SECTION 4

LOSS OF PRESTRESS

EMPHASIS ON ITEMS SPECIFIC TO POST-TENSIONED SYSTEMS

DEVELOPED BY THE PTI EDC-130 EDUCATION COMMITTEE
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LOSS OF PRESTRESS

- Friction
- Elastic shortening
- Anchor set
- Shrinkage
- Creep
- Relaxation

Initial losses
Specific to post-tensioning

Time dependent losses
(Long term losses)
Similar to pre-tensioning

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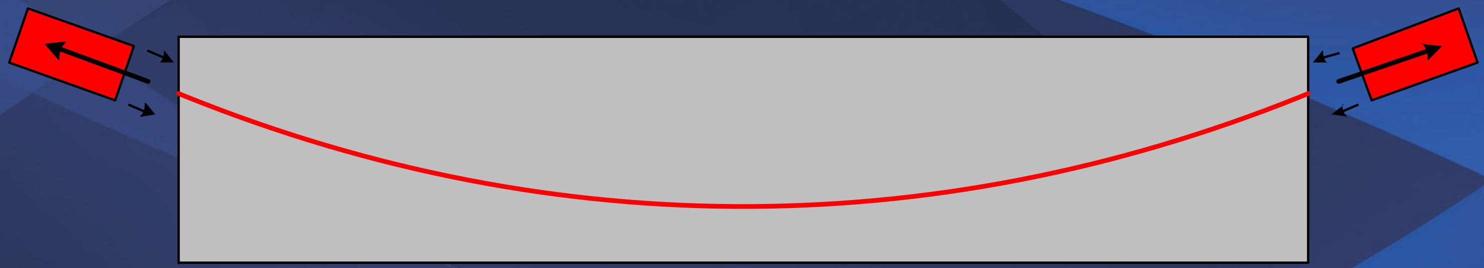
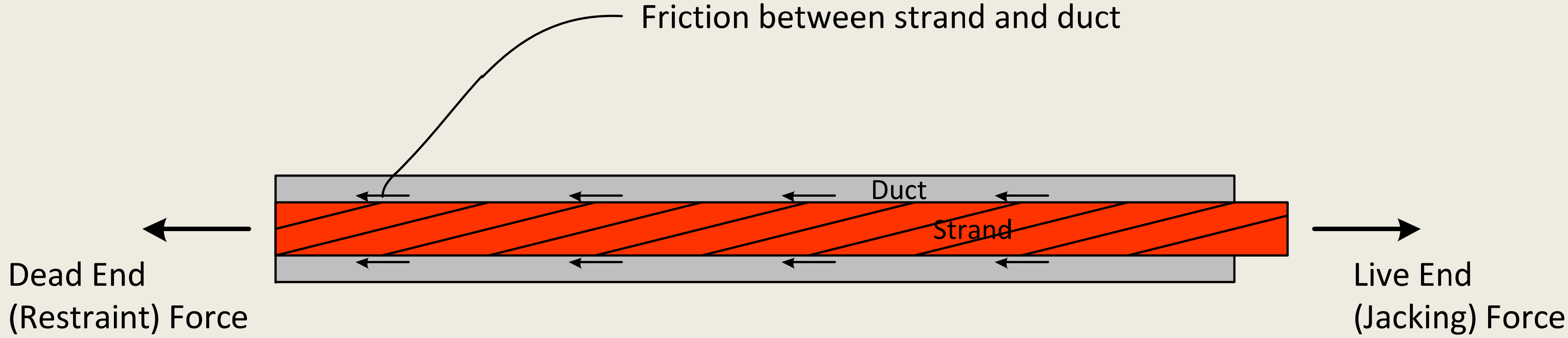
STRESSING OF PT STRANDS



The stressing jack bears against the concrete

- Concrete is compressed gradually as the strand is tensioned
- Many things occur simultaneously
  - Stressing, friction, elastic shortening

FRICTION LOSSES



Dead End Force < Live End Force

<u>Idealized</u> <u>Reality</u>

<u>Duct/Strand Cross-Section</u>

FRICTION LOSSES

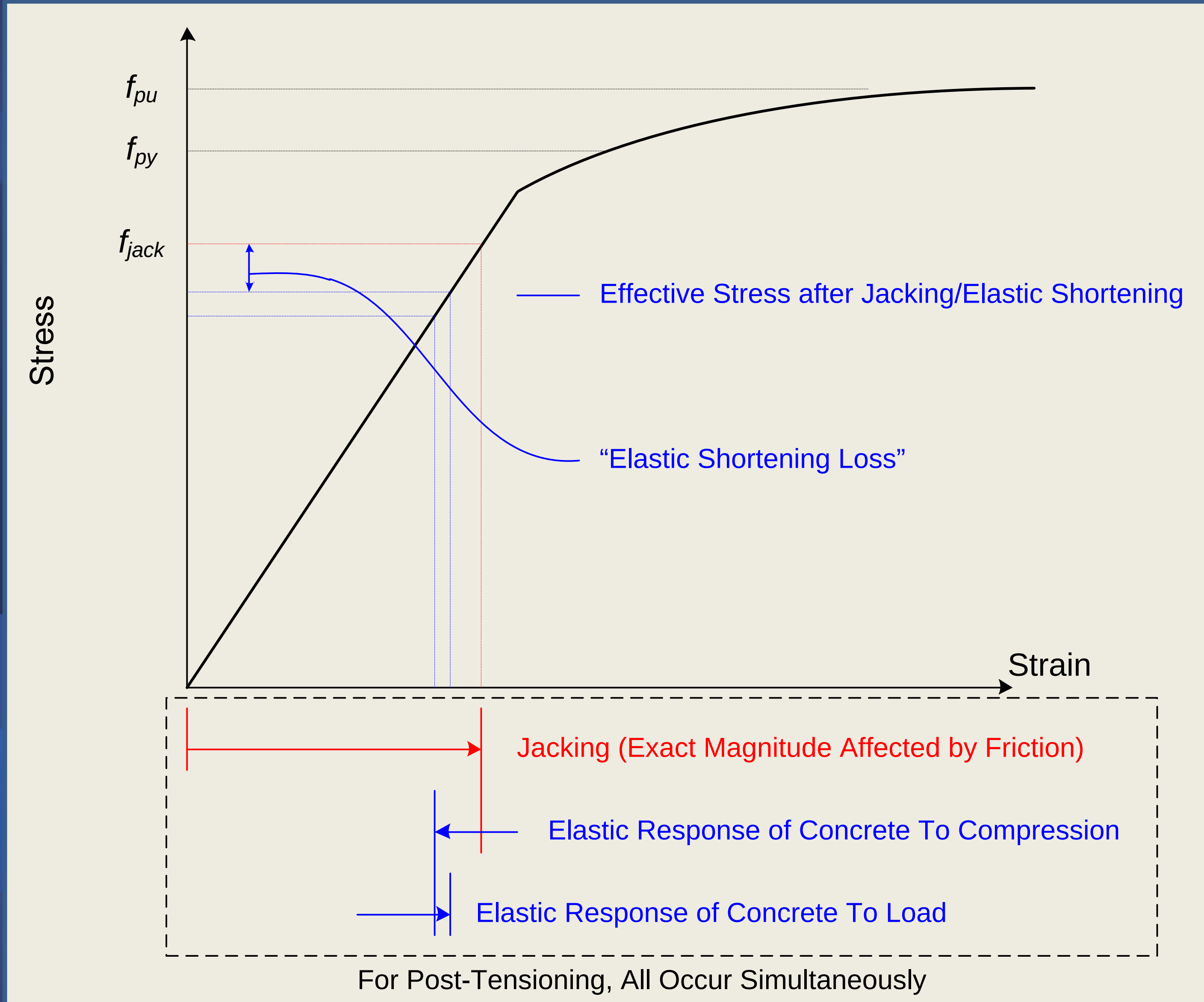
- Monitor elongation in addition to pressure during stressing

- Overcoming friction:
  - Over-tensioning (limited)
  - Stressing from both ends

FRICTION LOSSES

- Calculating losses
  - Function of:
    - Curvature friction coefficient
    - Angular change over length of strand
    - Wobble friction coefficient
    - Length from jack to point of interest
  - Reference:
    - Post-Tensioning Manual, Appendix A

ELASTIC SHORTENING LOSSES



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ELASTIC SHORTENING LOSSES

- Shortening of concrete compressed during stressing as the two occur simultaneously
- If only one strand (tendon) – no ES losses
- If multiple strands (tendons)
  - Tendons stressed early in the sequence will suffer losses as subsequent tendons are stressed
  - The first strand stressed will suffer the most total loss
  - The last strand stressed has zero loss
  - Reasonable to take the average of first and last

ELASTIC SHORTENING LOSSES

$$\underbrace{\Delta f_{pES}}_{\text{Change in strand stress due to elastic shortening loss}} = \overbrace{\underbrace{E_p}_{\text{Steel elastic modulus}} \underbrace{\epsilon_p}_{\text{Strain in strand}}}^{\text{Hooke's Law}}$$

Assume: Perfect bond between steel and concrete → $\epsilon_p = \epsilon_c$

Strain in the concrete, due to compressive stress applied:

$$\epsilon_c = \frac{f_{cgp}}{E_{ci}}$$

f_{cgp} — Concrete stress at prestressing centroid

E_{ci} — Concrete elastic modulus at time of stressing

$$\boxed{\Delta f_{pES} = \underbrace{\frac{N-1}{2N}}_{\substack{\text{Average of first and last strand that experience loss; the}\\ \text{last strand tensioned has zero loss, hence the (N-1) term.}}} \overbrace{\left(\frac{E_p}{E_{ci}}\right) f_{cgp}}^{\text{Substitution through previous steps}}}$$

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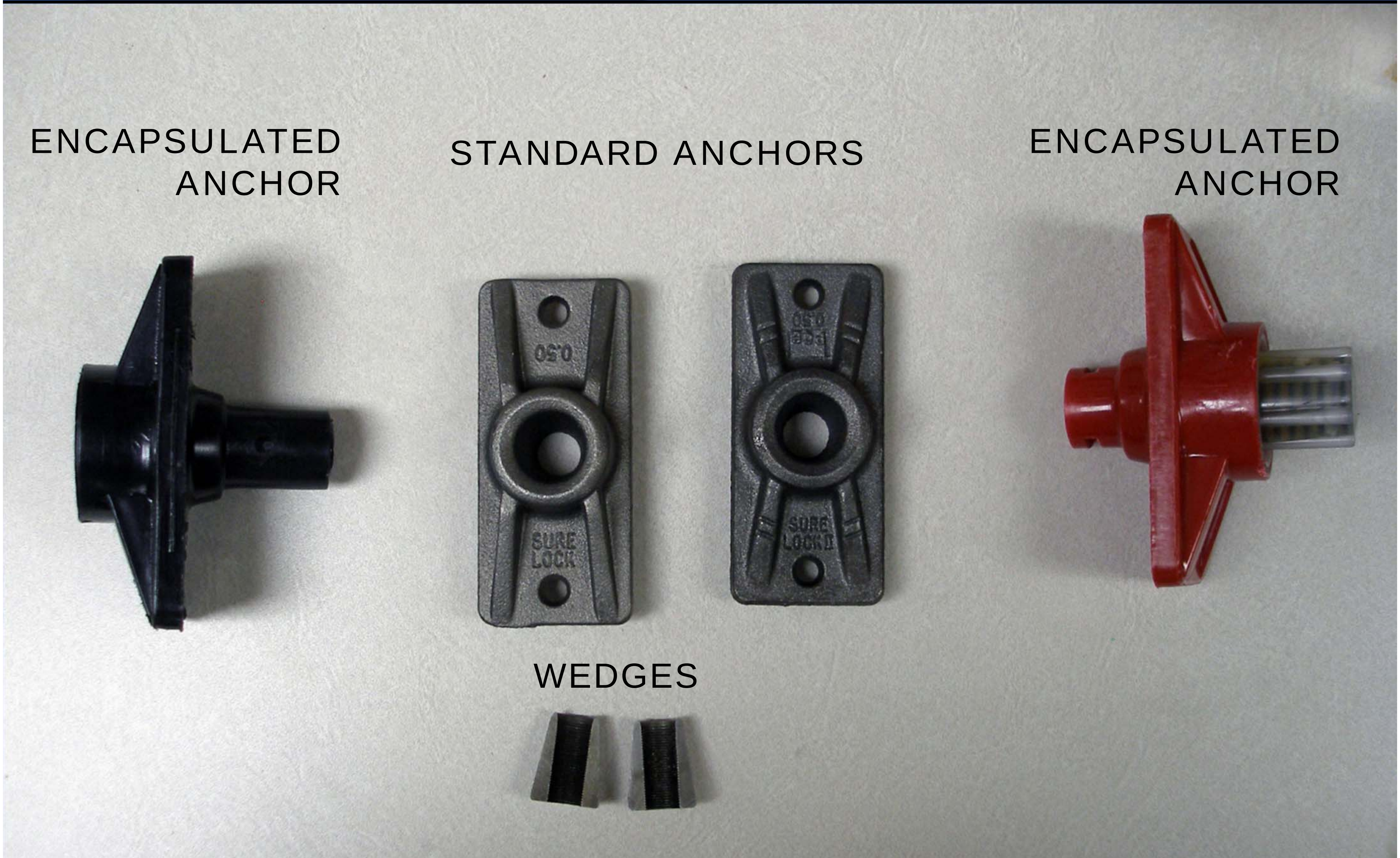
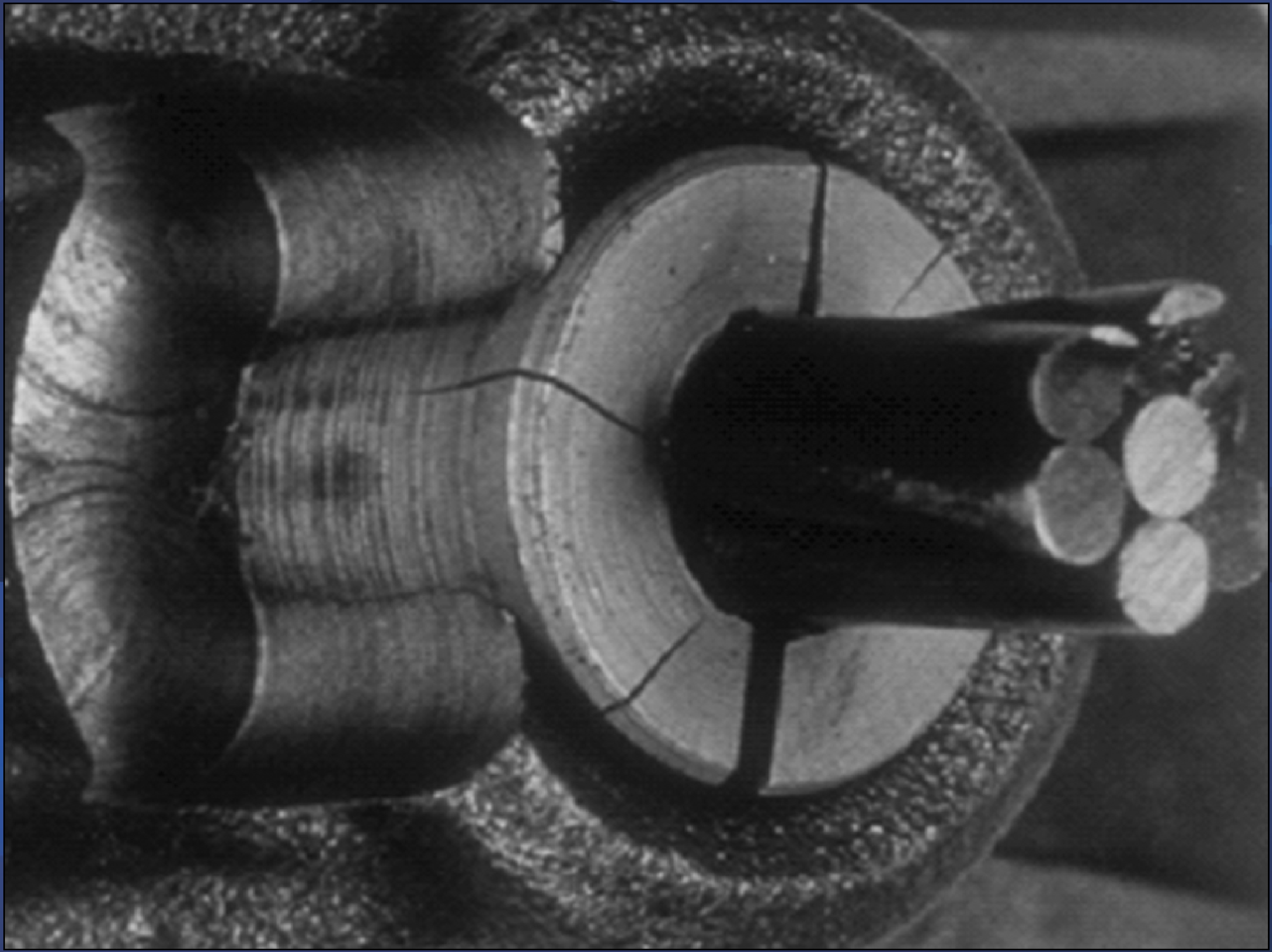
ANCHORAGE DEVICES



Source: PTI

ANCHORAGE DEVICES:



Source: PTI

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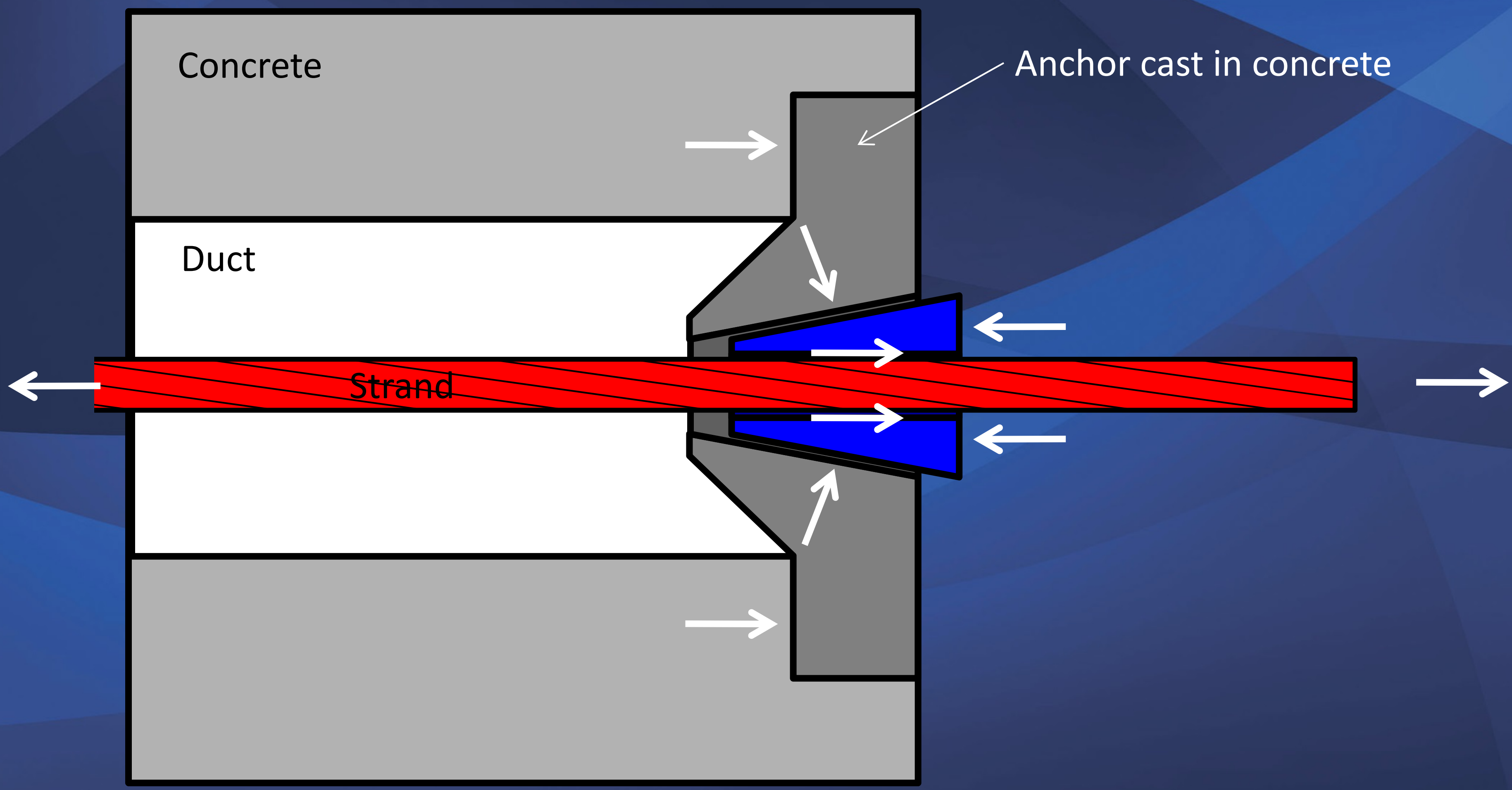
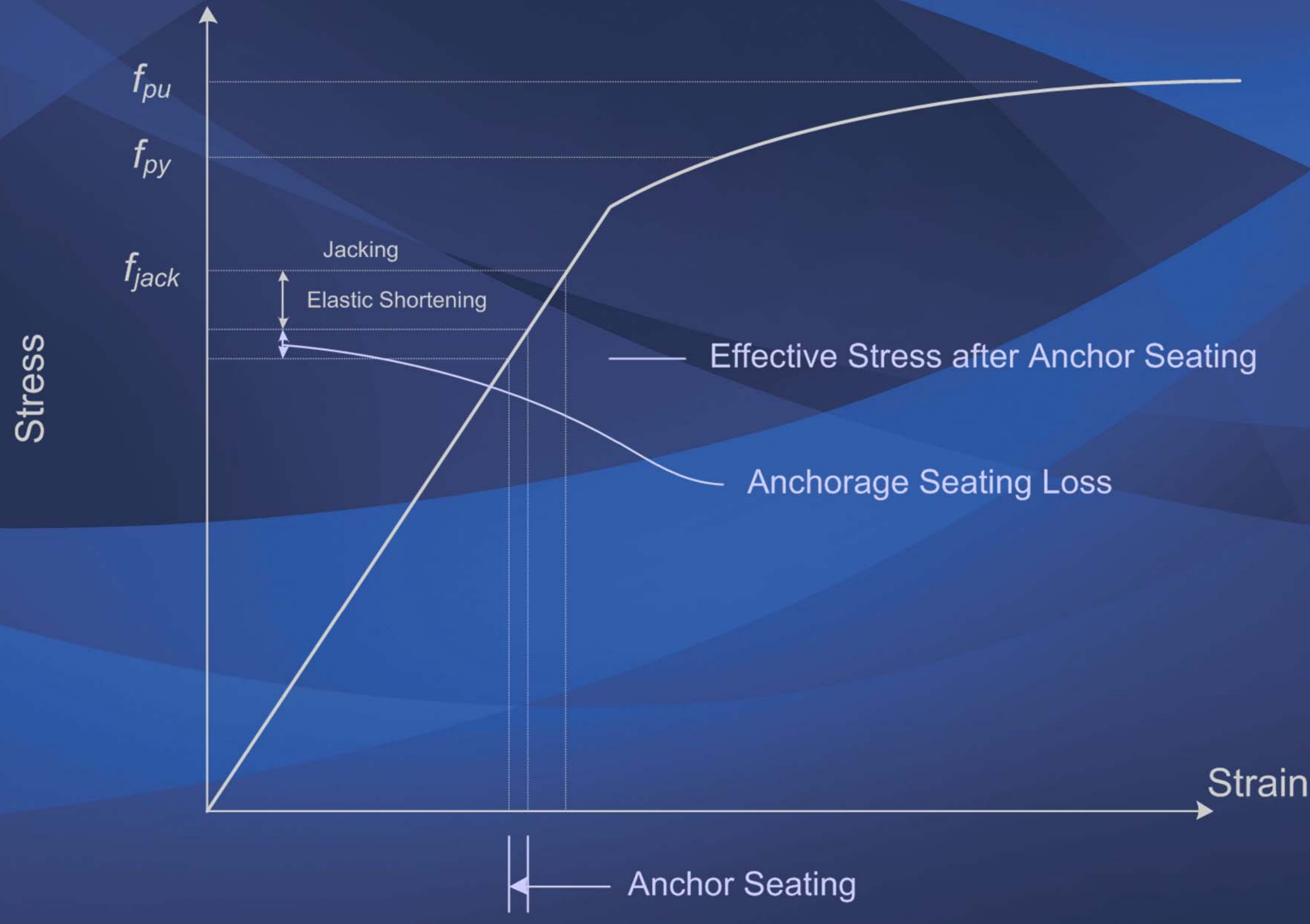
HOW ARE STRANDS ANCHORED?



ANCHORAGE SEATING LOSS



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ANCHORAGE SEATING LOSS

- Calculating losses
  - Some of the imposed strain on the strand is lost when the wedge seats in the plate
    - Function of:
      - Hardware used
      - Type of stressing jack (Power seating, etc.)
  - Reference: Post-Tensioning Manual, Appendix A

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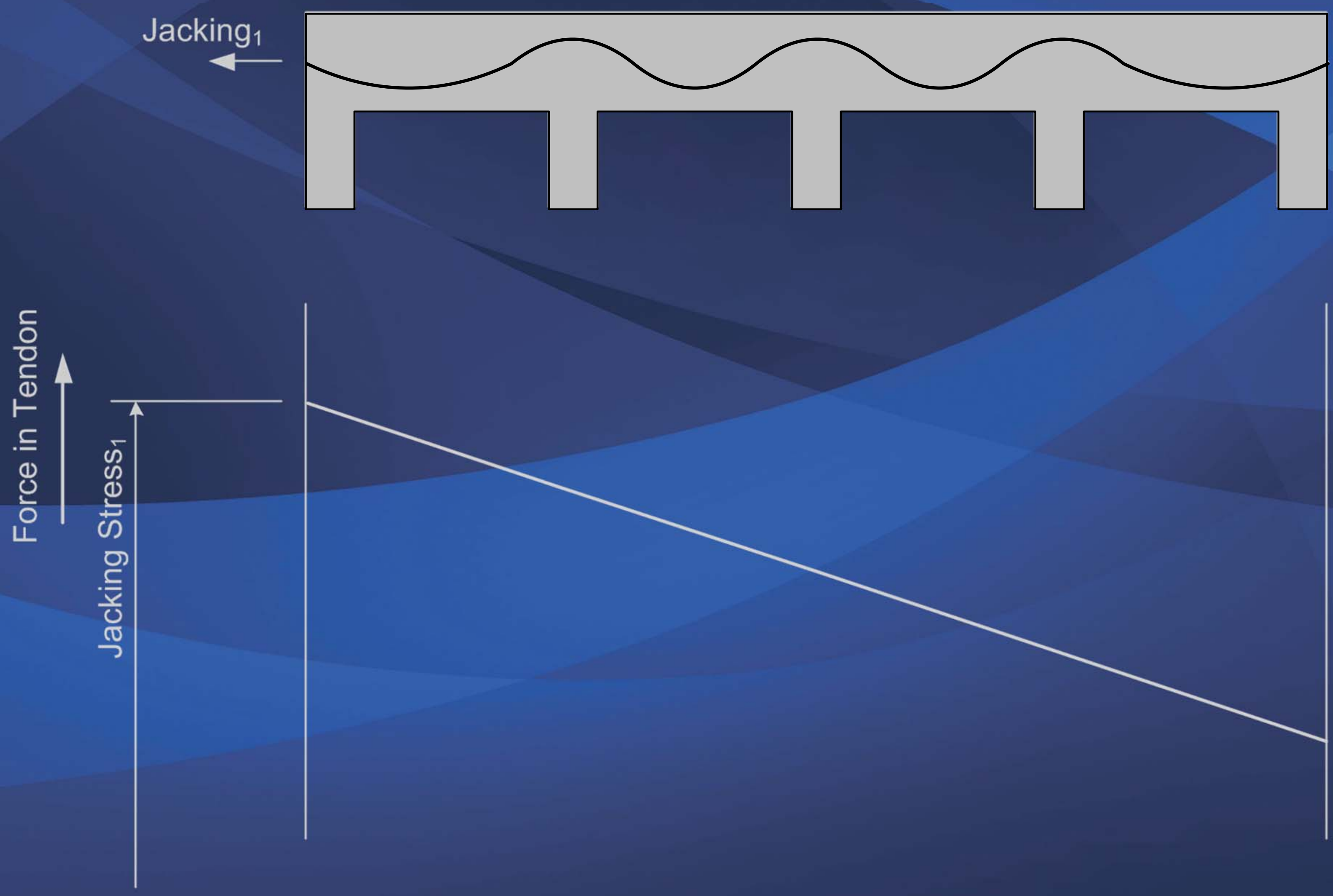
FRICTION AND ANCHORAGE LOSSES



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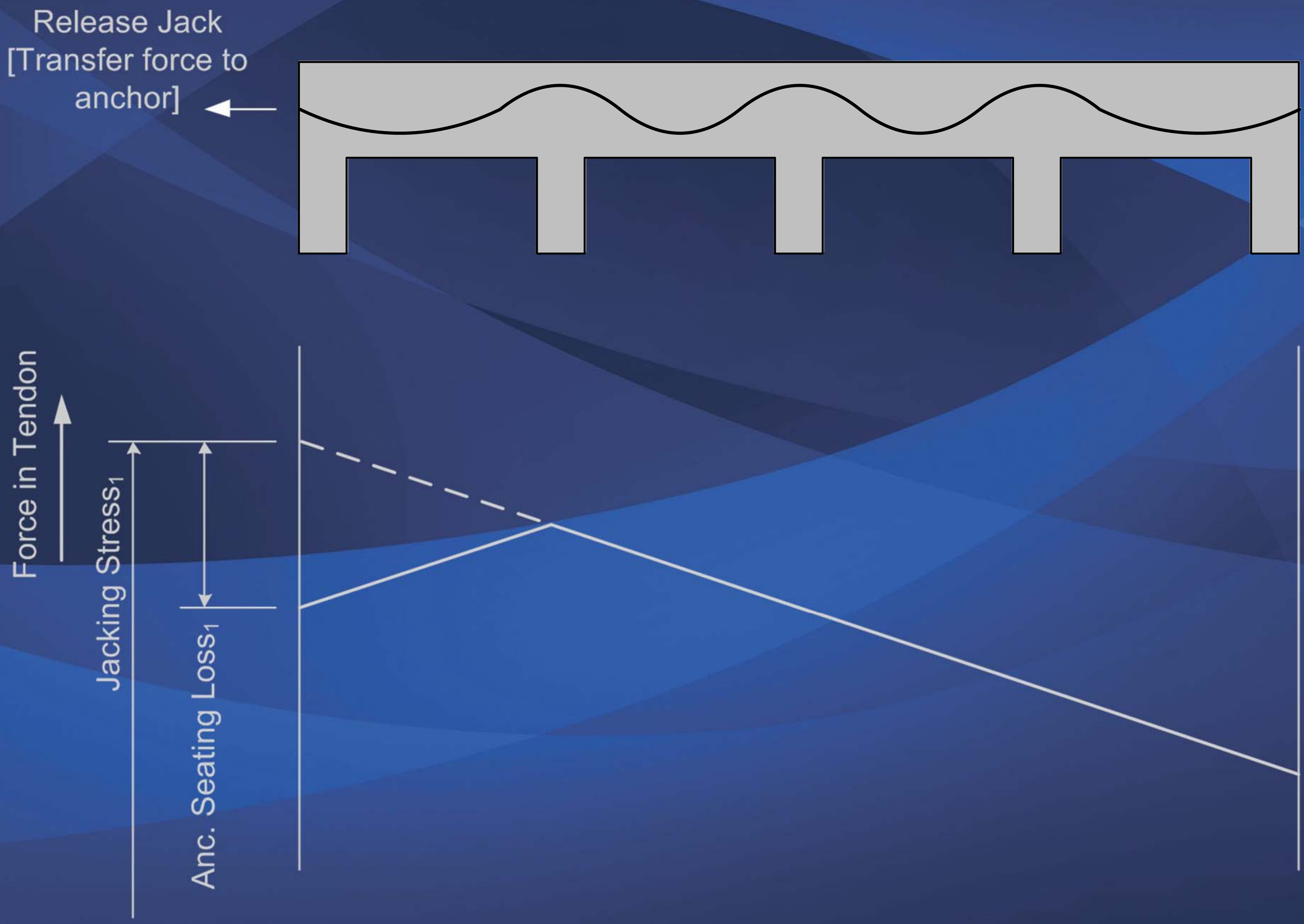
FRICTION AND ANCHORAGE LOSSES



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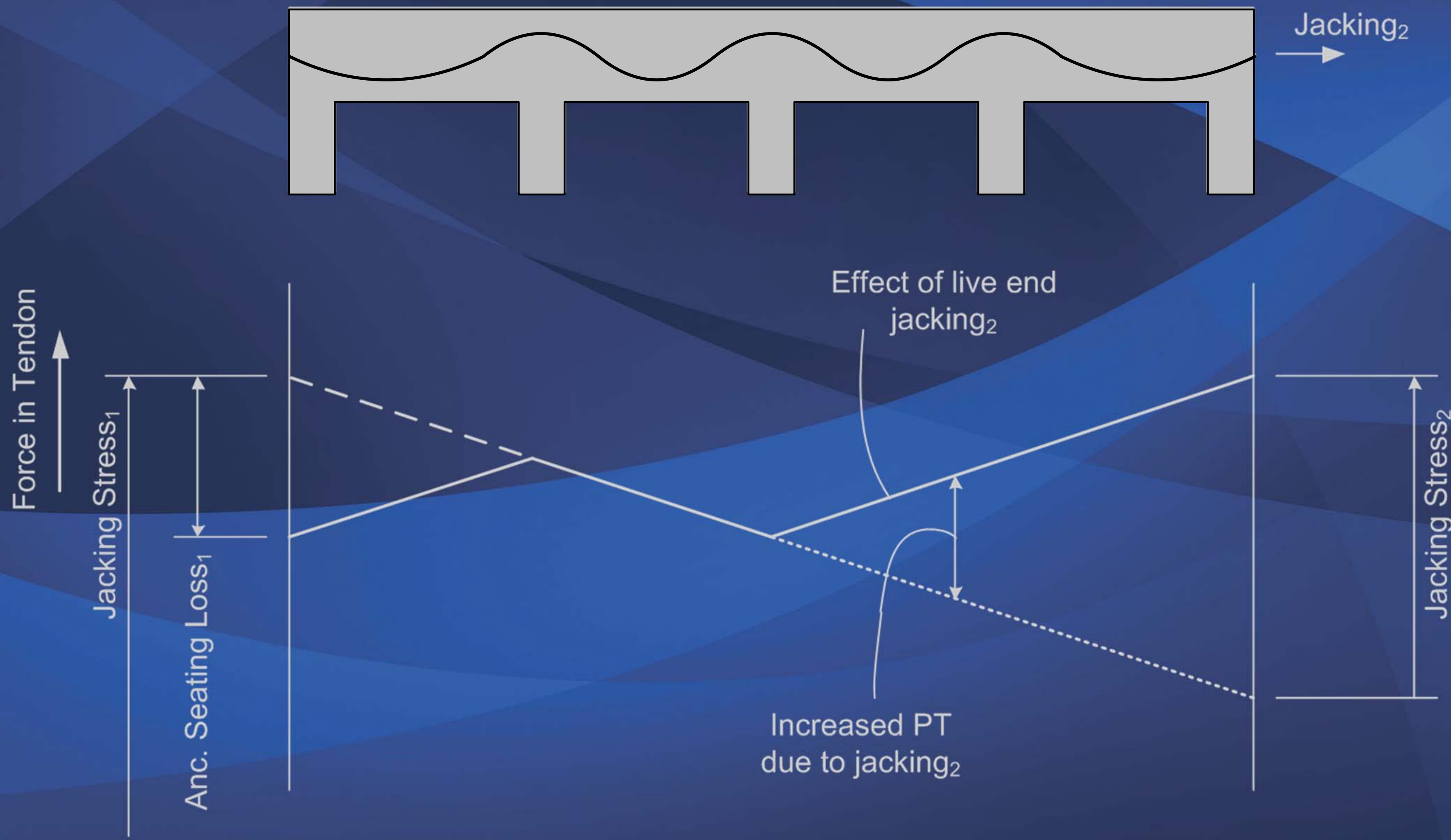
FRICTION AND ANCHORAGE LOSSES



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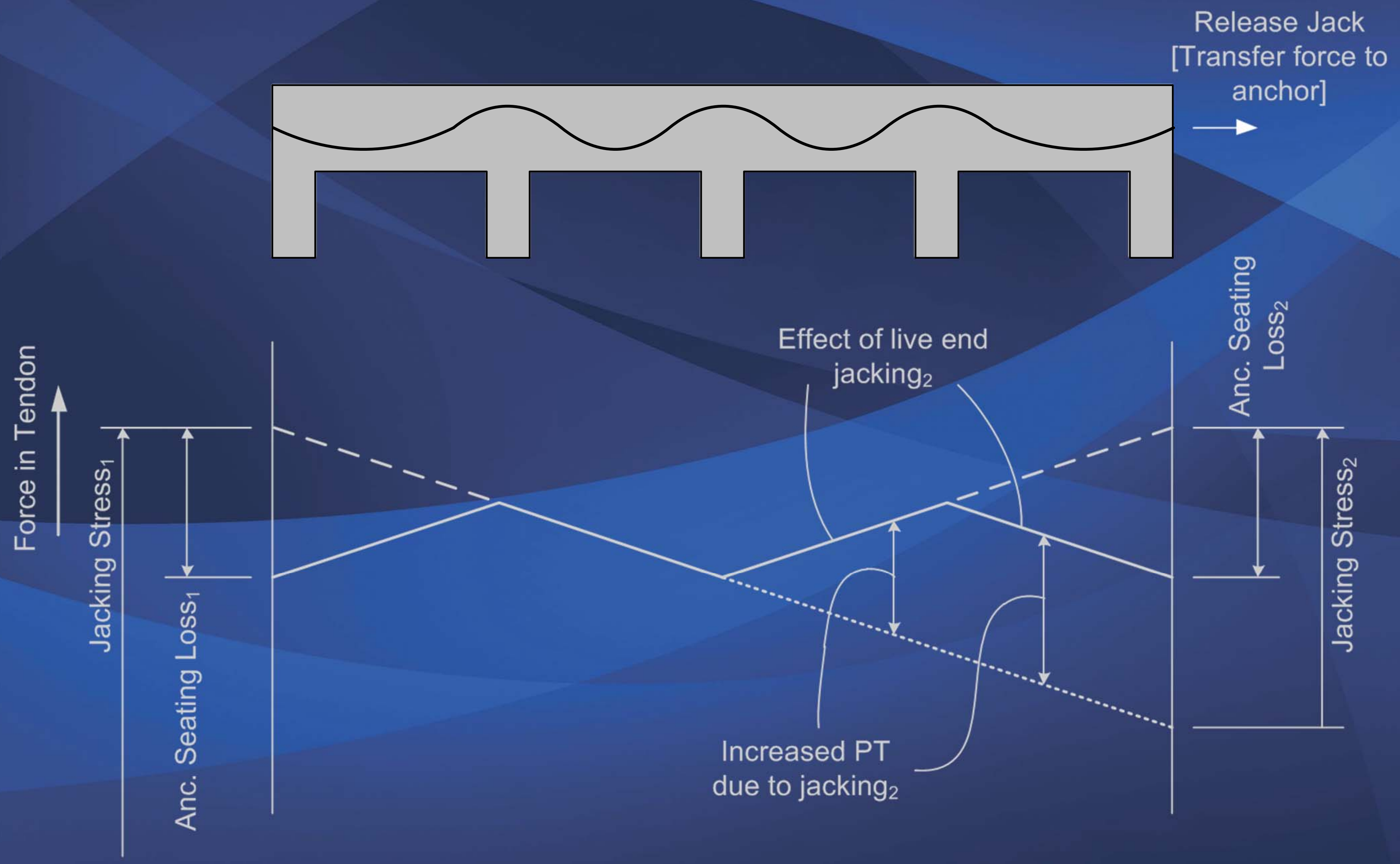
FRICTION AND ANCHORAGE LOSSES



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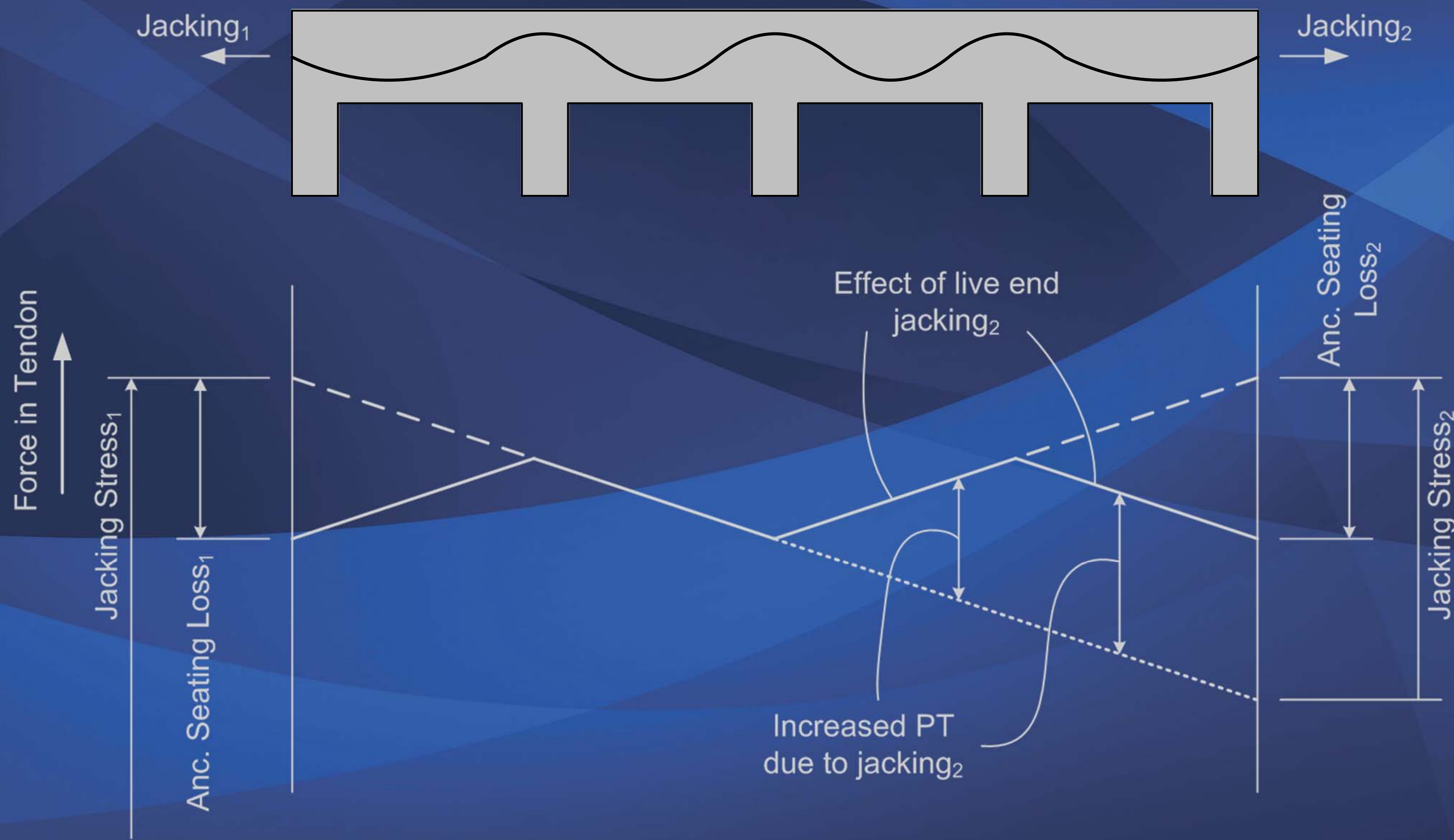
FRICTION AND ANCHORAGE LOSSES



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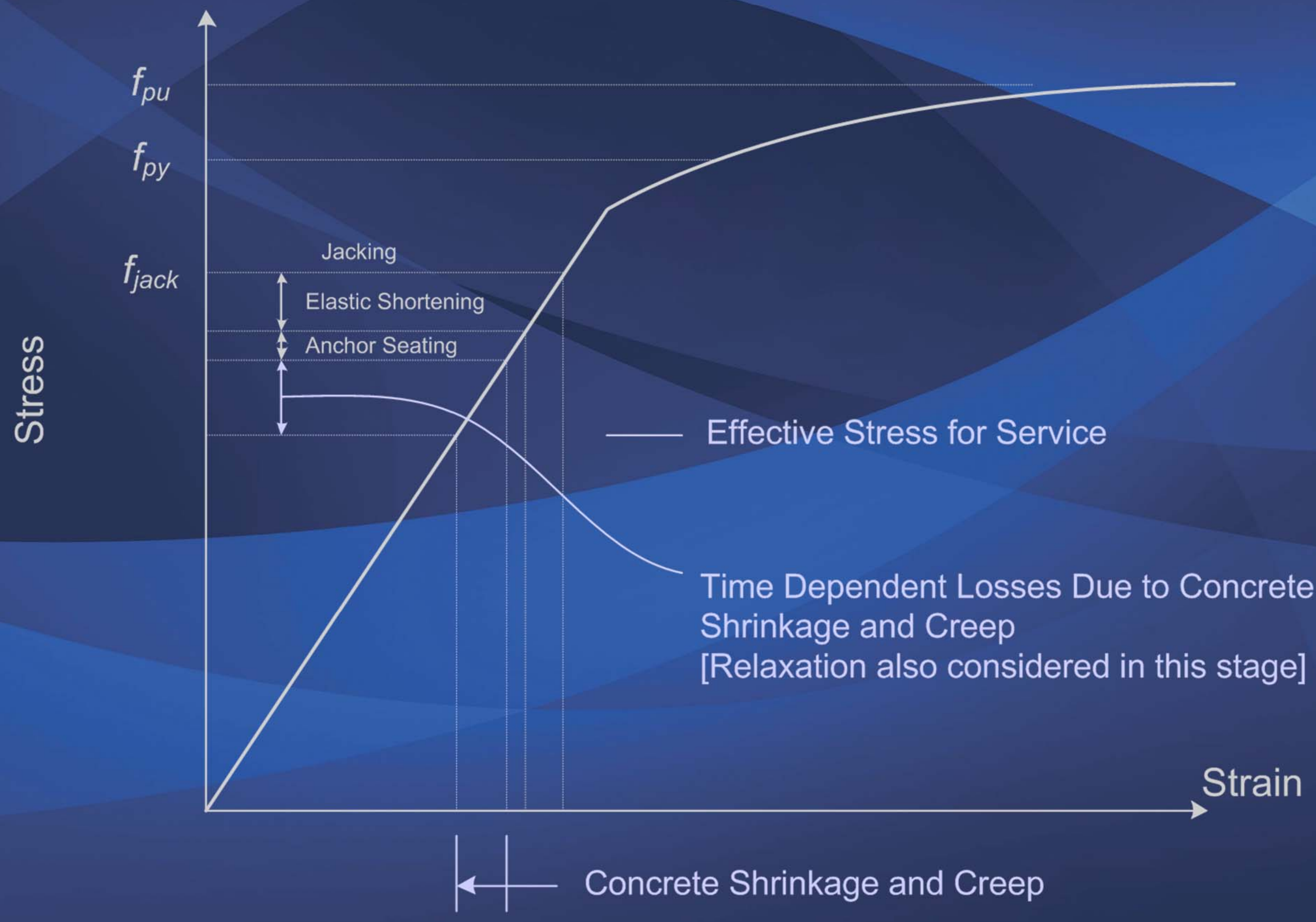
FRICTION AND ANCHORAGE LOSSES

- The variable prestress force in the previous slide is negligible for:
  - Strands less than 100 feet (single-end stressed)
  - Strands less than 200 feet (both ends stressed)

  - Reference: Bondy, K.B., "Variable Prestress Force in Unbonded Post-Tensioned Members," *Concrete International*, January 1992, pp. 27-33.

SHRINKAGE, CREEP, AND RELAXATION



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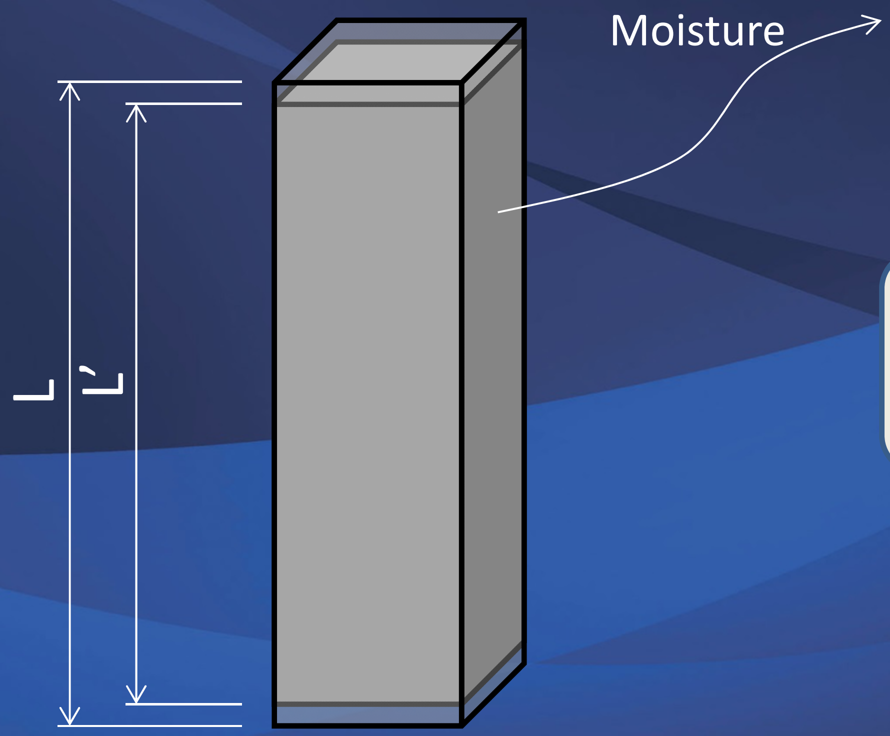
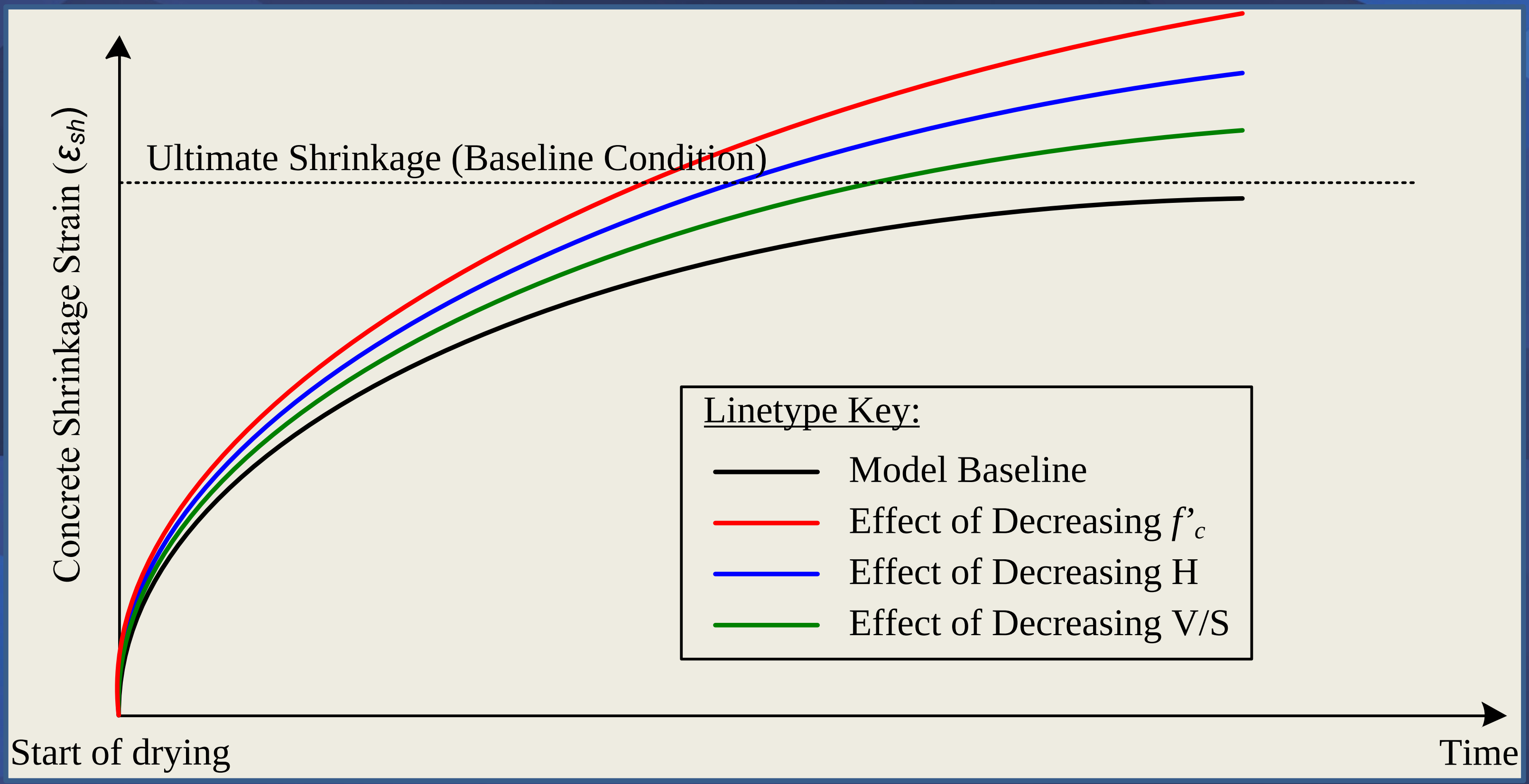
CONCRETE SHRINKAGE



$$\varepsilon_{sh} = \frac{\Delta L}{L} = \frac{L - L^{'}}{L}$$

CONCRETE SHRINKAGE



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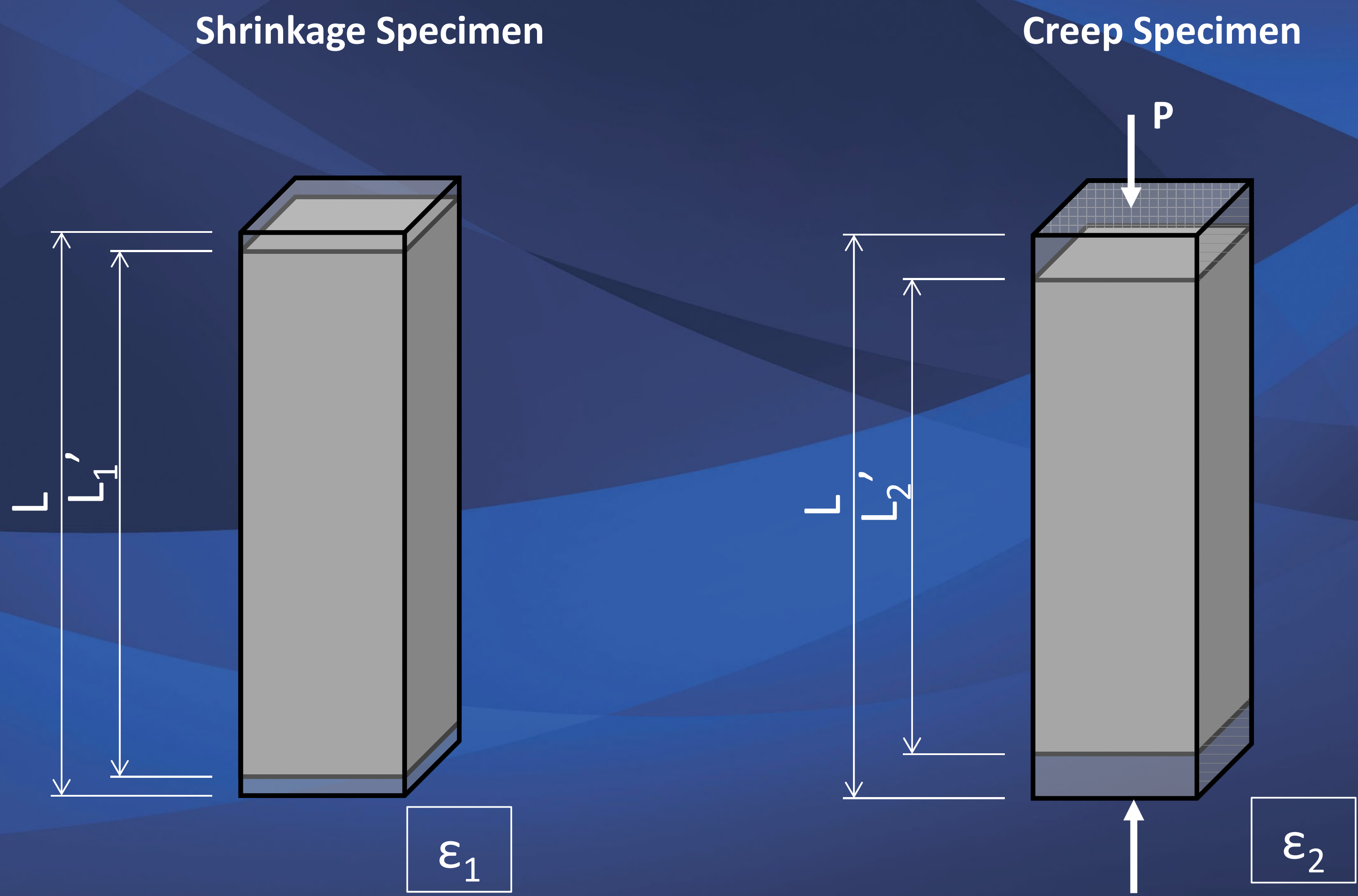
CONCRETE CREEP



Concrete shortening due to sustained compression

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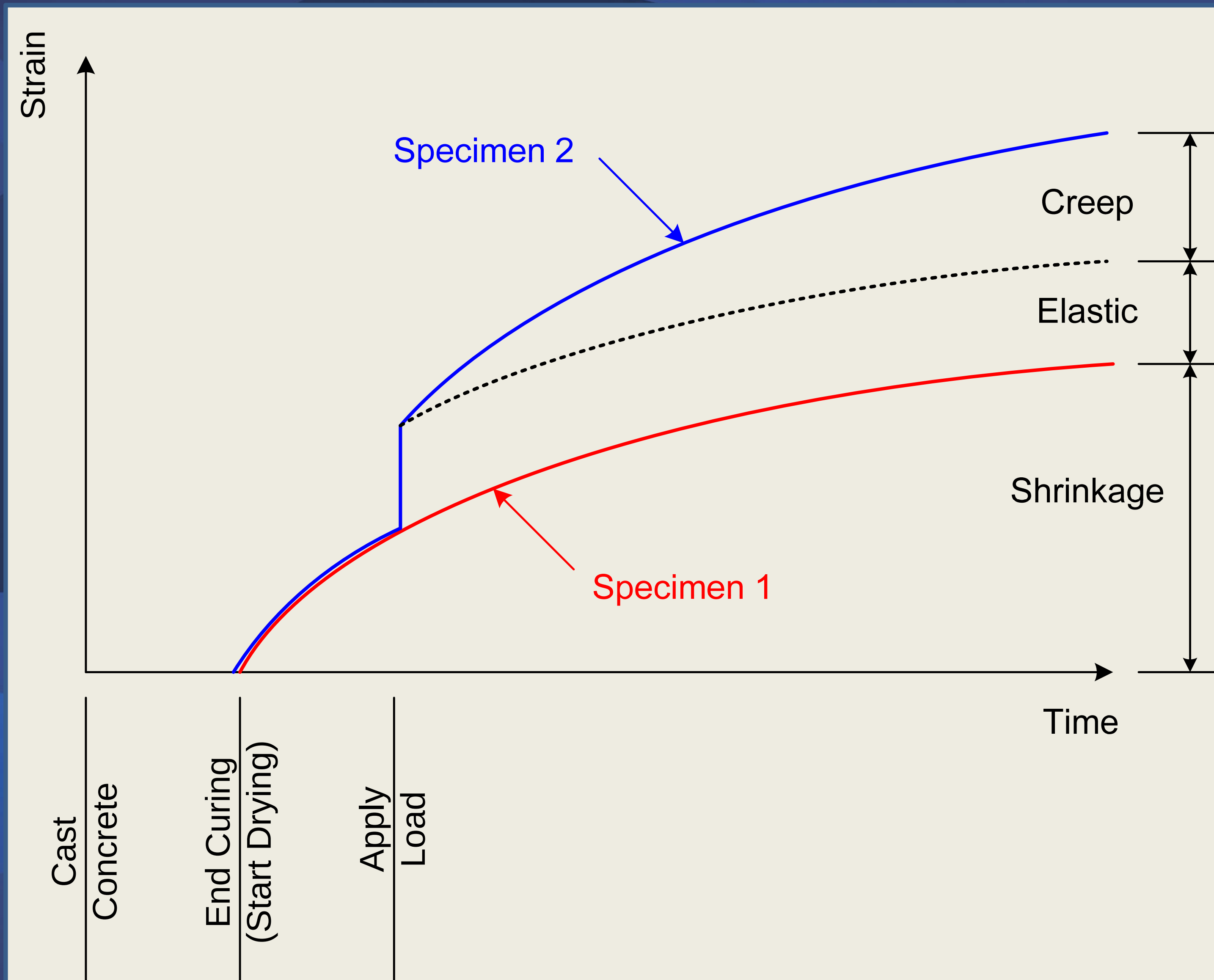
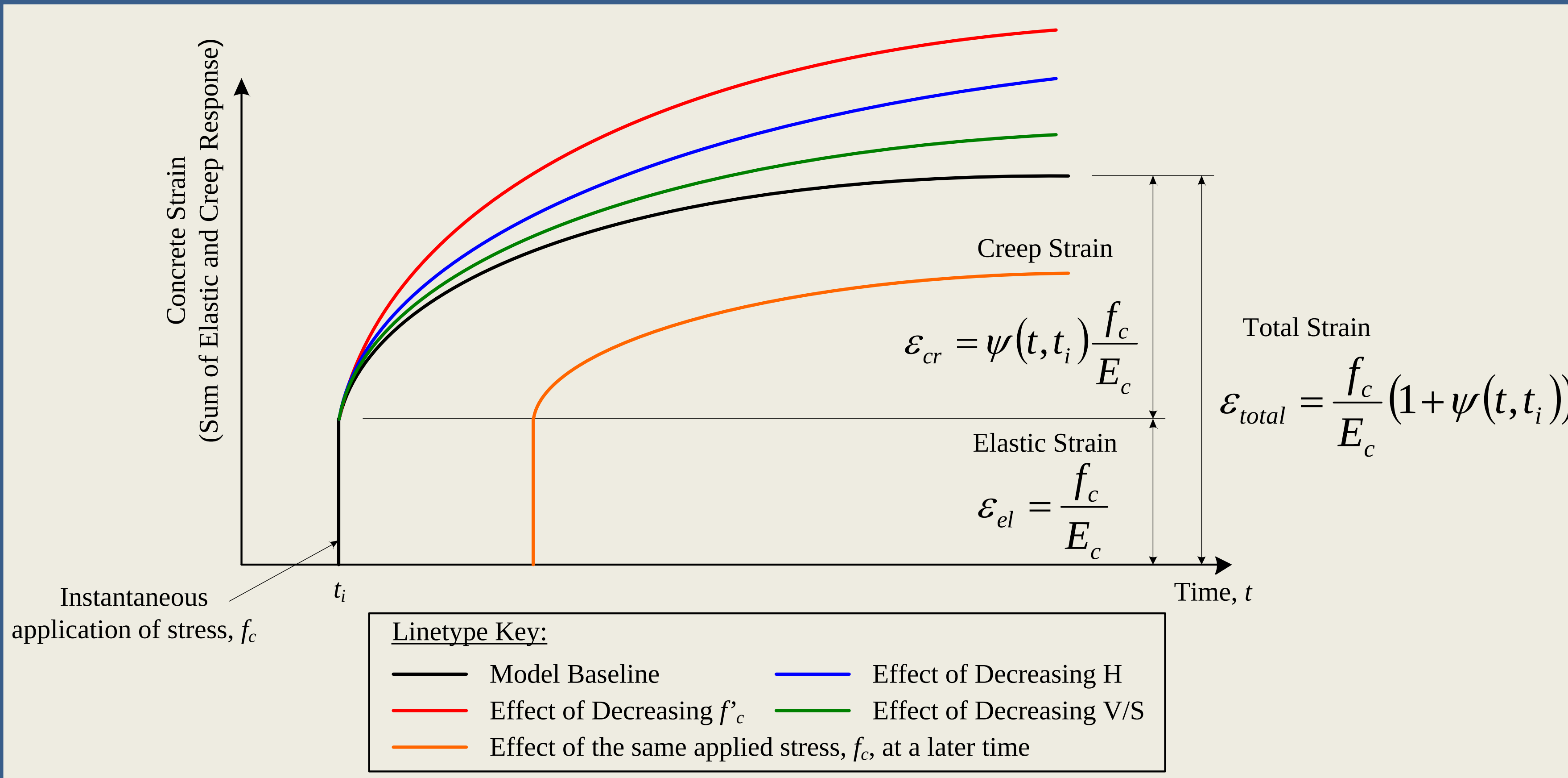
CONCRETE CREEP



CONCRETE CREEP



Creep strain is calculated by a creep coefficient, $\psi(t, t_i)$, that expresses creep strain as a function of elastic strain.

STEEL RELAXATION

- A loss of stress in the steel after being held at a constant elongation (sustained tension)
- For low-relaxation steel (industry standard) relaxation losses are very small compared to other loss components (~1-3 ksi)

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