Lecture 2

Permissible Stresses Materials and Systems for Pre-stressing

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ACI Maximum Permissible Stresses in Concrete and Reinforcement

2.8.1 Concrete Stresses in Flexure

Stresses in concrete immediately after prestress transfer (before time-dependent prestress losses) shall not exceed the following:

(a) Extreme fiber stress in compression ..... $0.60 f'_{ci}$

(b) Extreme fiber stress in tension except as permitted in (c) ..... $3\sqrt{f'_{ci}}$

(c) Extreme fiber stress in tension at ends of simply supported members .... $6\sqrt{f'_{ci}}$

Where computed tensile stresses exceed these values, bonded auxiliary reinforcement (nonprestressed or prestressed) shall be provided in the tensile zone to resist the total tensile force in concrete computed under the assumption of an uncracked section.

Stresses in concrete at service loads (after allowance for all prestress losses) shall not exceed the following:

(a) Extreme fiber stress in compression due to prestress plus sustained load, where sustained dead load and live load are a large part of the total service load ..... $0.45 f'_c$

(b) Extreme fiber stress in compression due to prestress plus total load, if the live load is transient ..... $0.60 f'_c$

(c) Extreme fiber stress in tension in precompressed tensile zone..... $6\sqrt{f'_c}$

(d) Extreme fiber stress in tension in precompressed tensile zone of members (except two-way slab systems), where analysis based on transformed cracked sections and on bilinear moment-deflection relationships shows that immediate and long-time deflections comply with the ACI definition requirements and minimum concrete cover requirements ..... $12\sqrt{f'_c}$

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2.8.2 Prestressing Steel Stresses

Tensile stress in prestressing tendons shall not exceed the following:

(a) Due to tendon jacking force ..... $0.94 f_{py}$
but not greater than the lesser of $0.80 f_{pu}$ and the maximum value recommended by the manufacturer of prestressing tendons or anchorages.

(b) Immediately after prestress transfer..... $0.82 f_{py}$
but not greater than $0.74 f_{pu}$.

(c) Post-tensioning tendons, at anchorages and couplers, immediately after tendon anchorage ..... $0.70 f_{pu}$

f_{py} = specified yield strength of prestressing tendons, in psi
f_y = specified yield strength of nonprestressed reinforcement, in psi
f_{pu} = specified tensile strength of prestressing tendons, in psi
f'_c = specified compressive strength of concrete, in psi
f'_{ci} = compressive strength of concrete at time of initial prestress

Example for Calculation of Stresses

A pretensioned simply supported 10LDT24 double T-beam without topping has a span of 64 ft (19.51 m) and the geometry shown in Figure 1.11. It is subjected to a uniform superimposed gravity dead-load intensity W_{SD} and live-load intensity W_L summing to 420 plf (6.13 kN/m). The initial prestress before losses is $f_{pi} \cong 0.70\, f_{pu} = 189{,}000$ psi (1,303 MPa), and the effective prestress after losses is $f_{pe} = 150{,}000$ psi (1,034 MPa). Compute the extreme fiber stresses at the midspan due to

(a) the initial full prestress and no external gravity load
(b) the final service load conditions when prestress losses have taken place.

Allowable stress data are as follows:

$f'_c = 6{,}000$ psi, lightweight (41.4 MPa)
$f_{pu} = 270{,}000$ psi, stress relieved (1.862 MPa) = specified tensile strength of the tendons
$f_{py} = 220{,}000$ psi (1.517 MPa) = specified yield strength of the tendons
$f_{pe} = 150{,}000$ psi (1,034 MPa)
$f_t = 12\sqrt{f'_c} = 930$ psi (6.4 MPa) = maximum allowable tensile stress in concrete
$f'_{ci} = 4{,}800$ psi (33.1 MPa) = concrete compressive strength at time of initial prestress
$f_{ci} = 0.6\, f'_{ci} = 2{,}880$ psi (19.9 MPa) = maximum allowable stress in concrete at initial prestress
$f_c = 0.45\, f'_c$ = maximum allowable compressive stress in concrete at service

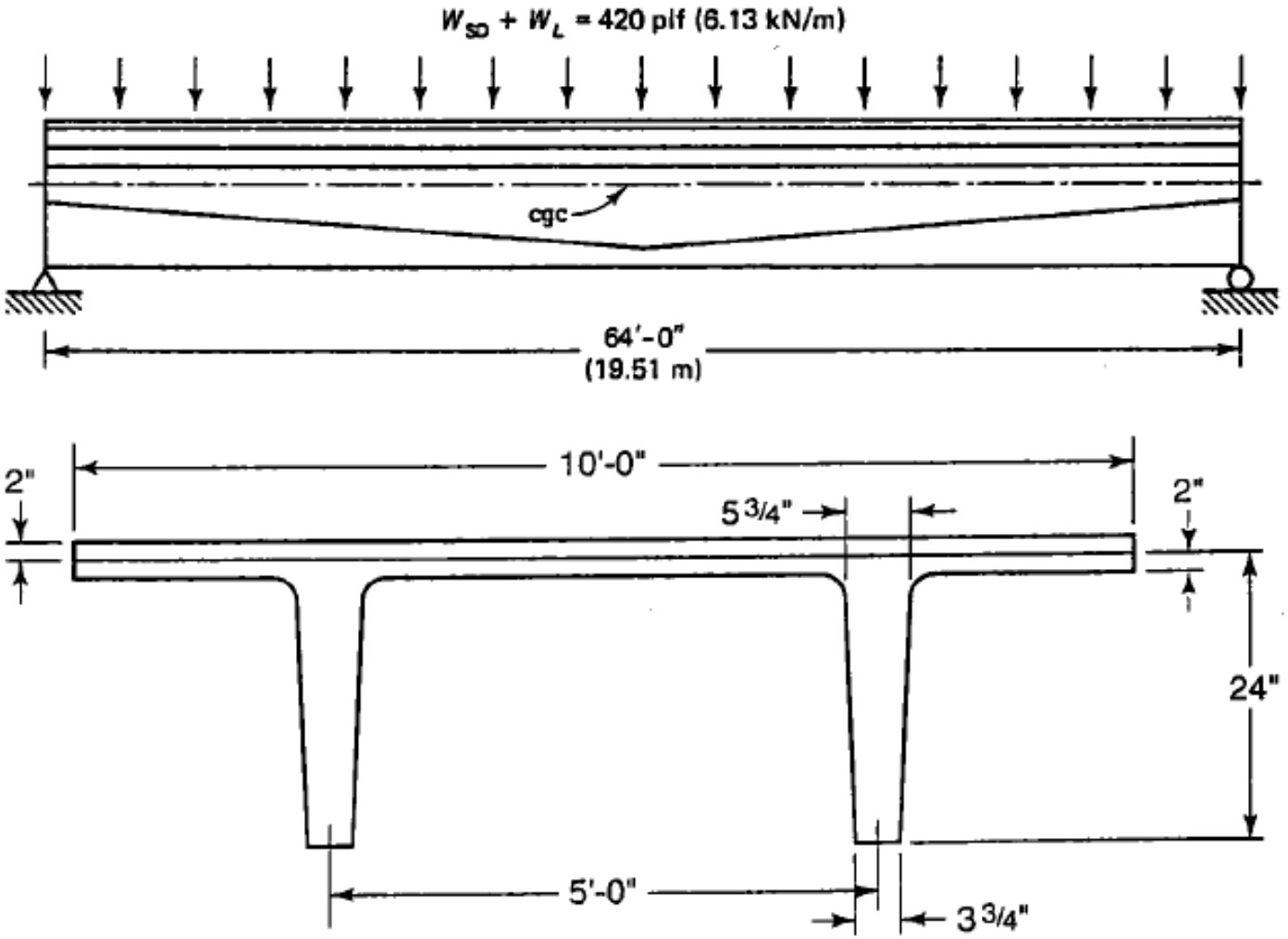
Assume that ten ½-in.-dia. Seven-wire-strand (ten 12.7-mm-dia strand) tendons with a 108-D1 strand pattern are used to prestress the beam.

$$A_c = 449 \text{ in.}^2 \ (2{,}915 \text{ cm}^2)$$

$$I_c = 22{,}469 \text{ in.}^4 \ (935{,}347 \text{ cm}^4)$$

$$r^2 = I_c/A_c = 50.04 \text{ in.}^2$$

Example for Calculation of Stresses



c_b = 17.77 in. (452 mm)

c_t = 6.23 in. (158 mm)

e_c = 14.77 in. (375 mm)

e_e = 7.77 in. (197 mm)

S_b = 1,264 in.^{3} (20,714 cm^3)

S_t = 3,607 in.^{3} (59,108 cm^3)

W_D = 359 plf (4.45 kN/m)

Lecture 2

Materials and Systems for Pre-stressing

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Pre-stressing

- Pre-Tensioning:

  Method of pre-stressing in which pre-stressing steel is tensioned before the concrete is placed.

- Post-Tensioning:

  Method of pre-stressing in which pre-stressing steel is tensioned after concrete has hardened.

Post-Tensioning

- Video 1
- Video 2
- Video 3

- Video 4 (Pre-tensioning)

Pre-Tensioning

Pre-Tensioning

Pre-Tensioning

Pre-Tensioning

Pre-Tensioning

Pre-Tensioning

Pre-Tensioning

Components

Strand/Tendon

- Strand:

  High strength steel wires wound around a center wire, typically seven-wire strand, conforming to ASTM A416/A416M.

- Tendon:

  A complete assembly of a prestressing element consisting of anchorages and couplers, prestressing steel, and sheathing or duct with PT coating for unbonded applications or grouted ducts, grout caps, and grout vents for bonded applications.

Strand/Tendon

Table 2.7 Seven-Wire Standard Strand for Prestressed Concrete

Nominal diameter of strand (in.)	Breaking strength of strand (min. lb)	Nominal steel area of strand (sq in.)	Nominal weight of strands (lb per 1000 ft)*	Minimum load at 1% extension (lb)
		GRADE 250		
$\frac{1}{4}$(0.250)	9,000	0.036	122	7,650
$\frac{5}{16}$(0.313)	14,500	0.058	197	12,300
$\frac{3}{8}$(0.375)	20,000	0.080	272	17,000
$\frac{7}{16}$(0.438	27,000	0.108	367	23,000
$\frac{1}{2}$(0.500)	36,000	0.144	490	30,600
$\frac{3}{5}$(0.600)	54,000	0.216	737	45,900
		GRADE 270		
$\frac{3}{8}$(0.375)	23,000	0.085	290	19,550
$\frac{7}{16}$(0.438)	31,000	0.115	390	26,350
$\frac{1}{2}$(0.500)	41,300	0.153	520	35,100
$\frac{3}{5}$(0.600)	58,600	0.217	740	49,800

Table 2.8 Seven-Wire Compacted Strand for Prestressed Concrete [ASTM A779]

Nominal diameter (in.)	Nominal Breaking strength of strand (min. lb)*	Nominal steel area ($in.^2$)	Nominal weight of strand (per 1,000 ft-lb)
$\frac{1}{2}$	47,000	0.174	600
0.6	67,440	0.256	873
0.7	85,430	0.346	1176

Bonded/Unbonded Tendon

- **Bonded Tendon:**

  Tendon in which pre-stressing steel is bonded to the concrete and is permanently prevented from moving relatively to the concrete.

- **Unbonded Tendon:**

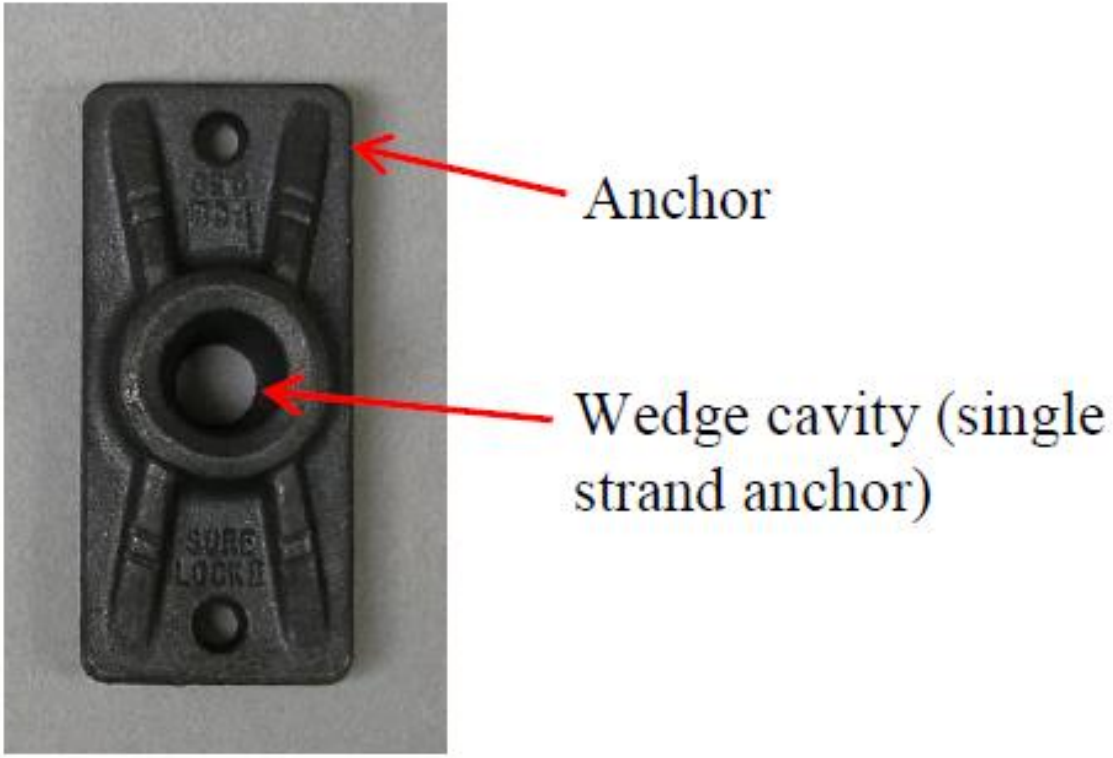
  Tendon in which the pre-stressing steel is prevented from bonding to the concrete, and is permanently free to move relatively to the concrete. The pre-stressing force is transferred to the concrete only by the anchorages or deviators.

Stress Bar

- High strength steel bar used in post-tensioning conforming to ASTM A722 / A722 M.

Anchor

- For unbonded single strand tendons, a device that houses the wedges and transfers the pre-stressing force to the concrete.



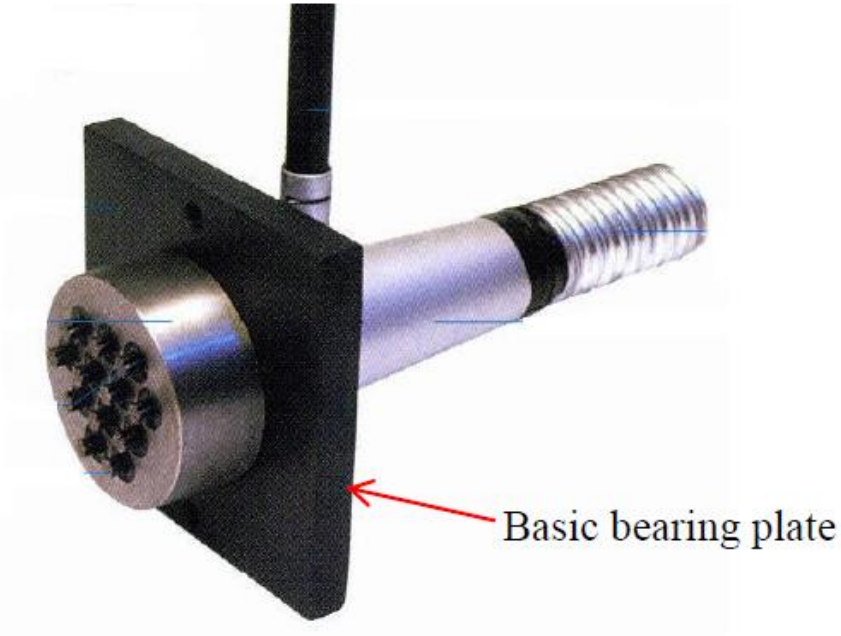
Anchor (Barrel)

- A special anchor used for single strand tendons, consisting of a cylindrical metal device housing the wedges. Normally used with a bearing plate to transfer the pre-stressing force to the concrete.

Barrel Anchor with wedges

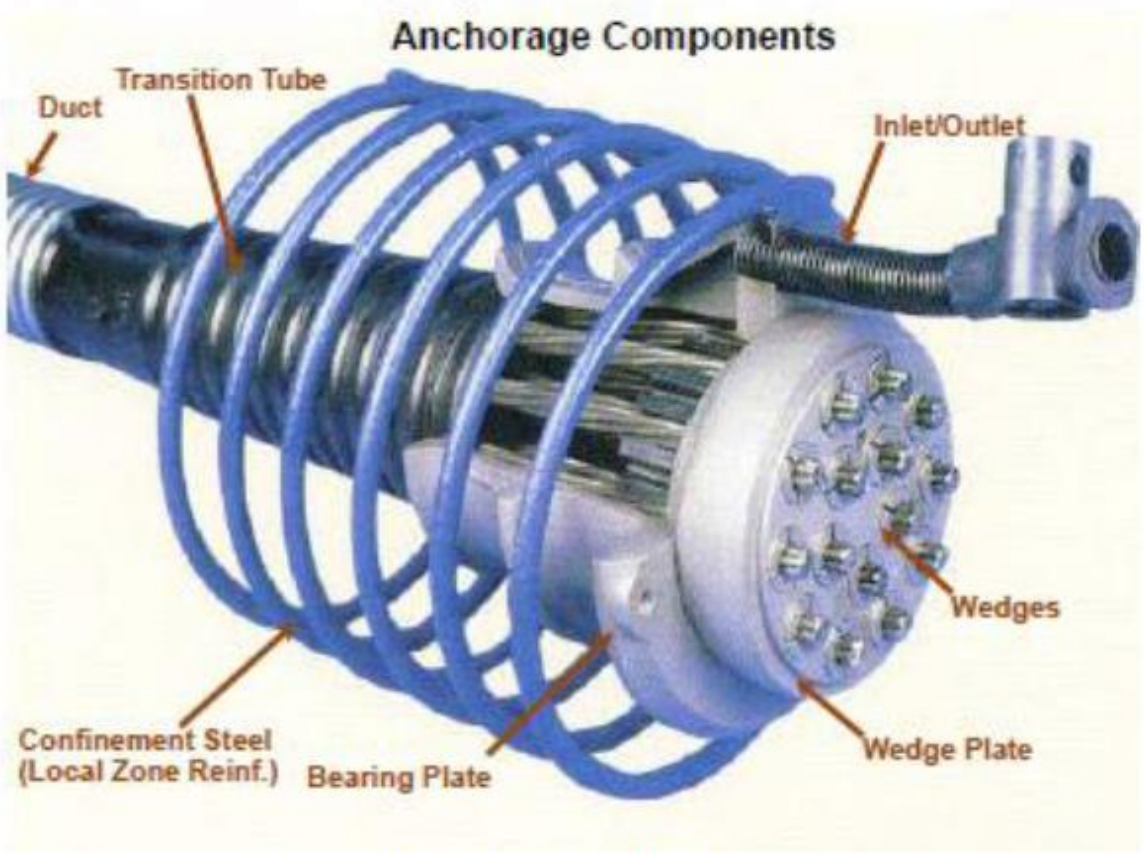
Bearing Plate (Basic/Special)

- Flat steel plate that transfers the tendon force directly into the concrete, meeting the analytical design requirements of PTI “Acceptance Standards for Post-Tensioning Systems, “Section 3.1”.



Anchorage (assembly)

A mechanical device consisting of all components required to transfer the posttensioning force from the pre-stressing steel to the structure, including all accessories for encapsulation or grouting Systems, “Section 3.1”.

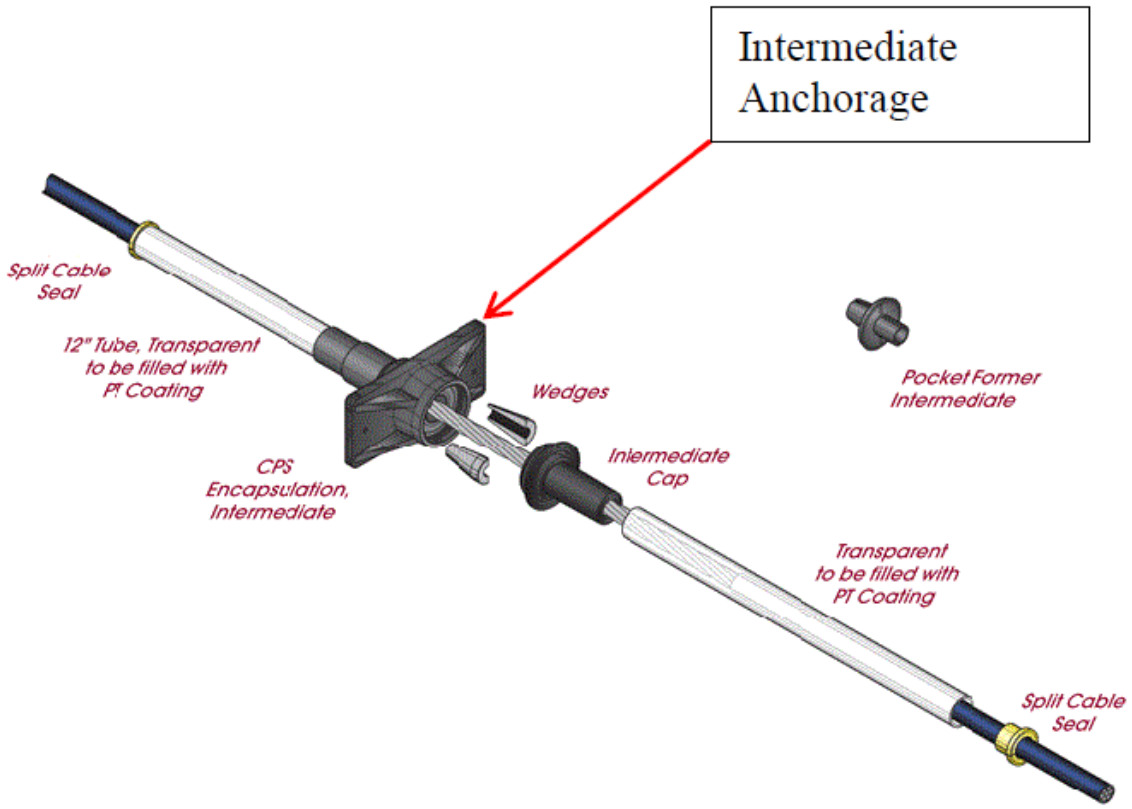


Anchorage (assembly) for multistrand tendons

Anchorage (assembly) for single strand tendons

Anchorage (intermediate)

- The anchorage located at any point along the tendon used to stress only a portion of the tendon at a construction joint. The tendon may be continuous or spliced at that location.



Anchorage (fixed)

- The anchorage that is not used for stressing of the tendon. For unbonded single strand tendons, this anchorage is normally attached to the tendon at the plant.

Anchorage (stressing)

- The anchorage at one or both ends of a tendon that is used for stressing.

Backup Bars

- For unbonded single strand tendons, minimum non pre-stressed reinforcement parallel to slab edge used to resist tensile forces in the concrete caused by the applied pre-stressing force.

Bursting Steel

- For unbonded single strand tendons, non pre-stressed reinforcement used to resist the tensile forces in the concrete caused by the applied pre-stressing force from multiple anchorages.

Confinement reinforcement

- Non pre-stressed reinforcement, typically a spiral, in the local anchorage zone.

Duct

- A conduit to accommodate pre-stressing steel installation and provide space for grouting.

Pocket former/Stressing pocket

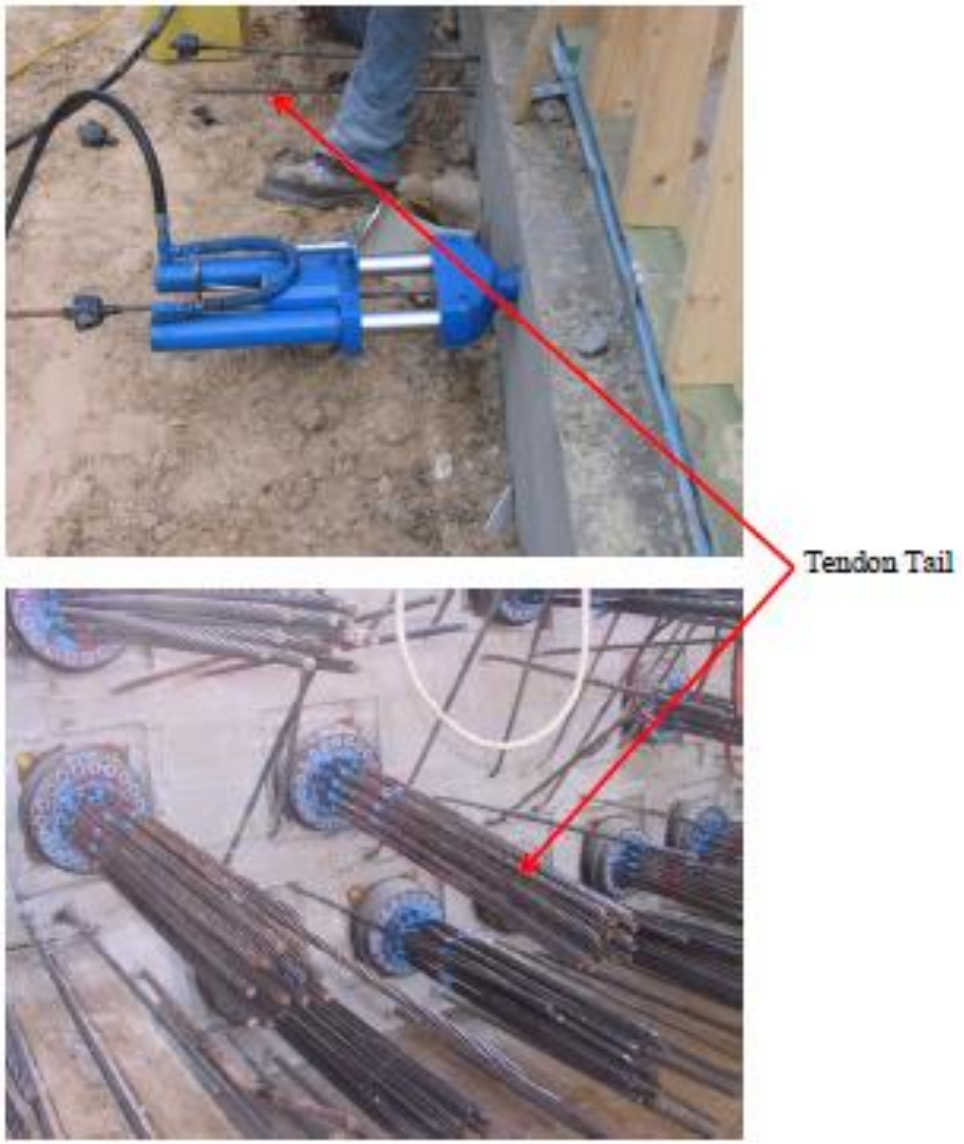
- A device that forms a temporary recess in the concrete to allow access for stressing.
- The recess created by the pocket formed between the stressing or intermediate anchorage and the edge of the concrete to allow the nosepiece access for stressing.

Sheathing

- For unbonded single strand tendons, an enclosure in which pre-stressing steel is encased to prevent bond with surrounding concrete that provides corrosion protection and contains PT coating.

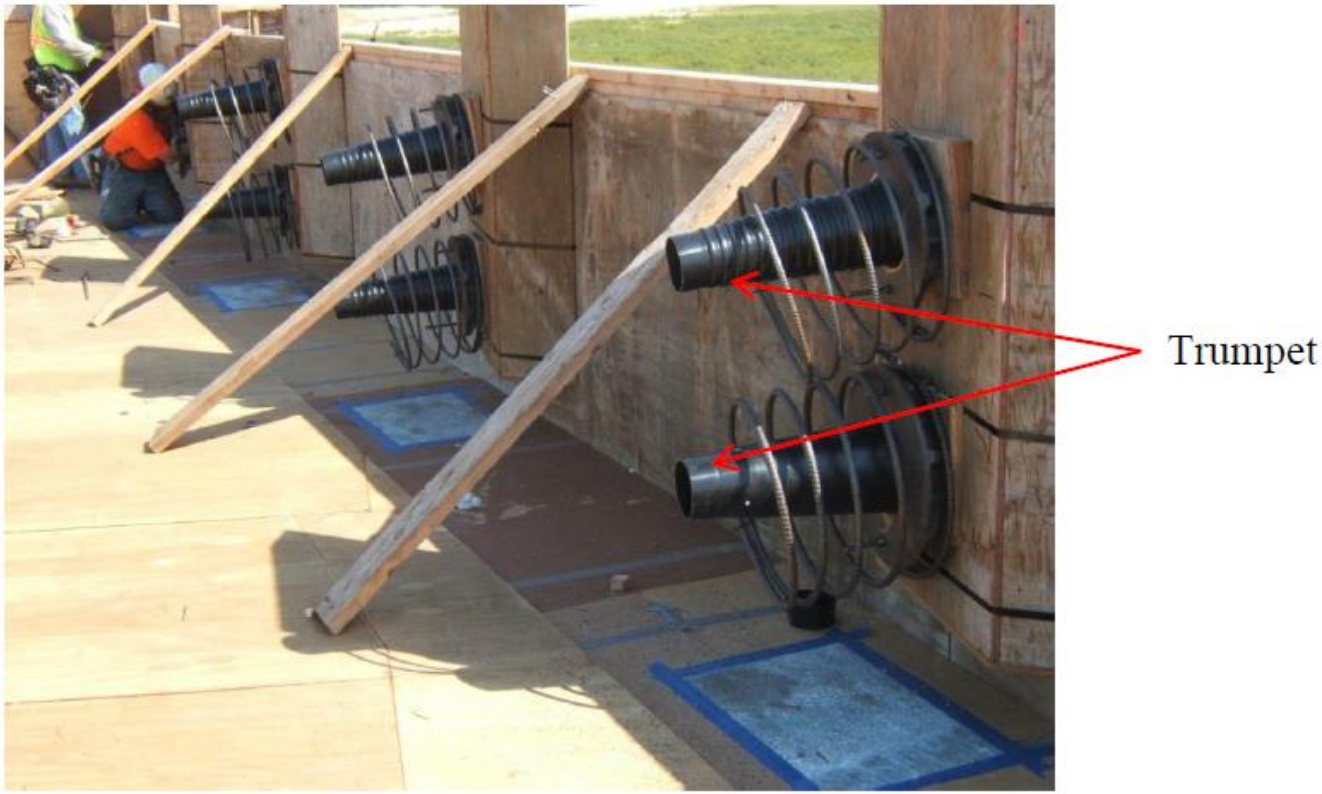
Tendon Tail

- The protruding length of the tendon outside of the stressing anchorage needed temporarily for stressing of the tendon.



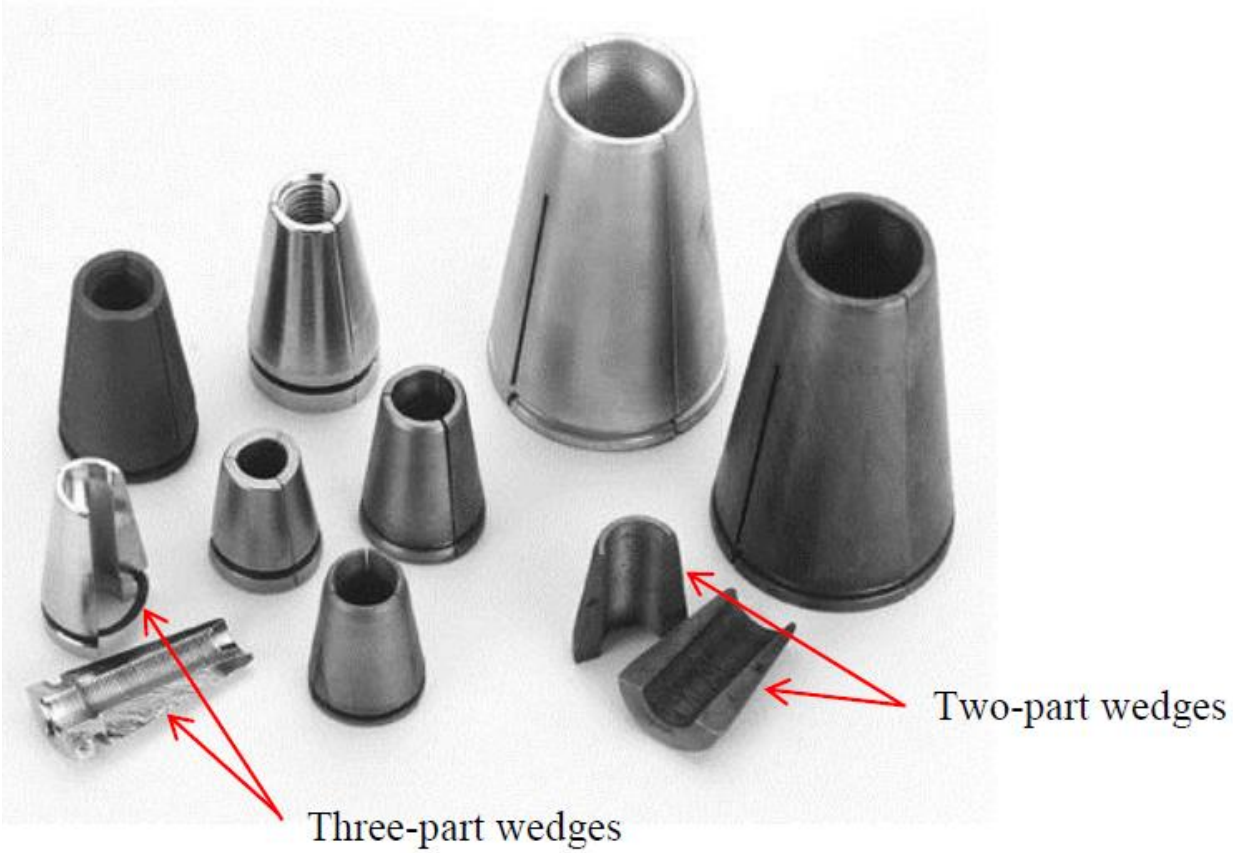
Trumpet/Transition Tube

- Connection piece between bearing plate and duct, in which the strands transition from the wedge plate pattern into a tight bundle inside the duct.



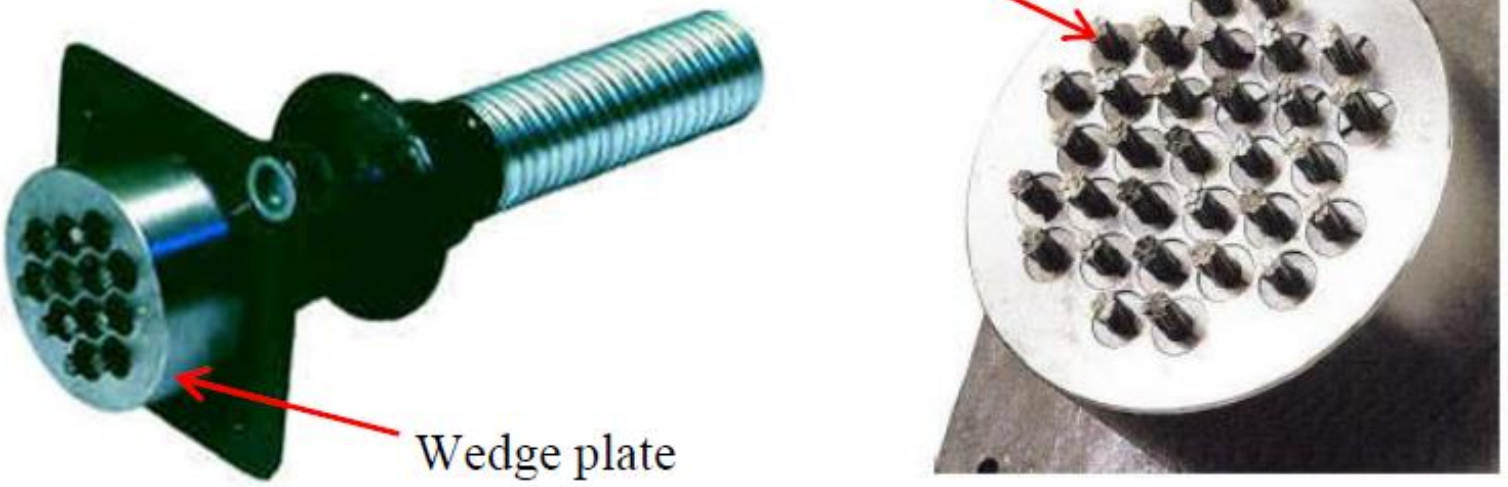
Wedges

- Pieces of tapered high-strength heat-treated steel with serrations (teeth) that penetrate the pre-stressing steel during transfer of pre-stressing force. Some anchorage systems use two-part wedges and some use three-part wedges.



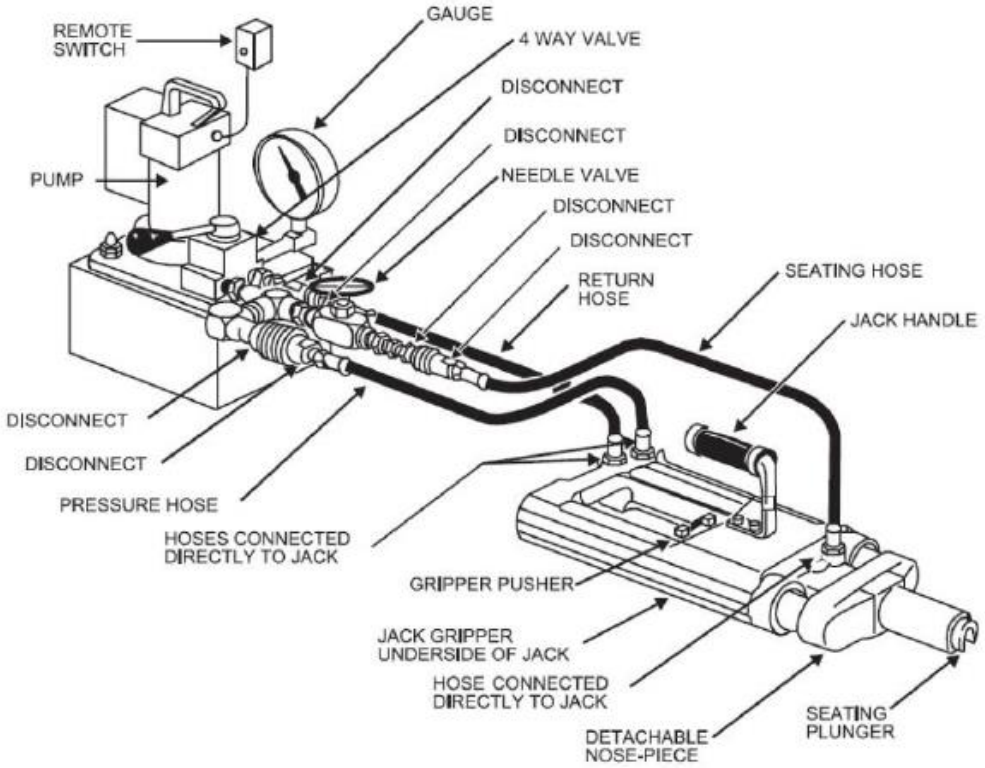
Wedge plate

- For multi-strand tendons, a device that houses the wedges and transfers the pre-stressing force to a bearing plate.



Stressing equipment

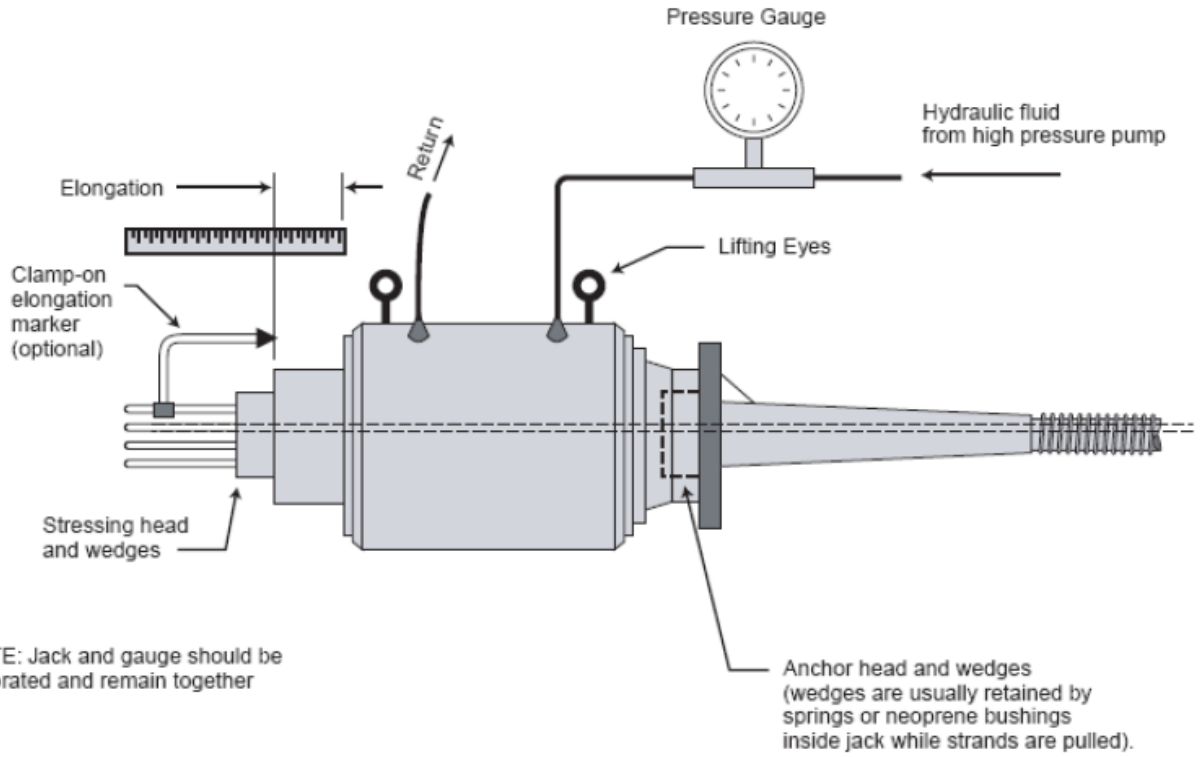
- Equipment used for stressing tendons, consisting of a hydraulic jack and gauge(s) calibrated as a unit, and a hydraulic pump.



Stressing equipment for single strands

Stressing equipment

- Equipment used for stressing tendons, consisting of a hydraulic jack and gauge(s) calibrated as a unit, and a hydraulic pump.



Stressing Equipment for multistrand tendons

Miscellaneous terms

Anchor set:

The movement of the wedges into the anchor or wedge plate, or nut into the bearing plate during the transfer of the prestressing force to the anchorage assembly.

Blowout:

A localized concrete failure resulting from tendon forces, which occurs in the vicinity of the anchorage(s) or at tendon deviation points during or after stressing.

Partial stressing:

Stressing of tendons to a force less than the full jacking force before the concrete reaches the concrete strength required for full stressing. Normally used to mitigate cracking due to plastic shrinkage and restraint to shortening.

Stage Stressing:

Miscellaneous terms

Slab Bolster:

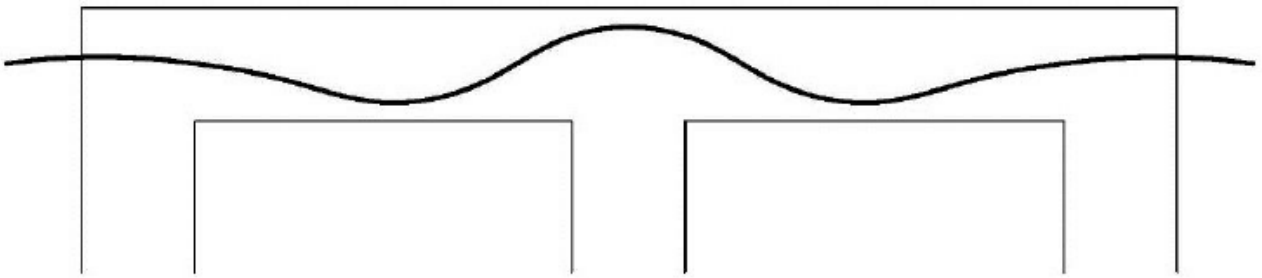
Continuous hardware used to support and hold post-tensioning tendons and reinforcing steel in place before and during concrete placement.

Added Tendon:

Tendon, usually short in length, added to continuous tendons and placed in specific locations, such as end bays, to increase the local pre-stressing force.

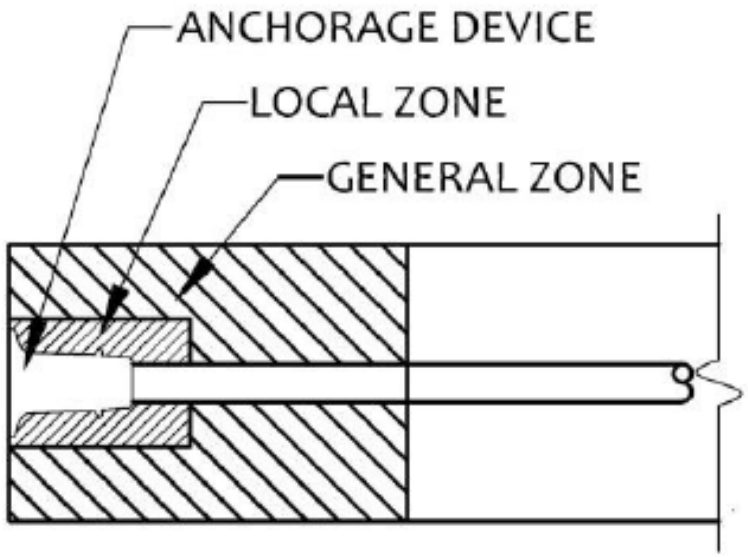
Tendon Profile:

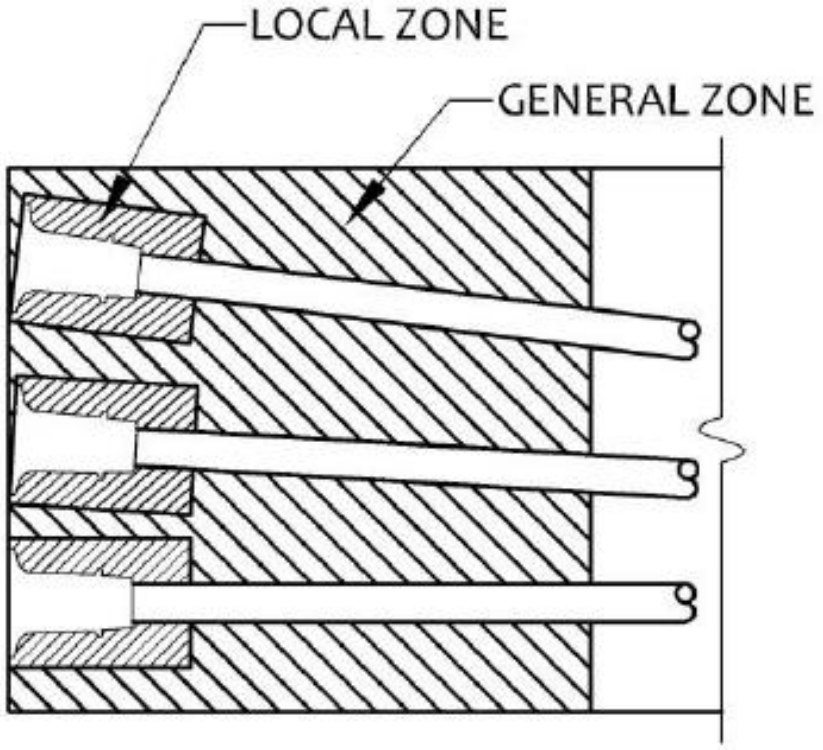
The specified path of a tendon from end to end in a member.



Anchorage Zone

The portion of the member through which the concentrated pre-stressing force is transferred to the concrete and distributed across the section. It includes the local and general anchorage zones.





Anchorage Zone

Local anchorage zone:

The prismatic region in which the concentrated pre-stressing force is introduced into the concrete, surrounding the bearing plate including confinement reinforcement and the minimum concrete cover. The length of the local anchorage zone extends over the confinement reinforcement.

General anchorage zone:

The region in which the concentrated pre-stressing force spreads out over the cross section of the structural member (Saint Venant Region). It includes the local anchorage zone. The general anchorage zone extends from the anchorage along the axis of the member for a distance equal to the overall depth of the member. The height of the general anchorage zone is equal to the overall depth of the member.

Grout

A mixture of cementitious materials and water, with or without mineral additives, admixtures or fine aggregate, proportioned to produce a pumpable consistency without segregation of the constituents injected into the duct to fill the space around the pre-stressing steel.

Materials and Systems of Prestressing

- **Assignment 1 (individual)**
  - 6 Pages (maximum 1 page each) summary of the 6 codes provided
  - Go through ASTM A416, ASTM A421, ASTM A615

  - **Submission (After 2 weeks alongwith tension test report)**