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Technical Session

PT Buildings II

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Anchorage Zone Reinforcement: How important and whose responsibility is it?

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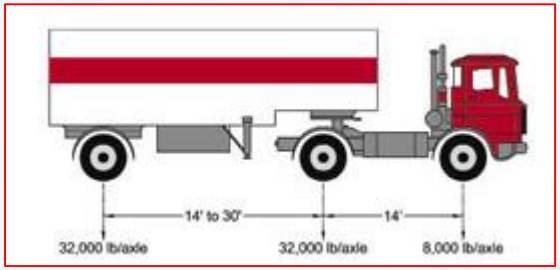
Presentation Content

- Introduction
- Types of anchorage devices
- Definition of anchorage zones
- Stresses in anchorage zones
- Main factors affecting the behavior of the zones
- Local zone reinforcement
- General zone reinforcement
- Responsibilities
- Summary

Introduction

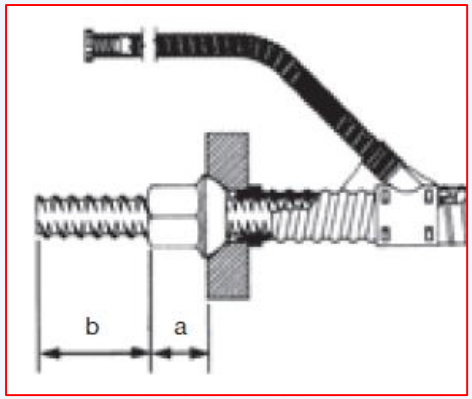
- Post-tensioning introduces large, concentrated forces into structures.
- Significant amount of energy is stored in stressed tendons. PTI's Anchorage Zone Design: "The spring energy stored in four 19-0.6" strand tendons of 650 ft. of length is theoretically sufficient to launch an HS 20-44 truck over a seven-story building".

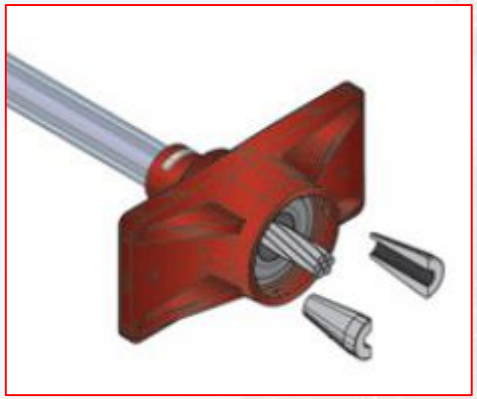


- These large forces are applied to the anchorage that in turn transfer high compressive and tensile stresses to the anchorage zone.
- The anchorage zone is critical for the proper performance of a post-tensioning tendon.

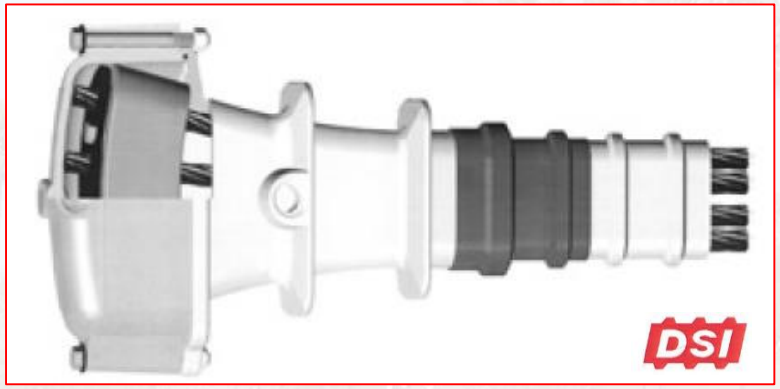
Types of anchorage devices

- Basic anchorage devices





- Special anchorage devices



Multiple bearing surfaces and performance typically evaluated by testing.

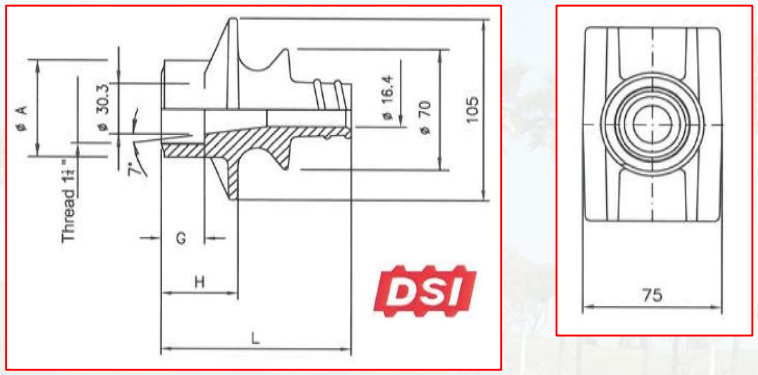
Types of anchorage devices (cont'd)

- Some mono-strand anchorages, used mostly abroad, are special anchorage devices with two bearing surfaces.

Type of Tendon		Unbonded	Bonded
Strand	Mono	B/S	B/S
	Multi	B/S	B/S
Bar		B	B

B: Basic anchorage device
S: Special anchorage device

Type of Anchorage Devices by Type of Tendons

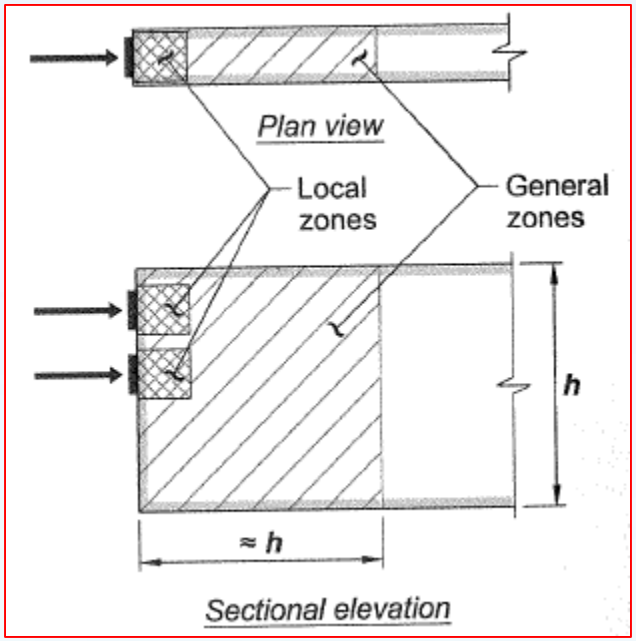


Unbonded monostrand anchorage

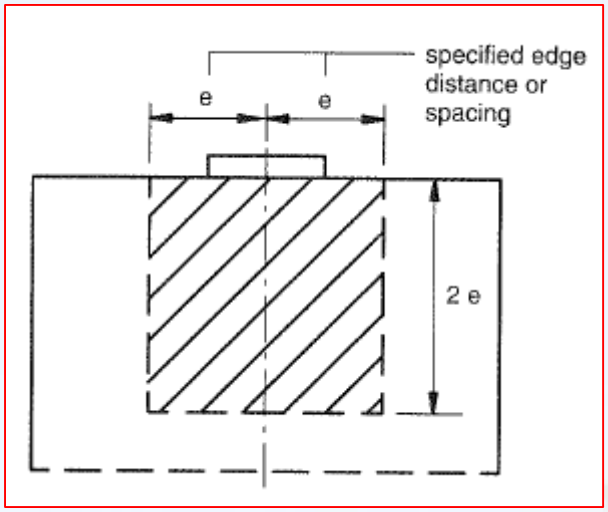
Definition of anchorage zones

Anchorage Zone	AASHTO LRFD	ACI 318
Local	The volume of concrete that surrounds and is immediately ahead of the anchorage device and that is subjected to high compressive stresses.	The rectangular prism of concrete immediately surrounding the anchorage device and any confining reinforcement.
General	The region adjacent to a post-tensioned anchorage within which the prestressing force spreads out to an essentially linear stress distribution over the cross-section of the component.	The portion of the member through which the concentrated prestressing force is transferred to the concrete and distributed more uniformly across the section.

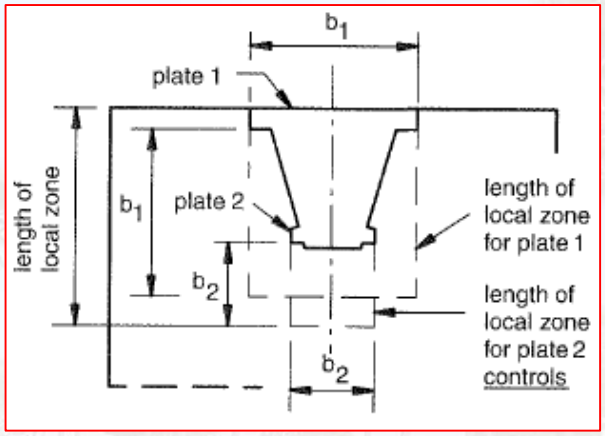
Definition of anchorage zones (cont'd)



Local and general zones (ACI 318-14)

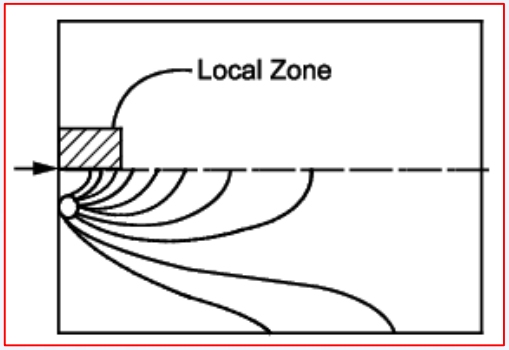


Local zone based on supplier's recommendation (AASHTO LRFD)

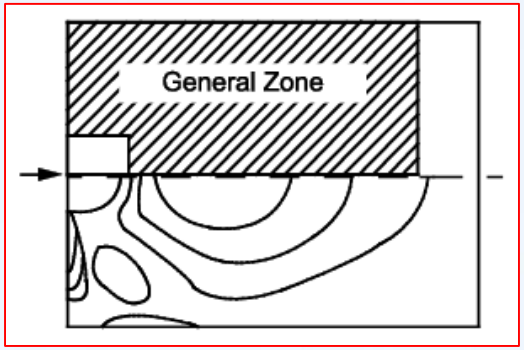


Local zone based on anchorage's dimensions (AASHTO LRFD)

Stresses in anchorage zones

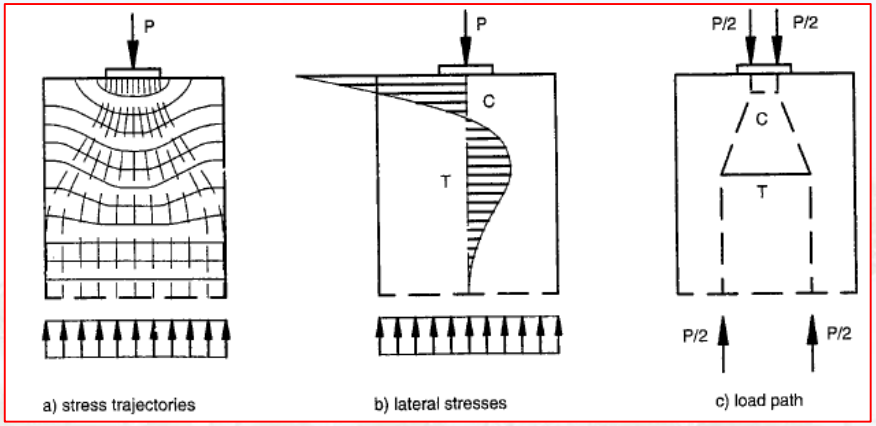


Principal Compressive Stresses
(AASHTO LRFD)



Principal Tensile Stresses
(AASHTO LRFD)

Example shows stresses in a rectangular beam loaded by concentric tendon anchorage force.



Flow of Stresses
(PTI Anchorage Design)

- Bearing and compressive stresses immediately ahead of the bearing plate.
- Tensile (bursting) stresses over some distance ahead of the bearing plate.
- Local tensile stresses (spalling) along the loaded edge of the member.

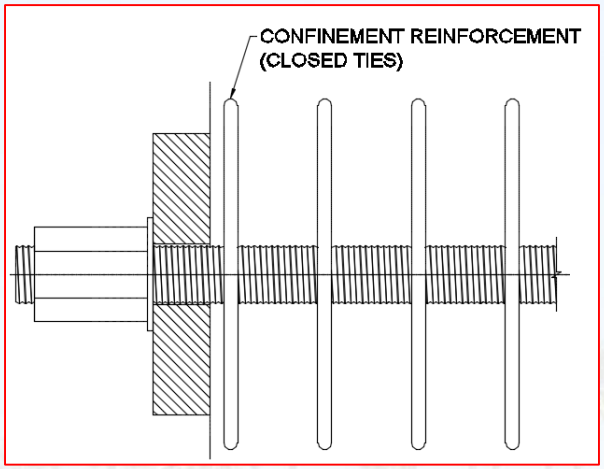
Main factors affecting the behavior of the zones

- Local zone:
  - Geometry of the anchorage device.

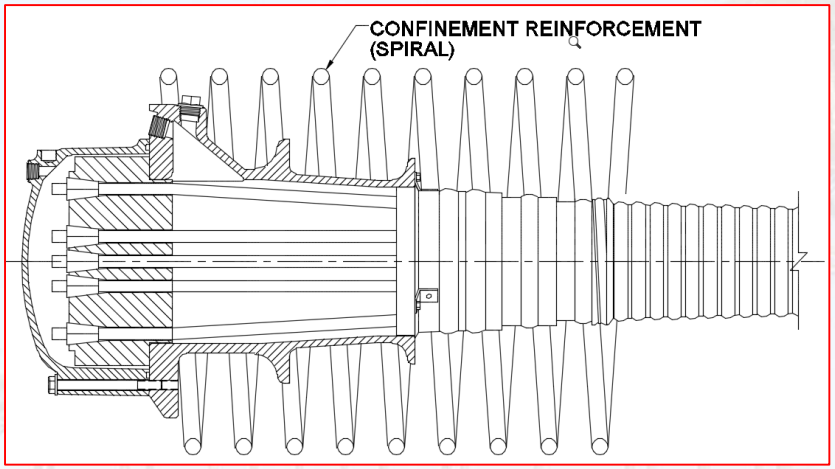
- General zone:
  - Tendon arrangement
  - Anchorage layout (i.e., number of anchorages, relative location)
  - Geometry of the structure
  - Stressing sequence
  - Other loading acting on the general zone (i.e., reaction forces, torsion).

Local zone reinforcement

- The local zone experiences very high stresses transferred by the bearing surfaces of the anchorage device.
- The main design consideration is the presence of high compressive stresses and the need of confinement reinforcement to increase the compressive strength of concrete.



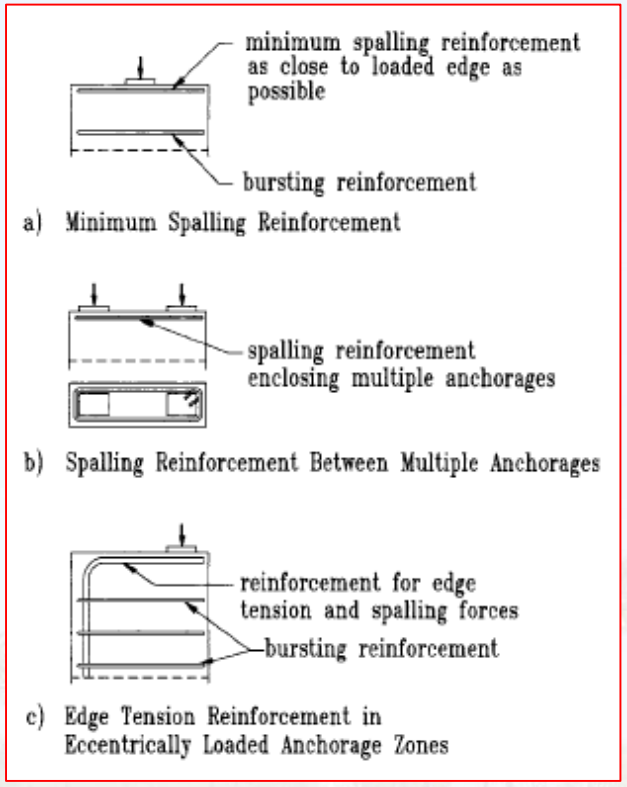
Basic Anchorage Device



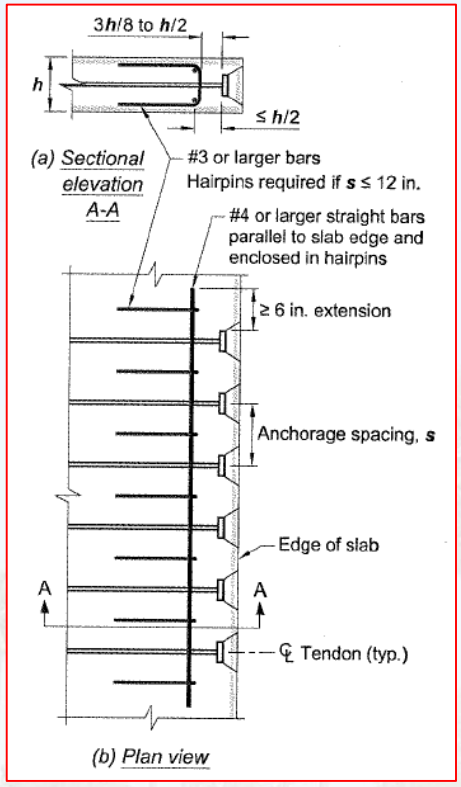
Special Anchorage Device

General zone reinforcement

- The main design consideration is the presence of tensile stresses including bursting, spalling and longitudinal edge tension.



Reinforcement Arrangement (AASHTO LRFD)

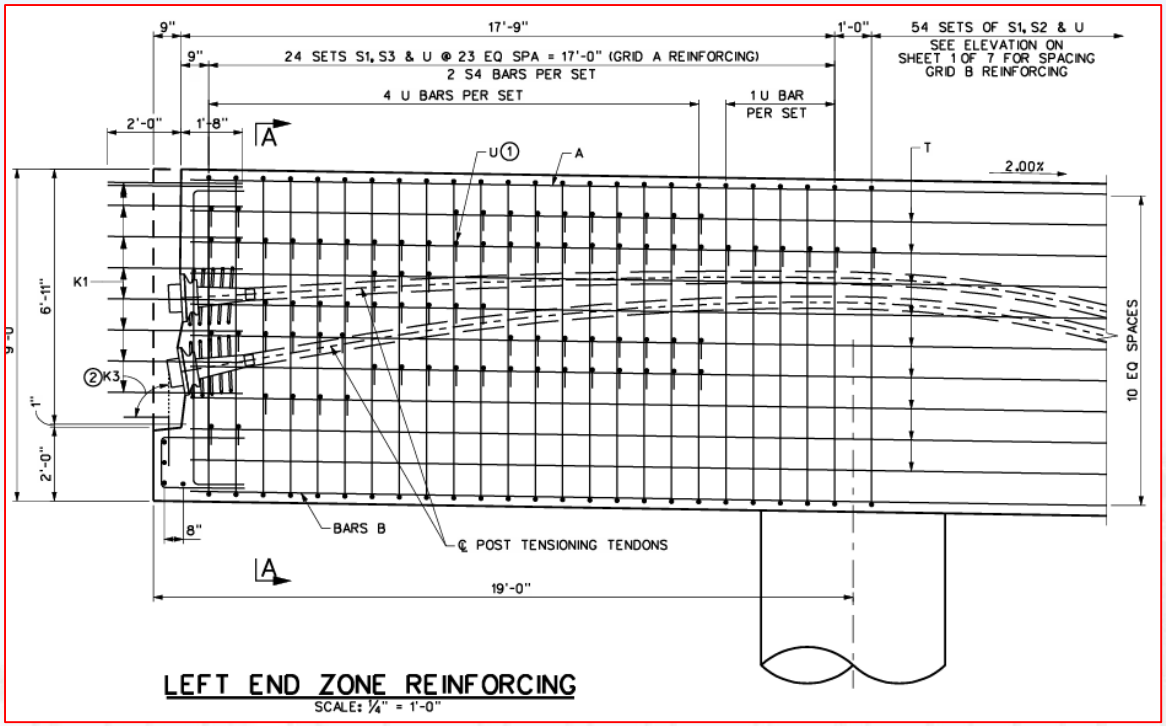


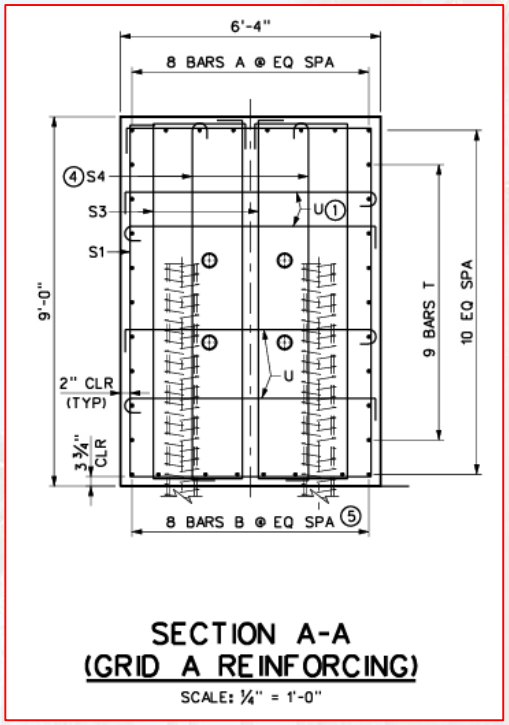
Reinforcement for Groups of Monostrand Anchors in Slabs (ACI 318)

ACI 318 prescribes the specific general zone reinforcement required for groups of ½" monostrand anchors in slabs of normal weight concrete.

General zone reinforcement (cont'd)

- The number of anchorages and their spacing have an impact on the level of stresses and the reinforcement needed in the general anchorage zone.





Anchorage Zone Reinforcement in a Bent Cap

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Responsibilities

- AASHTO LRFD Design Specifications (Section 5.10.9.2.4):
  - The Engineer of Record (EOR) is responsible for the design of the general zone for both basic and special anchorages.
  - The EOR is also responsible for the design of the local zones for basic anchorage devices.
  - The PT Supplier is responsible for supplying anchorage devices that satisfy:
    - Efficiency requirements (AASHTO LRFD Bridge Construction Specifications Section 10.3.2)
    - Acceptance test requirements in the case of special anchorage devices (AASHTO LRFD Bridge Design Specifications Section 5.10.9.7.3 and AASHTO LRFD Bridge Construction Specifications Section 10.3.2.3).
  - The PT Supplier shall provide records of the acceptance test and shall specify confinement and auxiliary reinforcement, minimum edge distance, minimum anchor spacing, and minimum concrete strength at time of stressing.

Anchorage Zone	Type of Anchorage Device	
	Basic	Special
Local	EOR	PT Supplier
General	EOR	EOR

Responsibilities (cont'd)

- ACI 318-14:
  - ACI 318 has general requirements when it comes to anchorages zones and evaluation and testing of anchorages devices.
  - It refers to detailed AASHTO provisions (Section R25.9).
  - Commentary Section R25.9.4.4.2 states that in some cases reinforcement requirements cannot be determined until specific tendon and anchorage device layouts are selected. It also states that design and approval responsibilities should be clearly assigned in the construction documents.

- Post-Tensioning Institute:
  - PTI/ASBI M50 Guide Specification for Grouted Post-Tensioning Section 2.1 Definitions: "The Design Engineer is responsible for the general zone design".
  - PTI's Anchorage Zone Design document states that the design elements associated with the general zone (e.g., tendon arrangement, anchorage layout, geometry of the structure, stressing sequence, other loading) are solely controlled by the EOR and therefore should be responsible for its adequacy.

Summary

- The division of responsibilities in the design of the anchorage zone should be clearly understood to avoid issues.
- The responsibility of the design of the general zone is of the EOR.
- While the EOR can delegate the design of the general zone to the Contractor and/or PT Supplier, it is not recommended as it is really a critical part of the overall structural design of the member.
- Coordination of both general and local zone reinforcement is important.
- Suppliers are exposed to a large number of post-tensioning projects on a regular basis and can assist the EOR during the design process.

Thank You!

Questions ?

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