SECTION 4

LOSS OF PRESTRESS

EMPHASIS ON ITEMS SPECIFIC TO POST-TENSIONED SYSTEMS

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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
The stressing jack bears against the concrete

- Concrete is compressed gradually as the strand is tensioned
- Many things occur simultaneously
  - Stressing, friction, elastic shortening
Dead End Force < Live End Force

Duct/Strand Cross-Section

Idealized

Reality

“Wobble” and “Curvature Effects”
FRICTION LOSSES

- Monitor elongation in addition to pressure during stressing

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

For Post-Tensioning, All Occur Simultaneously

Jacking (Exact Magnitude Affected by Friction)

Effective Stress after Jacking/Elastic Shortening

"Elastic Shortening Loss"

Elastic Response of Concrete To Compression

Elastic Response of Concrete To Load
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

\[ \Delta f_{pES} = E_p \epsilon_p \]

Hooke’s Law

Change in strand stress due to elastic shortening loss

Strain in strand

Steel elastic modulus

Assume: Perfect bond between steel and concrete \( \rightarrow \) \( \epsilon_p = \epsilon_c \)

Strain in the concrete, due to compressive stress applied:

\[ \epsilon_c = \frac{f_{cgp}}{E_{ci}} \]

Concrete stress at prestressing centroid

Concrete elastic modulus at time of stressing

Substitution through previous steps

\[ \Delta f_{pES} = \frac{N - 1}{2N} \left( \frac{E_p}{E_{ci}} \right) f_{cgp} \]

Average of first and last strand that experience loss; the last strand tensioned has zero loss, hence the \((N-1)\) term.
ANCHORAGE DEVICES

ENCAPSULATED ANCHOR

STANDARD ANCHORS

ENCAPSULATED ANCHOR

WEDGES
ANCHORAGE DEVICES:

Source: PTI

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HOW ARE STRANDS ANCHORED?

Concrete

Duct

Anchor cast in concrete

Strand
ANCHORAGE SEATING LOSS

- $f_{pu}$
- $f_{py}$
- $f_{jack}$

Jacking
Elastic Shortening

Effective Stress after Anchor Seating

Anchorage Seating Loss

Anchor Seating
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
FRICTION AND Anchorage LOSSES
FRICTION AND ANCHORAGE LOSSES

Release Jack [Transfer force to anchor]

Force in Tendon

Jacking Stress

Anc. Seating Loss

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FRICTION AND ANCHORAGE LOSSES

Force in Tendon

Jacking Stress

Anc. Seating Loss

Release Jack
[Transfer force to anchor]

Effect of live end jacking

Anc. Seating Loss

Jacking Stress

Increased PT due to jacking

Increased PT due to jacking

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FRICTION AND ANCHORAGE LOSSES

Effect of live end jacking 2

Increased PT due to jacking 2

Anc. Seating Loss 2

Jacking Stress 2

Jacking 2

Anc. Seating Loss 1

Jacking Stress 1

Jacking 1

Force in Tendon
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)

SHRINKAGE, CREEP, AND RELAXATION

- Effective Stress for Service
- Time Dependent Losses Due to Concrete Shrinkage and Creep [Relaxation also considered in this stage]
- Concrete Shrinkage and Creep

Stress vs. Strain graph with various stages including:
- $f_{pu}$ and $f_{py}$
- $f_{jack}$
- Elastic Shortening
- Anchor Seating
- Jacking
CONCRETE SHRINKAGE

\[ \varepsilon_{sh} = \frac{\Delta L}{L} = \frac{L - L'}{L} \]
CONCRETE SHRINKAGE

Ultimate Shrinkage (Baseline Condition)

Linetype Key:
- Black: Model Baseline
- Red: Effect of Decreasing $f'_c$
- Blue: Effect of Decreasing H
- Green: Effect of Decreasing V/S

Start of drying

Time

Concrete Shrinkage Strain ($\varepsilon_{sh}$)
Concrete creep

Shrinkage Specimen

Creep Specimen

Concrete shortening due to sustained compression
CONCRETE CREEP

Strain

Time

Cast Concrete End Curing (Start Drying) Apply Load

Specimen 2

Creep

Elastic

Shrinkage

Specimen 1
Creep strain is calculated by a creep coefficient, $\psi(t, t_i)$, that expresses creep strain as a function of elastic strain.

$$\varepsilon_{cr} = \psi(t, t_i) \frac{f_c}{E_c}$$

$$\varepsilon_{el} = \frac{f_c}{E_c}$$

$$\varepsilon_{total} = \frac{f_c}{E_c} (1 + \psi(t, t_i))$$
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)