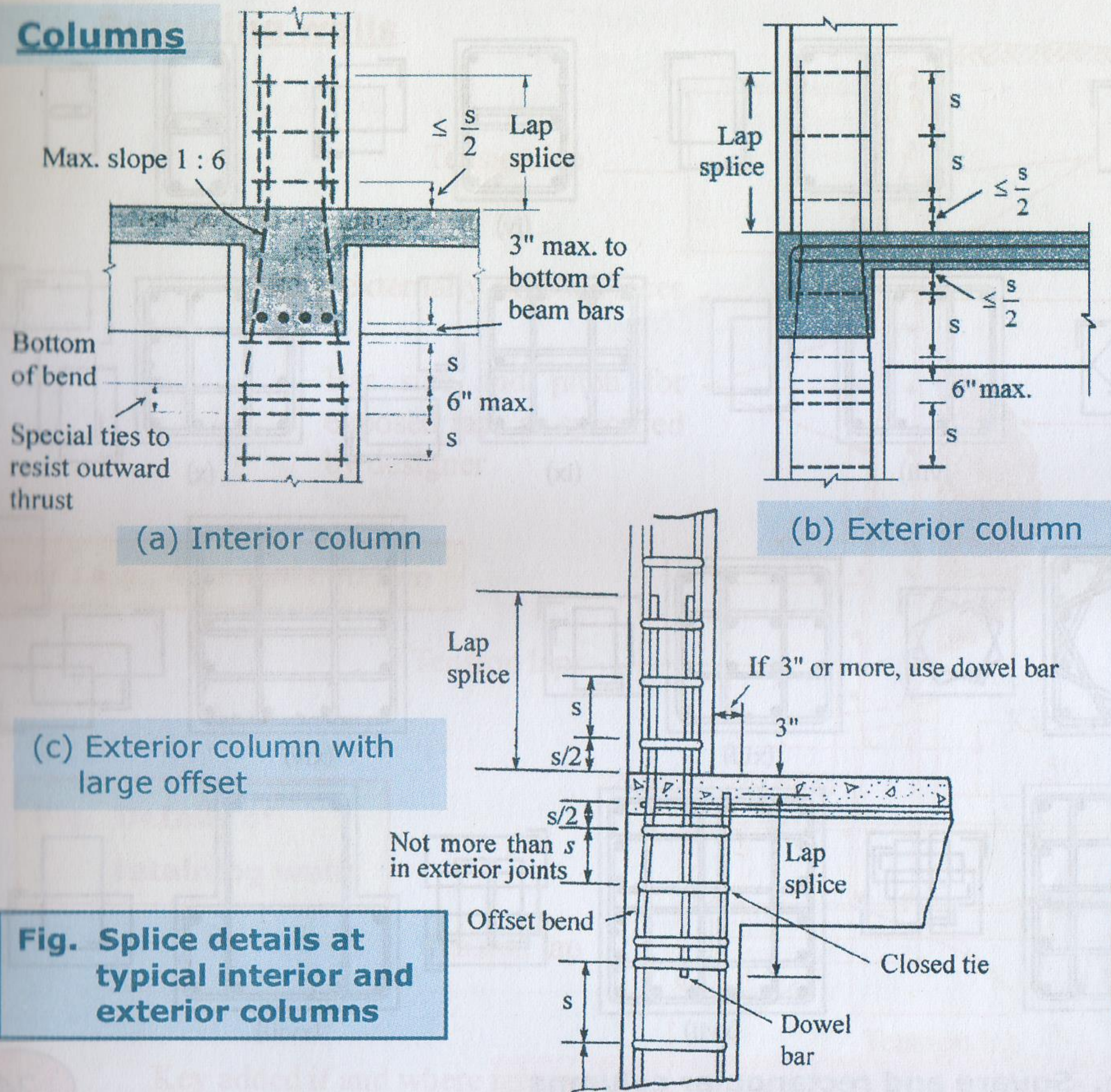
$$\rho_{min} = \frac{3\sqrt{f_c'}}{f_y} \ge \frac{200}{f_y}$$

for main steel

Reference : U Nyi Hla Nge

(2) Ordinary Moment-Resisting Frame Detailing *contd.*

Columns



(c) Exterior column with large offset

Fig. Splice details at typical interior and exterior columns

For tied columns, max. spacing is

(1) $s_{max} = 16\ d_b$

(2) $s_{max} = 48\ d_t$

(3) s_{max} = smaller dimension of column section

Note: *ties at least No. 3 in size; no unsupported main bar shall be farther than 6 in. clear from a supported bar. Lateral support is to be provided by the corner of a tie having an included angle ≤ 135°*

Note: $\rho_{min} = 0.01$; $\rho_{max} = 0.08$

for longitudinal bars

(non-seismic case)

Reference : U Nyi Hla Nge

(2) Ordinary Moment-Resisting Frame Detailing *contd.*

Columns *contd.*

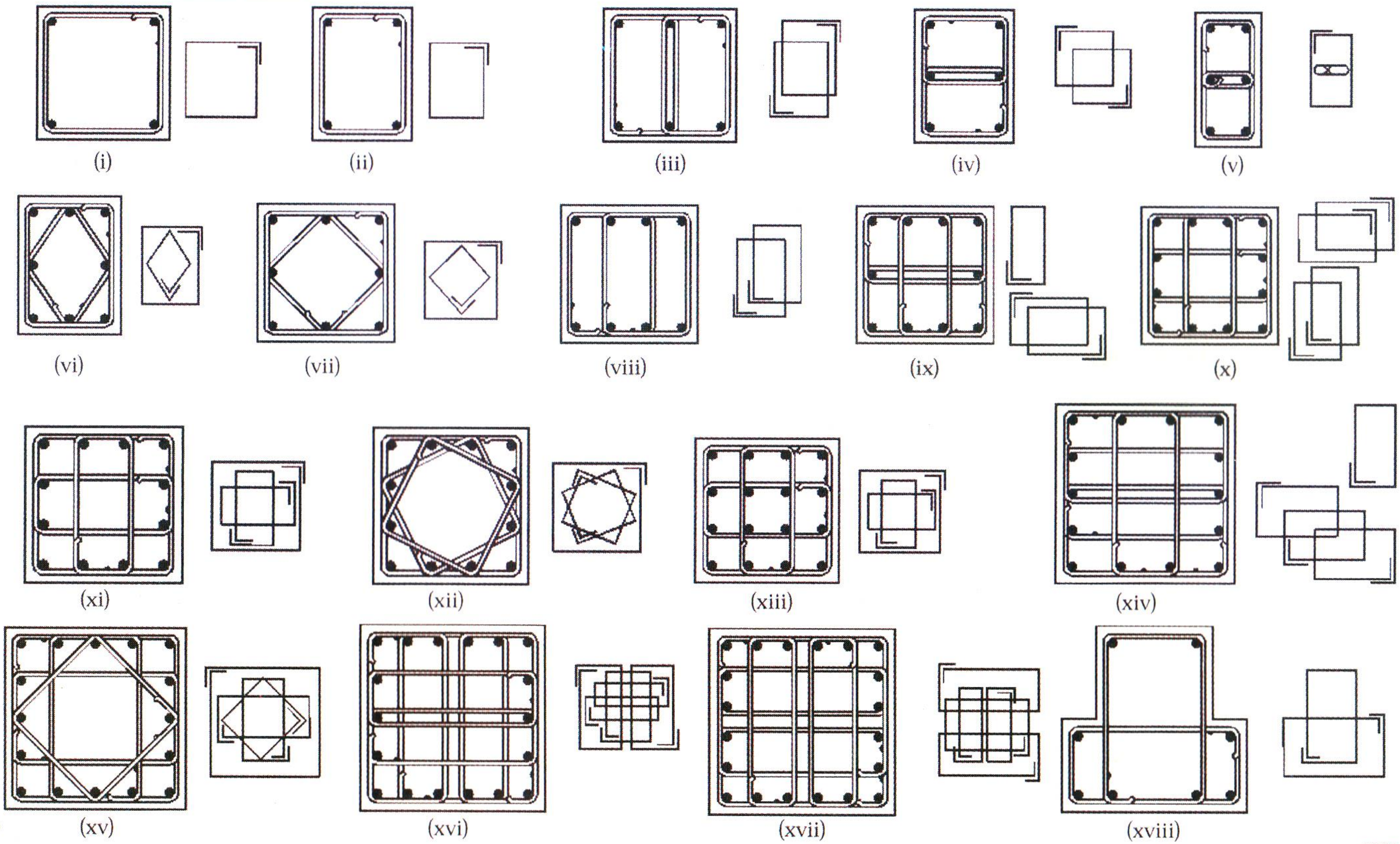


Fig. **Square and rectangular columns**

Reference : U Nyi Hla Nge

(4) Intermediate Moment-Resisting Frame Detailing

Beams

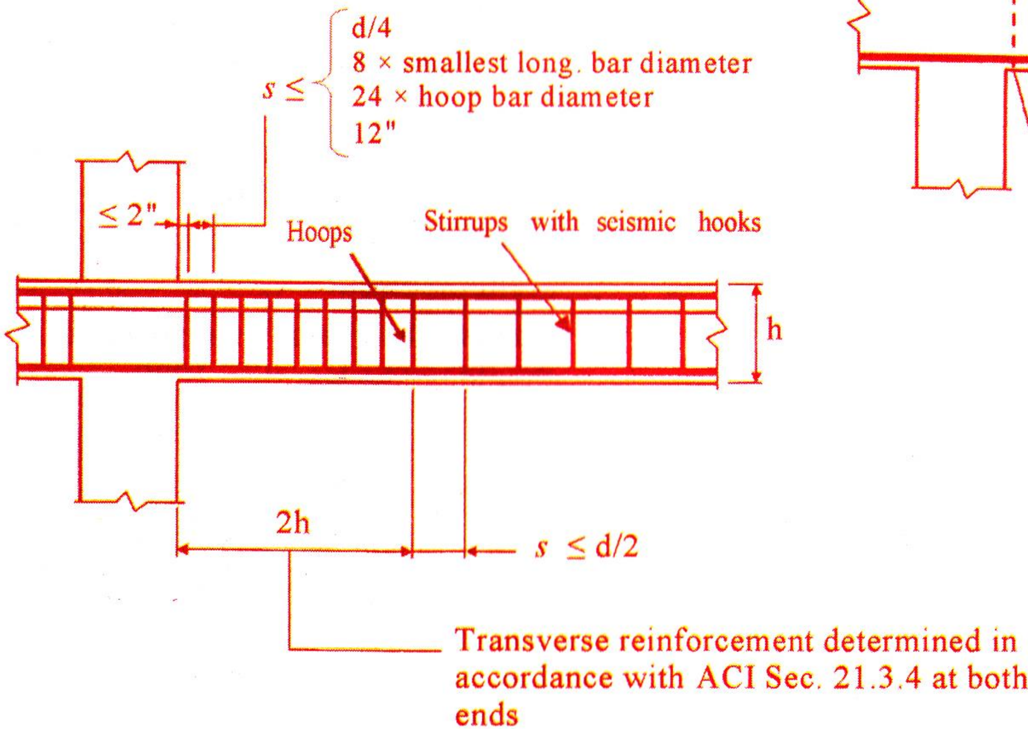


Fig. Transverse reinforcement requirements for beams

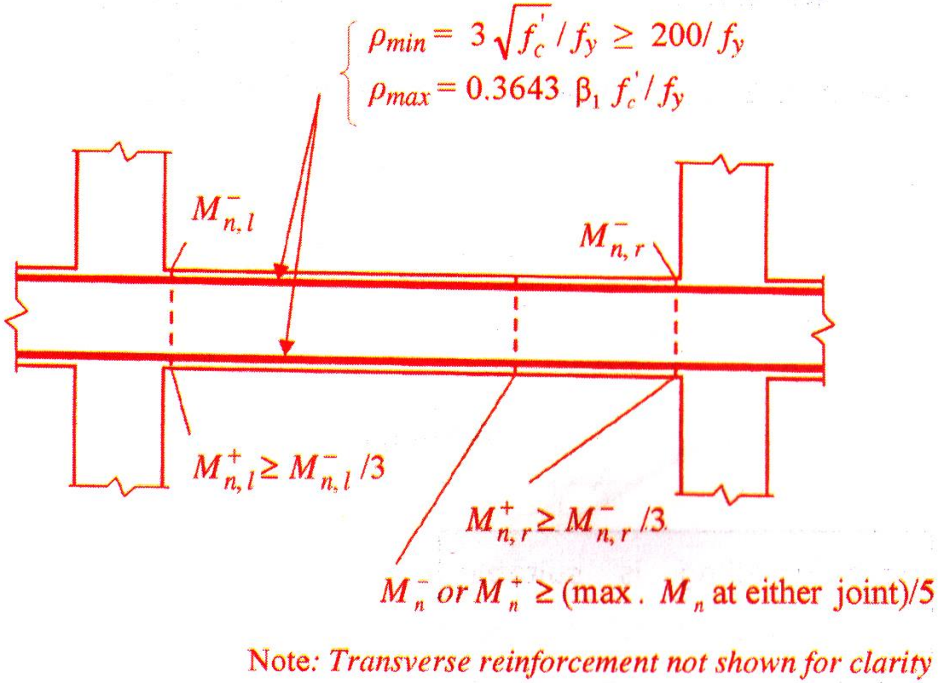


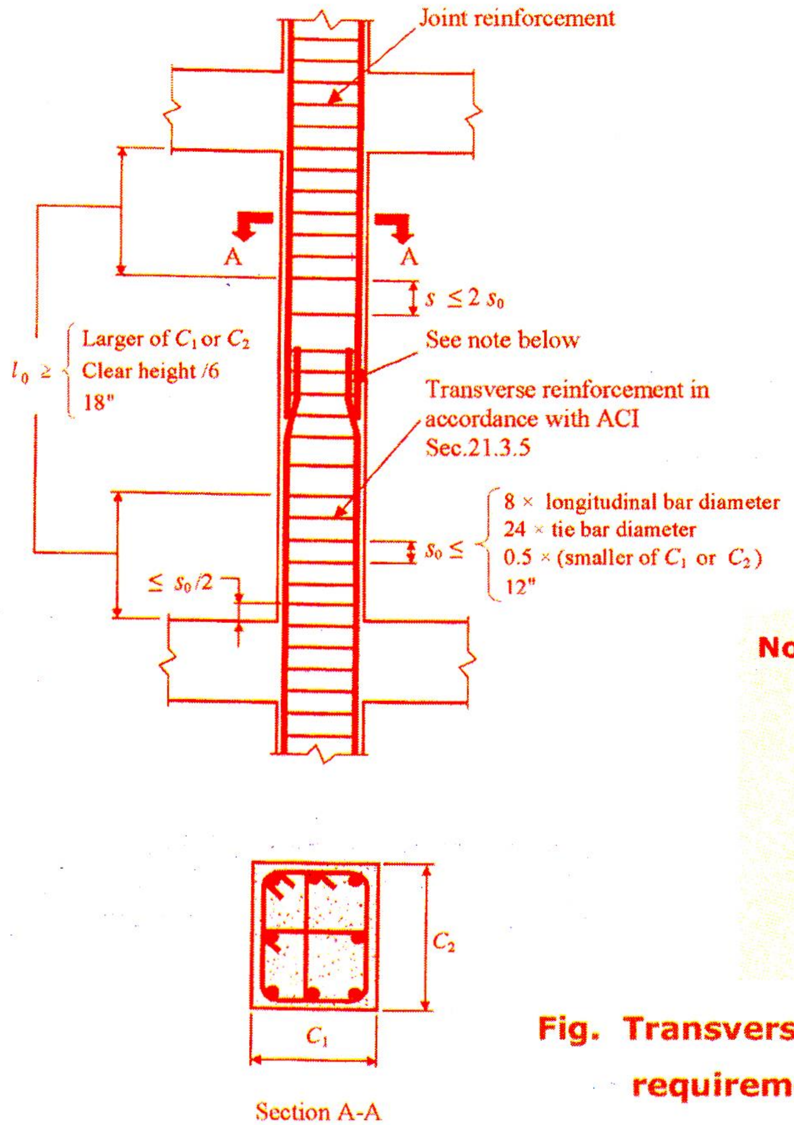
Fig. Flexural requirements for beams

$$\beta_1 = 0.85 \text{ for } f_c' \leq 4000 \text{ psi}$$
$$= 0.80 \text{ for } f_c' = 5000 \text{ psi}$$

Reference : U Nyi Hla Nge

(4) Intermediate Moment-Resisting Frame Detailing *contd.*

Columns

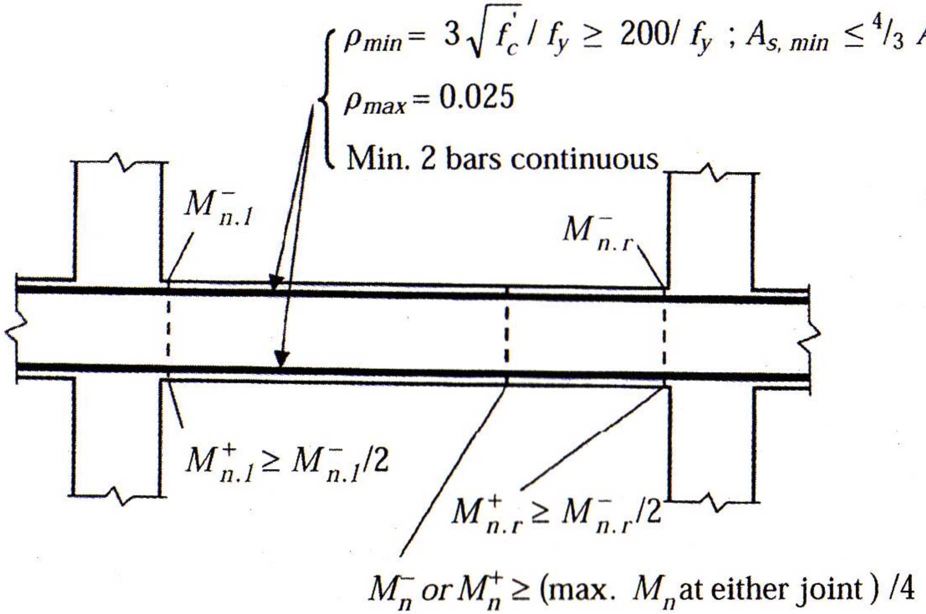


Note: ***There is no restriction on the location of longitudinal bar splices for intermediate moment frames. The splice may be located away from the potential hinge regions (i.e., near the joints) as shown above.***

Fig. Transverse reinforcement requirements for columns

(5) Special Moment-Resisting Frame Detailing

Beams



Note: *Transverse reinforcement not shown for clarity*

Fig. Flexural requirements for beams

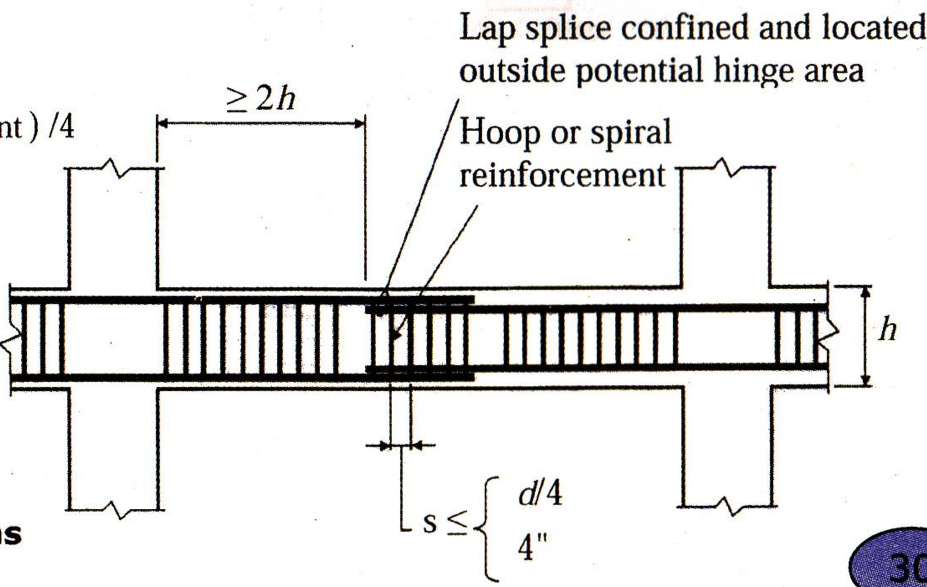


Fig. Lap splice requirements for beams

Reference : U Nyi Hla Nge

(5) Special Moment-Resisting Frame Detailing *contd.*

Beams *contd.*

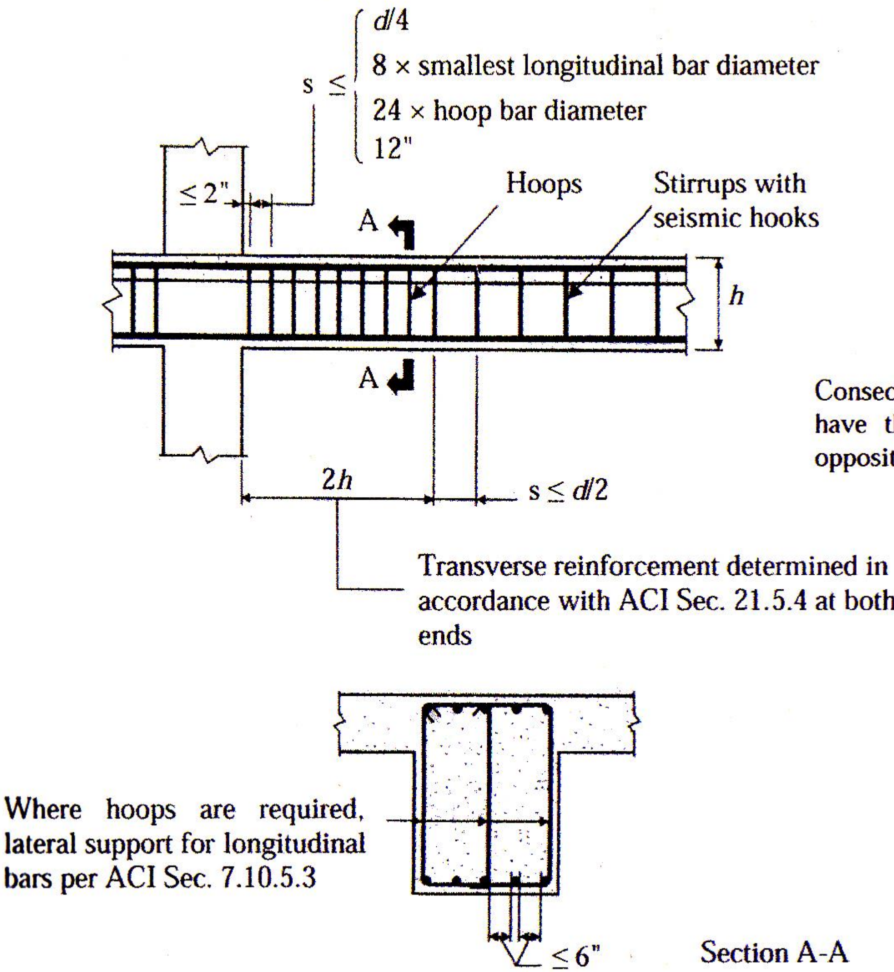


Fig. Transverse reinforcement requirements for beams

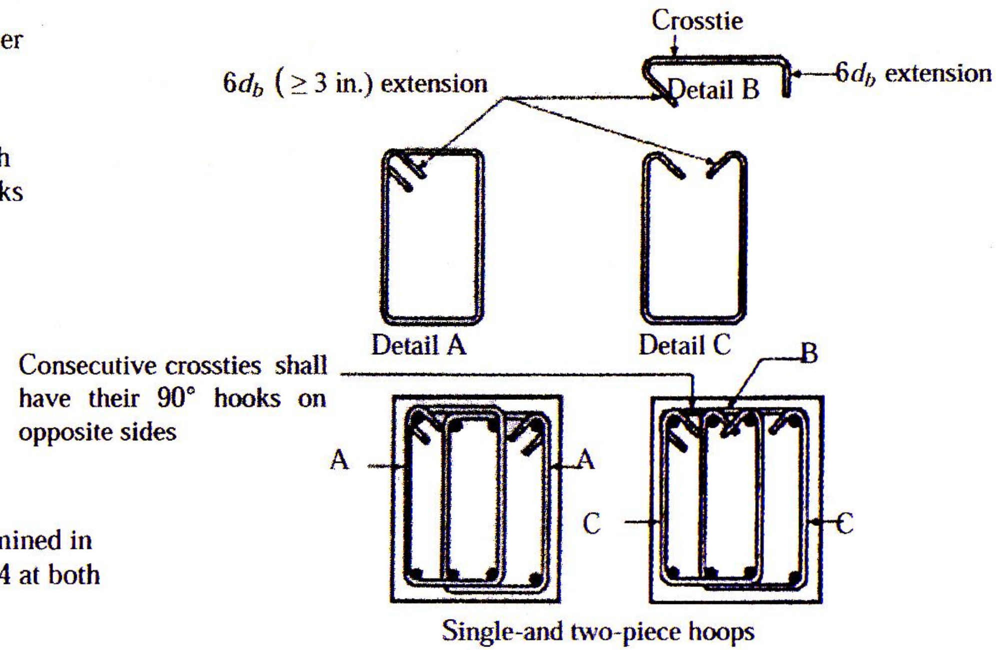


Fig. Hoop reinforcement for beams

(5) Special Moment-Resisting Frame Detailing *contd.*

Columns

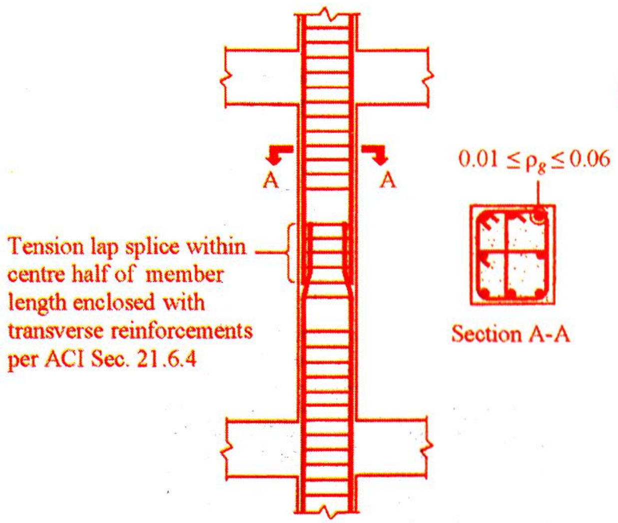


Fig. Longitudinal reinforcement requirements and splices in columns

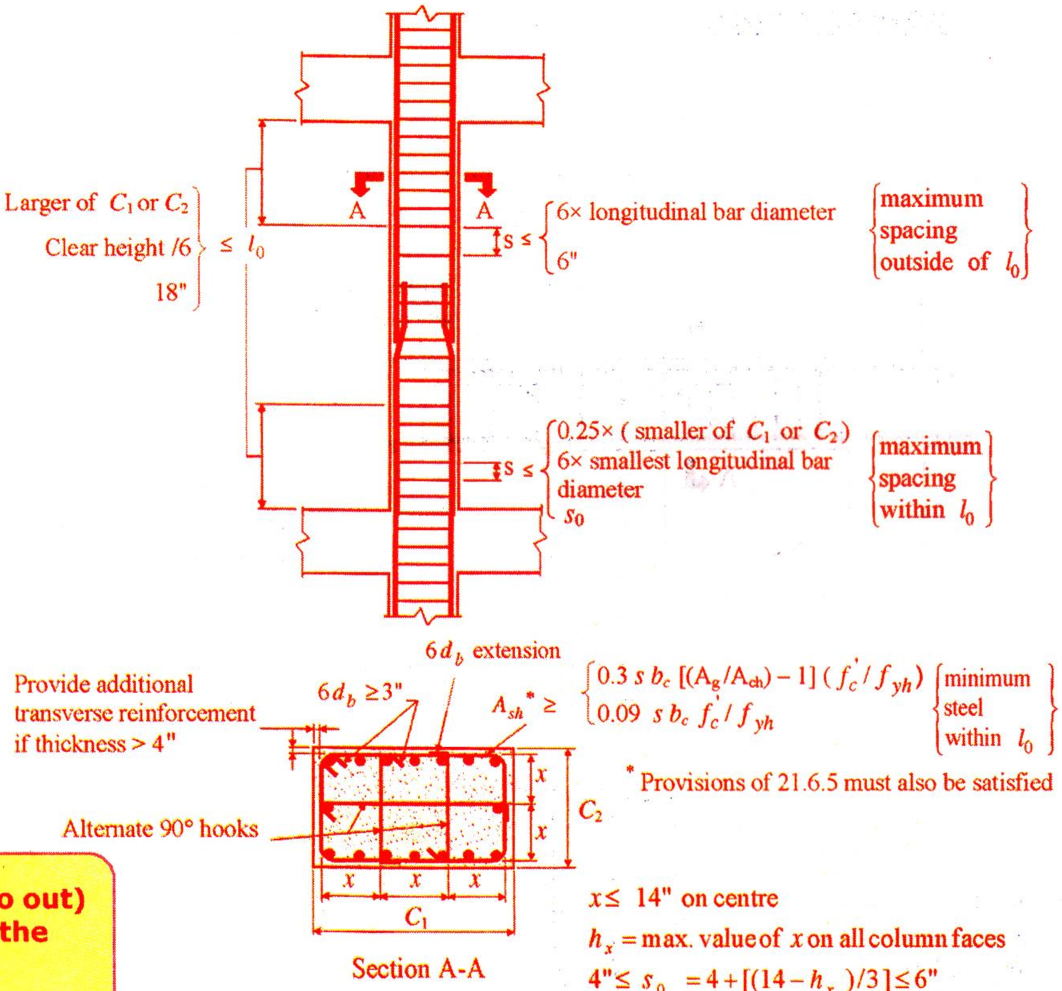


Fig. Transverse reinforcement requirements for columns (rectangular hoops)

b_c = dimension of column core (out to out) in the direction perpendicular to the legs that constitute A_{sh}

A_{ch} = cross sectional area of column core, measured out to out of stirrup steel

Reference : U Nyi Hla Nge

Code Provisions and Best Practices

- • Follow MNBC, ACI, Eurocode standards
- • Proper anchorage and lap splices
- • Shear detailing and confinement
- • Detailing improves ductility and resilience
- • Proper management for Captive Effect

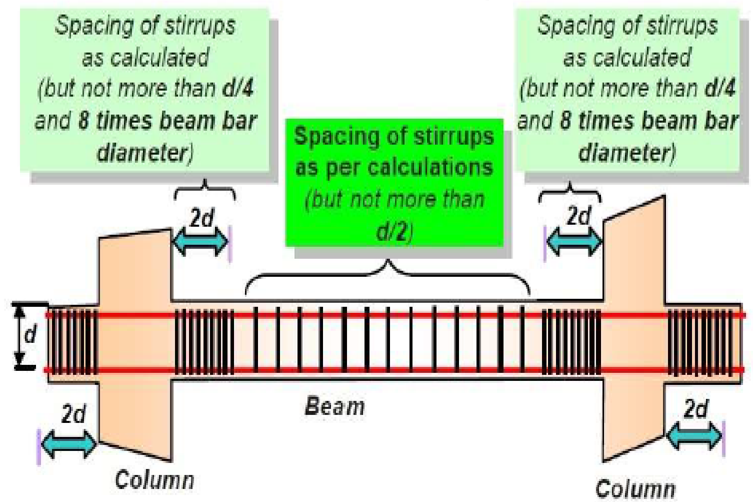
Recommended
Reference Document

Document No. IITGN-WB-EQ4-V3.0
IITGN-WB-EQ5-V3.0
Final Report: IS 13920 Code and Commentary
IITGN - World Bank Project on Seismic Codes

Ductile Design and Detailing of Reinforced Concrete Structures Subjected to Seismic Forces – Code of Practice (IS 13920 : 2016) Proposed Modifications and Commentary

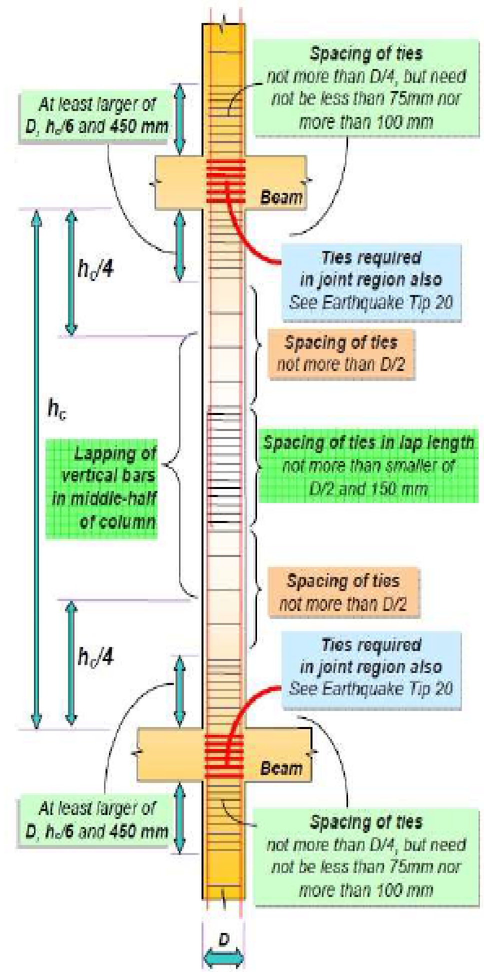
Comparative clauses of detailing a beam (Ordinary and Ductile)

Beam detailing (Ordinary and Ductile)				
Aspect Description	Ordinary detailing (IS 456:2000)		Ductile detailing (IS 13920:2016)	
	Clause	Detail	Clause	Detail
Response reduction factor (as per IS 1893:2016)		R = 3		R = 5
Axial stress limit	43.2	$\le 0.2 f_{ck}$	6.1	$\le 0.08 f_{ck}$
Width - Depth ratio	--	Not available	6.1.1	≤ 0.3
Minimum Width	--	Not available	6.1.2	200 mm
Minimum Depth	--	Design of deep beams are allowed	6.1.3	25 % of Clear span (design of deep beams not allowed)
Flexural reinforcement (Min.)	26.5.1.1 (a)	85/fy (in%)	6.2.1	$0.24 * (f_{ck})^{0.5}/f_y$ (in%)
Flexural reinforcement (Max.)	26.5.1.1 (b)	4.00%	6.2.2	2.50%
Flexural reinforcement (overriding clauses)	--	Not available	6.2.3 and 6.2.4	Yes, Available
Bond (Anchorage)	26.2.1	Development length only	6.2.5	Development length + (10 Times Bar dia.)
Lap splices (location)	26.2.5	Splices shall be provided as far as from the sections of maximum stress and be staggered	6.2.6.1	Shall not be provided with in joint
				Within distance of 2d from face of the column
	26.2.5.1	When bars are spliced at maximum stressed points such as increasing lap and closer spacing of stirrups		Within quarter length of beam adjoining plastic hinge
Transverse reinforcement (Min. Link dia and spacing)	--	No clause specifying min. diameter	6.3.2	Min. diameter of link is 8 mm
	26.5.1.6	Min. shear reinforcement ≥ $(0.4*b)/(0.87*F_y)$	6.3.5 (a)	Min. Link spacing ≤ d/4
	26.5.1.5	Max. Spacing shall be restricted 0.75*d and 300 mm.	6.3.5 (b)	8 times diameter of the smallest longitudinal bar
			6.3.5 (c)	100mm
Transverse reinforcement (closer spacing)	26.2.5.1	Closer spacing of stirrups shall be provided over lap splices	6.3.5.2	Closely spacing over a length 2d on either side of plastic hinge location



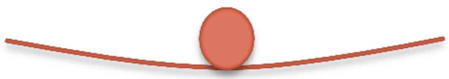
Comparative clauses of detailing a column (Ordinary and Ductile)

Column detailing (Ordinary and Ductile)				
Aspect Description	Ordinary detailing (IS 456:2000)		Ductile detailing (IS 13920:2016)	
	Clause	Detail	Clause	Detail
Response reduction factor (as per IS 1893:2016)		R = 3		R = 5
Axial stress limit	43.2	$\geq 0.2f_{ck}$	7.1	$> 0.08F_{ck}$
Aspect ratio	--	No specific clauses	7.1.2	(Min./Max.) Dimension ≥ 0.45
Minimum Dimensions	--	No specific clauses	7.1.1 (a)	20 times max. diameter of bar in the beam anchoring in to column at joint
	--	No specific clauses	7.1.1 (b)	300mm
Long. reinforcement (Min.)	26.5.3.1	0.80%	--	No specific clauses
Long. reinforcement (Max.)	26.5.3.1	6% (But limited to 4%)	--	No specific clauses
Lap splices (location)	SP-34, Fig 7.9A - 7.9 E and IS 456:2000, cl.26.2.5	Lap splice shall be provided at 75mm above floor level. But shall not be provided in the locations where stress can be maximum	7.3.2.1 ©	Shall be provided only in central zone
				Shall not be provided in joint
				Shall not be provided withina distance of 2d from the face of beam
Transverse reinforcement (Min. Link dia and spacing)	26.5.3.2 (c,2)	Diameter shall not be less than 1/4th of largest longitudinal bar dia.	7.4.2 (a)	Min dia. Is 8mm/10mm depending on diameter of main bar
	26.5.3.2 (c,2)	Spacing shall not be less than the following:	7.4.2 (b, d)	Max. spacing shall be limited to 300mm or half of the least lateral dimension of column
		Least lateral dimension of compression members	8.1 (b) (1)	Min spacing shall be less than 1/4th of min. dimension of the column
		16 times the smallest dia of long. Bar	8.1 (b) (2)	Min. spacing shall be less than 6 times the diameter of smallest main bar
		300mm		
			8.1 (b) (3)	Min spacing shall be 100mm
Cross tie limit		Yes. To be provided when exceeds 300mm	7.4.2 ©	Yes. To be provided when exceeds 300mm
Transverse reinforcement (closer spacing)	--	No specific clauses	8.1 (a)	Shall be provided in locations of flexural yielding only and over lap splices

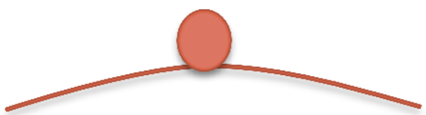


STEEL STRUCTURE (AISC Seismic Provisions)

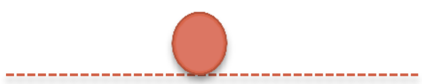
Structural Stability



Stable Equilibrium



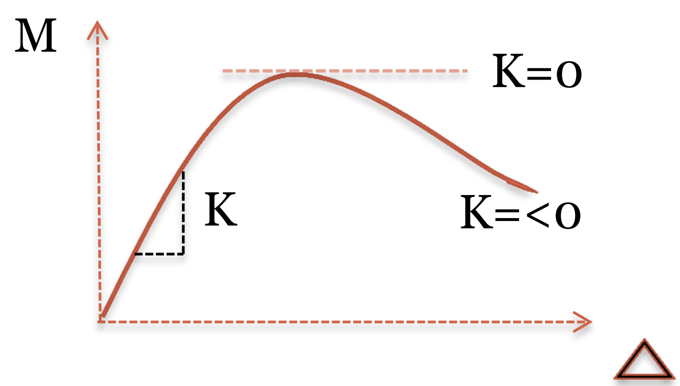
Instable Equilibrium

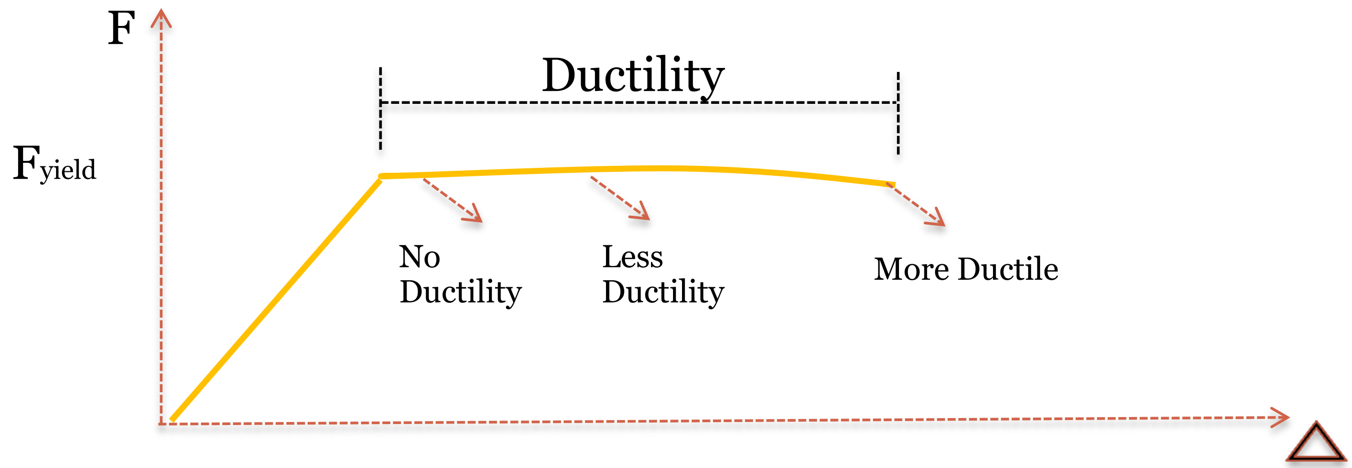


Neutral Equilibrium

- Structure Stiffness down as Loads up
- Change in stiffness due to large deformation and/or material inelastic
- Load capacity reach when stiffness = 0 (Neutral Equilibrium)
- When stiffness negative = -ve (Instable Equilibrium)

Structural Stability Failure





Ductility = Ability to sustain large inelastic deformations without significant loss in strength

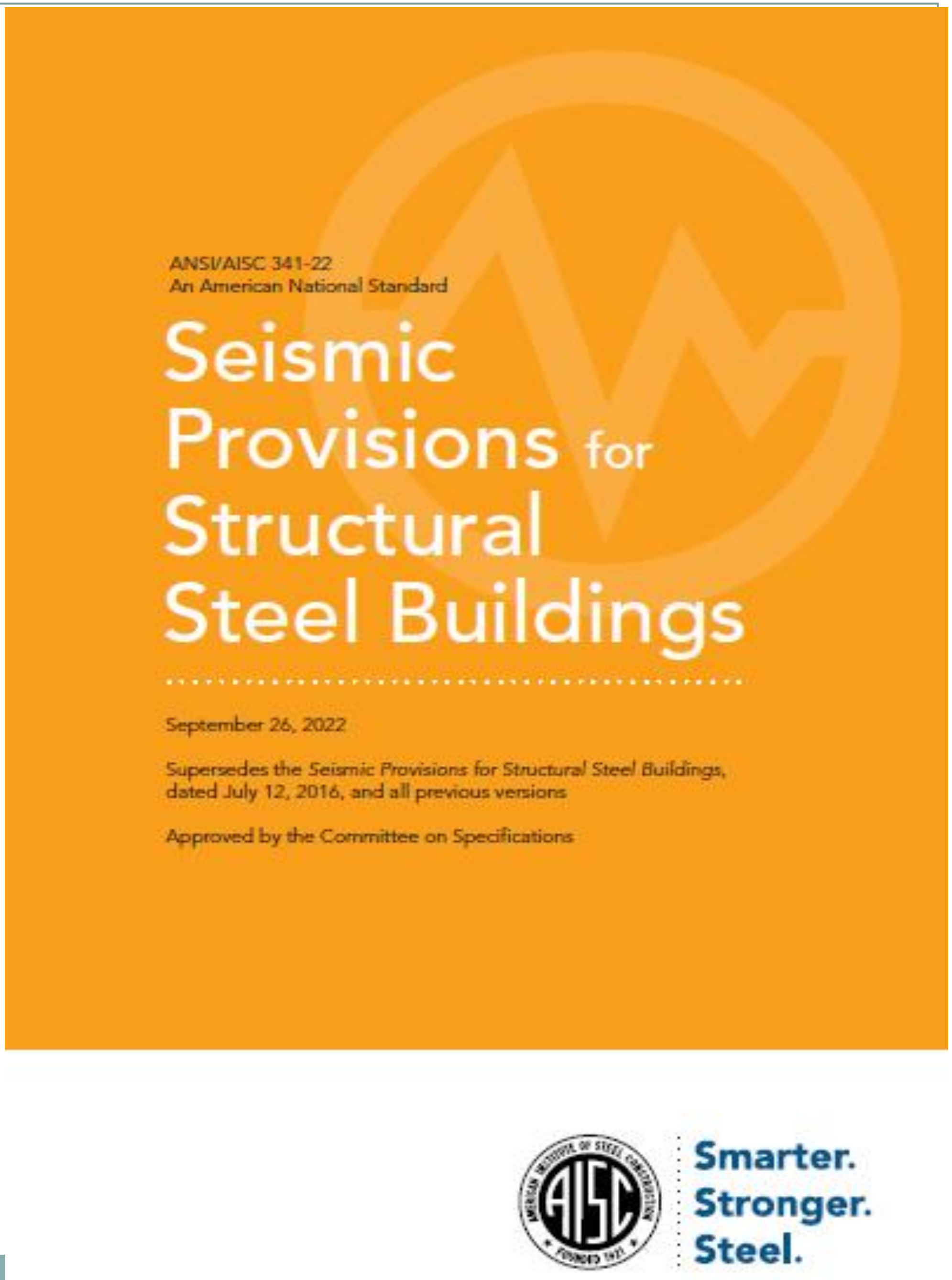
FOR STABLE EQUILIBRIUM

Material Requirement

Member & Connections Requirement

Structure Requirement

Recommended Reference Document


ANSI/AISC 341-22
An American National Standard

Seismic Provisions for Structural Steel Buildings

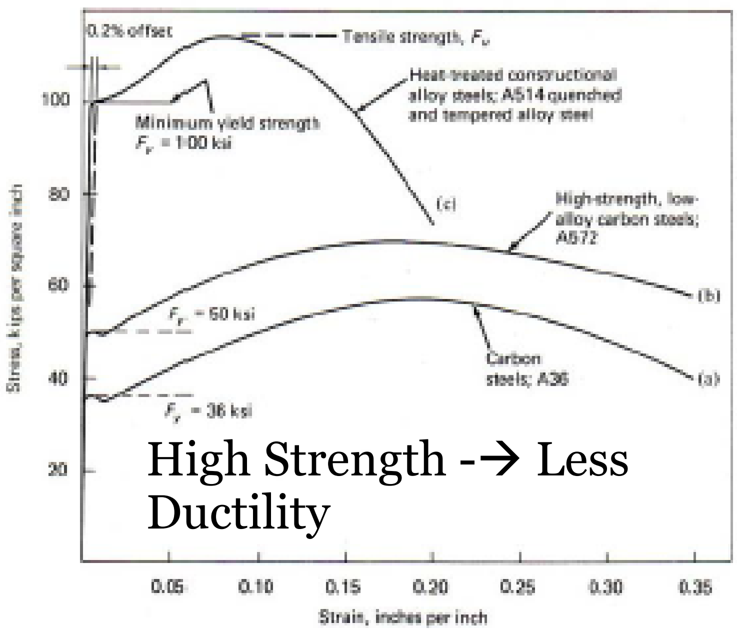
September 26, 2022

Supersedes the *Seismic Provisions for Structural Steel Buildings*, dated July 12, 2016, and all previous versions

Approved by the Committee on Specifications

MATERIAL REQUIREMENTS

- Limit maximum Yield Stress = 50 Ksi
- Use expected yield stress F_y (expected) = R_y F_y (min. yield stress)



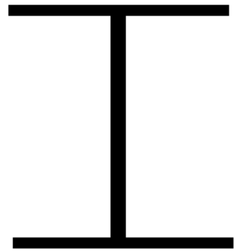
TRUE STRENGTH FACTOR

ตารางที่ 2 ค่าตัวคูณเพื่อหากำลังครากจริงของวัสดุ[2]

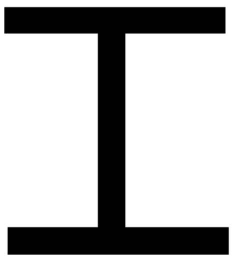
ชนิดของหน้าตัดและวัสดุ	R_y
เหล็กรีดร้อน (Hot-Rolled Section)	
ASTM A36	1.5
ASTM A572	1.3
เหล็กกลวง (Hollow Steel Section)	
ASTM A500	1.3
ท่อเหล็ก (Structural Steel Pipe)	
ASTM A53	1.4

MEMBER REQUIREMENTS

- Use compact section
- Use expected yield stress F_y (expected) = R_y F_y (min. yield stress)
- Use low b/t rations with adequate lateral bracing

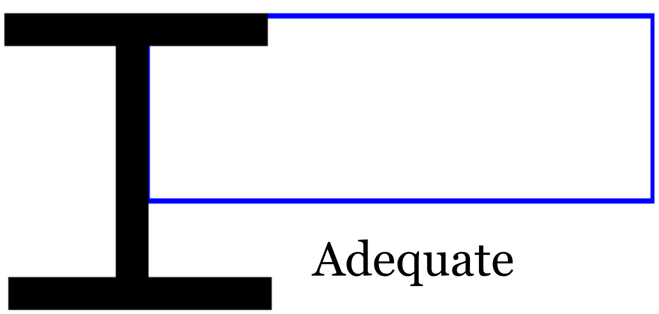


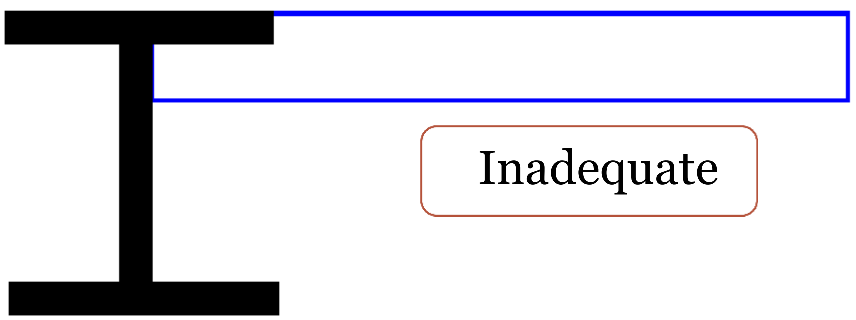
Non-compact section

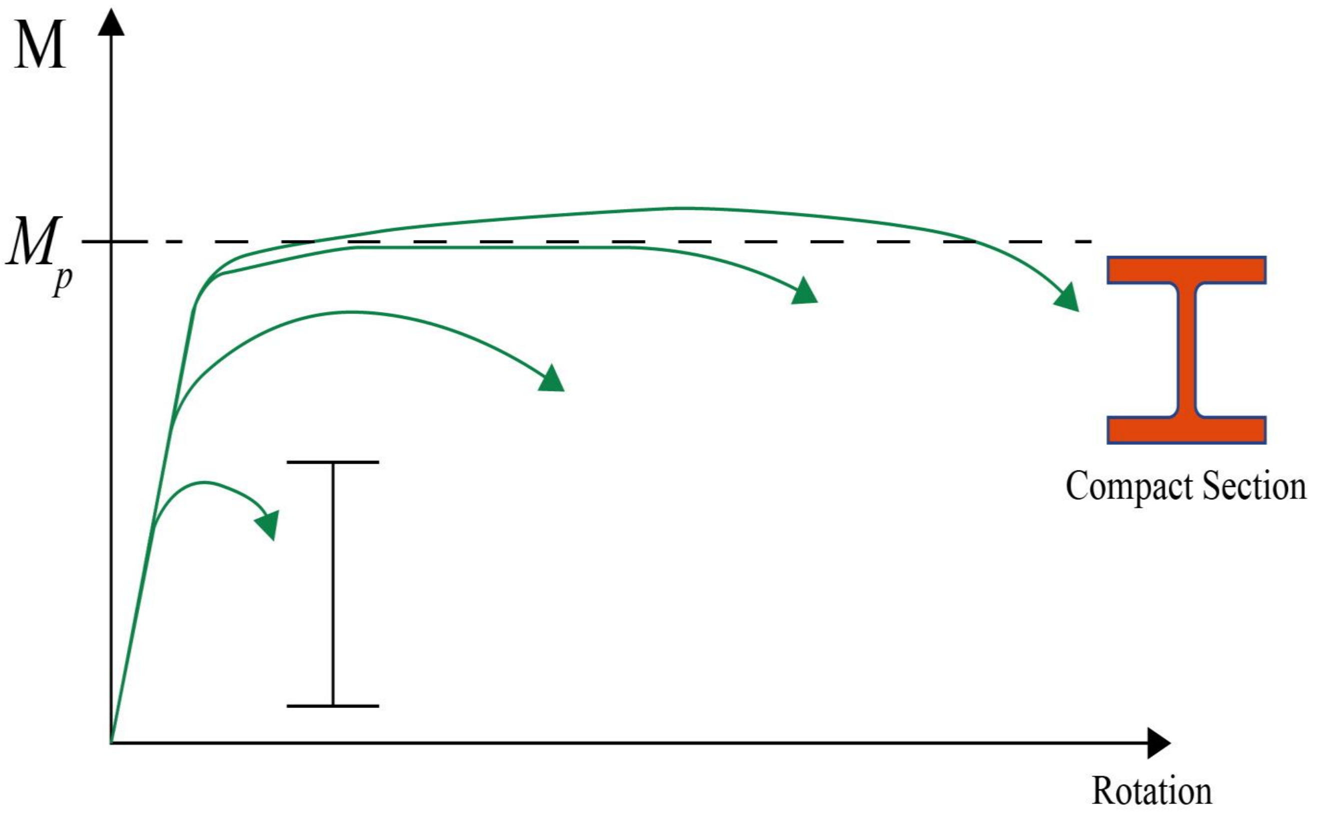


Compact section

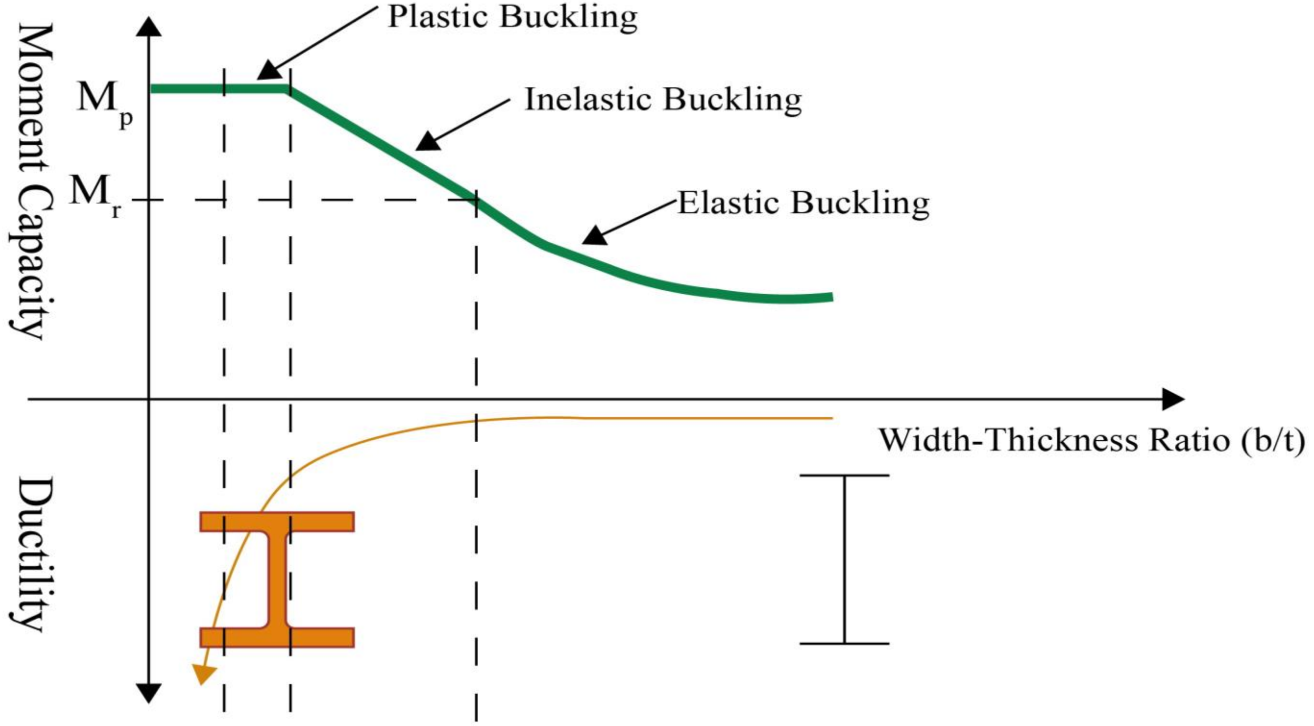
* Prevent Lateral Torsional Buckling







M
M_p
Compact Section
Rotation


Plastic Buckling
Inelastic Buckling
Elastic Buckling
Moment Capacity
M_p
M_r
Width-Thickness Ratio (b/t)
Ductility

Moment Frame

- OMRF (Joint design for 1.1 $R_y M_p$)

Ductility class medium

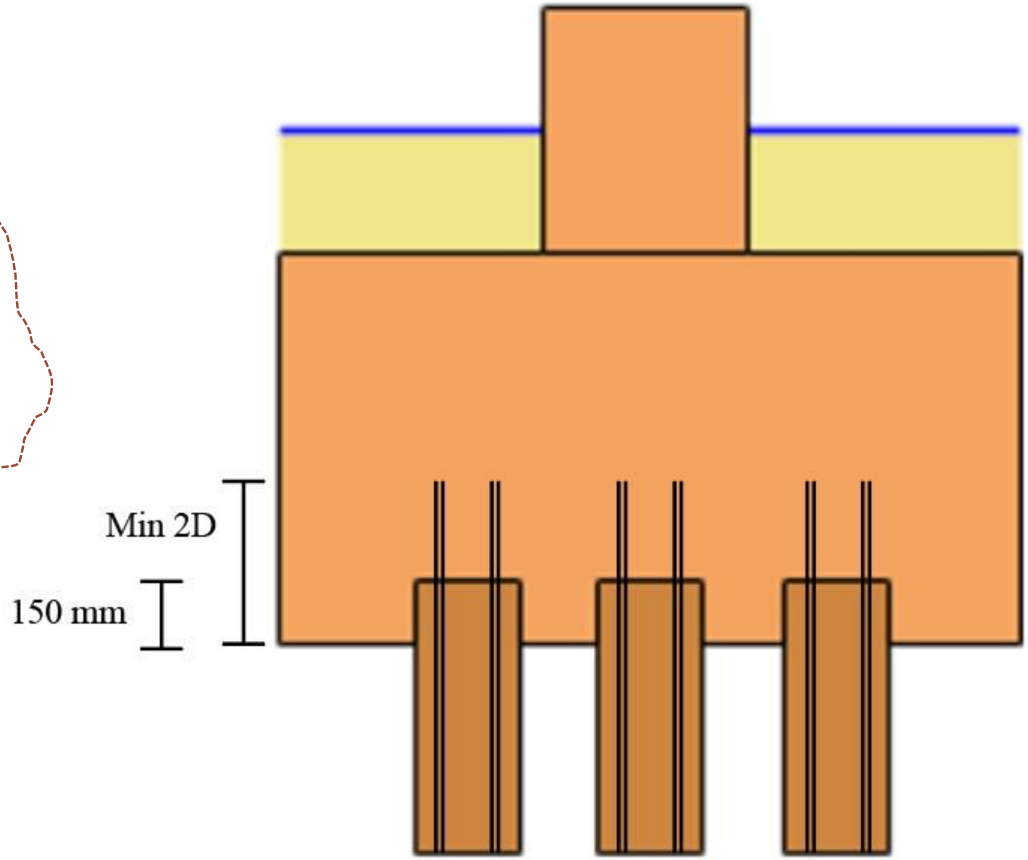
- IMRF (0.02 radian rotation requirement at joint)

Ductility class high

- SMRF (0.04 radian rotation requirement at joint)

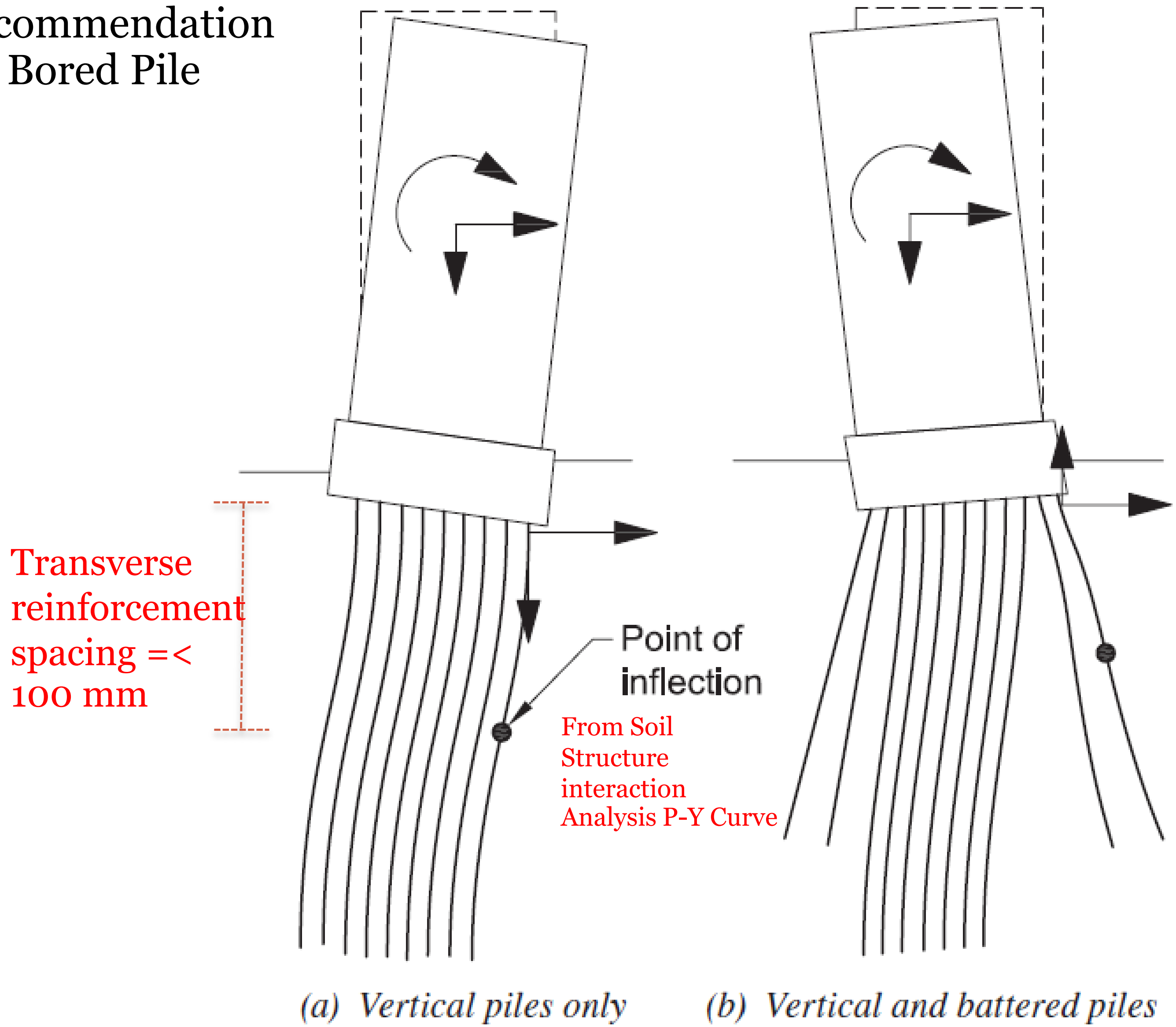
Pile Reinforcement Recommendation
For Driven Pile / Pressed Pile

PILE HEAD
TREATMENT
IS
NECESSARY



Fixed connection for Ductility & Energy Dissipation

Pile Reinforcement Recommendation for Bored Pile



C-D4.1. Deformations of piles and forces acting on an individual pile.

Code Provisions and Best Practices

- • Follow AISC strength limit
- • Ductile member shall be weakest in the Load Path
- • Provide connections stronger than members
- • Avoid high strength steel in ductile elements
- • Use cross section with low b/t ratios
- • Provide adequate bracing

Lessons from Mandalay

- • Importance of code compliance
- • Need for skilled professionals
- • Retrofitting and maintenance
- • Risks of informal construction

Comparison of Structures

- • Properly detailed structures: Minor damage / No damage
- • Poorly detailed structures: Severe damage or collapse

Detailing improves performance significantly

Recommendations

- • Enforce seismic design codes
- • Train foreman, engineers, architects, and workers
- • Retrofit vulnerable structures
- • Conduct public awareness campaigns
  - Lack of Permit / Inspection
  - Hiring unskilled/ uncertified workers
  - Using substandard materials
  - Inadequate foundation system
  - Unpermitted extensions (overloading the original structure)
  - Lack of material testing
  - Absence of engineering design, etc.

Poverty & Affordability / Lack of access to formal service /difficult permitting process / Traditional construction methods / Lack of awareness for long term risks

Conclusion

- • Earthquake detailing is critical for safety
- • Mandalay earthquake highlights the need

Structural safety = Ductile design + Detailing + Supervision + Enforcement

For cross border engineering services among Asean countries

- ASEAN OCCUPATIONAL SKILL STANDARD
FOR
CONSTRUCTION

- LOCAL PRACTICES AWARENESS TRAINING ON CONSTRUCTION COMPLIANCE
For
Foreign Workers & Foremen

Importance of Earthquake-Related Detailing in Construction:

Thank you very much
for
kind attention

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ACPE (Civil), Thailand RFPE (Civil)

Any Questions?