Modeling different types of tendons

An overview of modeling various types of tendons as objects within SAP2000 is presented as follows:

Prestressed tendons

Construction procedure:

- Prestressing strands are tensioned and possibly depressed for tendon profiles which are not linear.
- Concrete is cast such that tendons are within the structural object.
- Once the concrete hardens, forms are removed and strands are cut at their ends.
- Tendon forces transfer to the concrete and elastic shortening occurs.
- Long term losses due to creep, shrinkage, and steel relaxation begin to take place.

Actual behavior:

- Tendon loads transfer to the concrete over a transfer length.
- Applicable losses include elastic shortening and long-term effects (creep, shrinkage, and steel relaxation).
- Strain compatibility exists in that tendons and concrete are bonded.
- Section stiffness is based on contributions from both the section and the tendons.

Modeling in SAP2000:

Prestressed tendons are modeled in SAP2000 with the following considerations:

- Set coefficients to zero for frictional losses due to curvature and wobble effects. Specify zero anchorage slip loss. These parameters are zero because concrete is placed around stressed tendons.
- The effect of transfer length could be modeled as follows (note that it is not possible to model transfer length using anchorage slip loss, because it will, in the absence of friction losses, reduce the presstress forces in the entire tendon, not just the transfer length zone):
    - Model the tendons in the transfer length zone by separate tendon objects. Determine their length based on the code requirements for the transfer length. Either apply constant average force or jack from one end that is towards the middle of the beam and specify the friction losses such that the force on the other end of the tendon (ie. at the end of the beam) is zero.
- Jack tendons from both ends.
- In the analytical model, tendon load transfers to the concrete at anchorage locations rather than over transfer length. The effect of transfer length may be modeled through anchorage-slip loss.
- Use staged construction to apply prestressing load to isolated and adequately supported prestressed members. At this point, prestressing only affects the individual objects, and not the rest of the structure. Next, connect prestressed members to the rest of the structure, and apply any additional loading.

Post-tensioned, bonded tendons

Construction procedure:

- Concrete is cast with duct openings.
- After concrete hardens, tendons are passed through the ducts, then stressed to the appropriate tension level and anchored. Friction losses (due to wobble and curvature) and anchorage slip losses occur. Elastic-shortening losses are accounted for by stressing tendons to the target force.
- Tendons are then grouted and long-term losses begin to take place.

Actual behavior:

- Load transfers to the concrete at anchorage locations.
- Applicable losses include those in the short term, except for elastic shortening, and the long term.
- Strain compatibility: Before grouting, the tendon can move within the duct, relative to surrounding material. Strain compatibility takes effect after grouting, when the tendon becomes bonded within the member. Deformation of the tendon and the surrounding material is then compatible.
- Section stiffness: Before anchoring tendons, only the concrete contributes to structural stiffness. Duct openings should be subtracted if their void significantly affects the cross section. After grouting, both the concrete and the tendons contribute to stiffness.

Modeling in SAP2000:

Post-tensioned, bonded tendons may be modeled with the following considerations:

- Tendons are fully boned once they are added to a SAP2000 model.
- Use staged construction to model the condition where tendon stiffness is added only once tendons are anchored and grouted, otherwise both the tendon and concrete contributions are present during all phases.
- Either target force or manual iterations to achieve target force must be applied to compensate for losses from elastic shortening.

- Target force or manual iterations for target force must be applied to compensate for elastic-shortening losses. For additional details, please see the Tendon FAQ article.

Post-tensioned, unbonded tendons

Construction procedure:

- Concrete is cast with duct openings.
- After the concrete hardens, tendons are passed through the ducts, stressed, and anchored. Elastic-shortening losses, friction losses (due to wobble and curvature), and anchorage-slip losses take place.
- Long-term losses begin to take place, and tendons are never grouted.

Actual behavior:

- Load transfers to the concrete at anchorage locations.
- Applicable losses include all types of short-term and long-term loss.
- Strain compatibility: Between anchorage locations, tendons can move within the ducts relative to surrounding material. When compared with bonded-tendon behavior, this design mitigates high force concentration by distributing localized stresses along tendon length.
- Section stiffness: Prior to anchoring tendons, only the concrete contributes to stiffness. Duct openings should be subtracted if voids significantly affect stiffness. Once tendons are anchored, both tendons and concrete contribute to stiffness.

Modeling in SAP2000:

Post-tensioned, unbonded tendons may be modeled with the following considerations:

- Straight tendons may be handled much like external tendons. For reference, please see the section which follows.
- Modeling curved tendons may be more complex, though the process is similar to that for external tendons with deviator blocks.

Post-tensioned, external tendons

Post-tensioned, external tendons are similar to unbonded tendons except that external tendons attach to the concrete at several discrete locations, including anchorage points and deviator blocks.

Construction procedure:

- Concrete is cast with duct openings and deviator blocks.
- Tendons are passed through these openings, stressed, then anchored.
- Losses from elastic shortening, friction (due to wobble and curvature), and anchorage slip occur.
- Long-term losses begin to take place.

Actual behavior:

- Load transfers to the concrete only at anchorage locations.
- Applicable losses include elastic shortening, friction loss only at deviator blocks, and long-term losses.
- Strain compatibility: Tendons and concrete move relative to one another at deviator blocks.
- Section stiffness: Prior to anchoring tendons, only the concrete contributes to stiffness. After anchoring, both the concrete and the tendons contribute to section stiffness.

Modeling in SAP2000:

Post-tensioned, external tendons are modeled in SAP2000 with the following considerations:

- Staged construction is necessary to model the condition in which tendon stiffness only contributes to structural properties once tendons are anchored, otherwise both tendons and concrete affect section properties before tendons are anchored in the actual structure.
- Tendons may be modeled outside of material domain such that portions are external to a structural object. Also, when an external tendon may affect other objects, those objects may be assigned to a group which is specified to remain unaffected. These techniques are useful for modeling tendons within a box section which is modeled as a frame.
- CSI Software assumes that tendons do not slip over deviator blocks, though slip may be modeled using a partial equal constraint for a condition without friction, or a friction-pendulum link to capture friction.
- Friction losses from wobble and curvature either may be neglected by specifying zero loss, or may be captured by modeling internal and external portions as separate tendon objects, then assigning losses to each segment.

  For additional information, please see the External tendon article.