Modeling different types of tendons

This page provides an overview of how different types of tendons can be modeled in SAP2000. Only tendons modeled as elements are considered and described on this page.

Pre-tensioned Members

Construction procedure:

- Pre-stressing strands are tensioned and possibly depressed for tendon profiles that are not straight.
- Concrete is cast "around" the tendons.
- Once the concrete is hardened, forms are removed and the strands are cut.
- The force from tendons gets transferred to the concrete and elastic shortening loss takes place.
- Long term losses due to creep, shrinkage and steel relaxation take place.

Actual Behavior:

- Load transfer: Loads from tendons to concrete are transferred over transfer length.
- Applicable losses: Elastic shortening and long term losses due to creep, shrinkage and steel relaxation.
- Strain compatibility: The tendons and the concrete are bonded to each other, therefore there is strain compatibility between the two elements.
- Section stiffness: After the transfer, the section stiffness is based on the contribution from both the concrete section and the tendon.

Modeling in SAP2000:

This type of tendon can be modeled in SAP2000 with the following considerations:

- Set zero coefficients for frictional losses due to curvature and wobble effects. Set zero anchorage slip losses, unless anchorage

slip losses are used to model the effect of transfer length (see below). There are no friction losses and anchorage slip losses, since the concrete is poured around stressed tendon.
- Jack the tendons from both ends.
- In the SAP2000 model, the tendon load will get transferred to the concrete at anchorages instead of over the transfer length. If needed, anchorage slip losses could be used to approximately represent the effect of transfer length.
- Use staged construction analysis to apply the pre-tensioning tendon loads to *isolated*, but adequately supported, pre-tensioned member (please note that this will indeed simulate the pre-tensioning, as the applied load affect only the member in question and do not have impact on the rest of the structure). Once the pre-tensioning is applied, connect the member to the rest of the structure and apply additional loads. Note that if pre-tensioning is applied while the member is connected to other members in the structure, the pre-tensioning may affect other members in the model, which may not be desirable.

Post-tensioned Members, Bonded Tendons

Construction procedure:

- Concrete is cast with duct openings.
- After the concrete hardens, tendons are pulled through the ducts, stressed to the desired level of tension and anchored. Friction losses (due to wobble and curvature) and anchorage slip losses take place. Note that elastic shortening losses are compensated for by stressing the tendons to the desired level of target force.
- Tendons are grouted.
- Long term losses take place.

Actual Behavior:

- Load transfer: Load gets transferred to the concrete at anchorages.
- Applicable losses: All short-term (except for elastic shortening) and long-term losses are applicable.
- Strain compatibility: Before grouting, the tendon can move relative to the surrounding concrete. After grouting, tendon is

bonded to the concrete and hence the deformation of the tendon and the surrounding concrete must be compatible.
- Section stiffness: Prior to anchoring the tendons, the stiffness is provided only by the concrete itself. Note that the duct openings should be subtracted from the section, if they significantly affect the stiffness of the cross-section. After grouting, both the concrete and the tendons contribute to the stiffness of the section.

Modeling in SAP2000:

This type of tendon can be modeled in SAP2000 with the following considerations:

- Tendons are fully bonded once added in the SAP2000 model.
- Staged construction must be used to model the condition that the tendon stiffness is added only when the tendons are added. Without staged construction, the stiffness of the section prior to anchoring the tendons contains the contribution from both the tendons and the concrete.
- Target force or manual iterations for target force must be applied to compensate for elastic shortening losses.

Post-tensioned Members, Unbonded Tendons

Construction procedure:

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

Actual Behavior:

- Load transfer: Load gets transferred to the concrete at anchorages.
- Applicable losses: All short-term and long-term losses are applicable.

- Strain compatibility: Tendon can move relative to the concrete. Compared to bonded tendons, this helps to distribute potential localized high stresses along the length of the tendon.
- Section stiffness: Prior to anchoring the tendons, the stiffness is provided only by the concrete section itself. Note that the duct openings should be subtracted from the section, if they significantly affect the stiffness of the cross-section. After tendons are anchored, both the concrete and the tendons contribute to the stiffness of the section.

Modeling in SAP2000:

This type of tendon can be modeled in SAP2000 with the following considerations:

- Straight tendons can be treated much like external tendons (see the section on external tendons below).
- Modeling of curved tendons is more difficult, but it can be done similarly to external tendons with deviator blocks.

Post-tensioned Members, External Tendons

This type to tendon is similar to unbonded tendons, except for the fact that it is attached at the concrete at several discrete locations, namely anchorage and deviator blocks.

Construction procedure:

- Cast concrete with anchorages and deviator blocks used to deviate the tendons.
- Pull tendons through anchorages and deviator blocks. Stress and anchor the tendons. Elastic shortening losses, friction losses (due to wobble and curvature) and anchorage slip losses take place.
- Long term losses take place.

Actual Behavior:

- Load transfer: At anchorages only.
- Applicable losses: Elastic shortening, friction losses (at deviator blocks only) and long-term losses

- Strain compatibility: tendons and concrete can move relative to each other at deviator blocks.
- Section stiffness: Prior to anchoring the tendons, the stiffness is provided only by the concrete itself. After tendons are anchored, both the concrete and the tendons contribute to the stiffness of the section.

Modeling in SAP2000:

This type of tendon can be modeled in SAP2000 with the following considerations:

- Staged construction must be used to model the condition that the tendon stiffness is added only when the tendons are added. Without staged construction, the stiffness of the section prior to anchoring the tendons contains the contribution from both the tendons and the concrete.
- Model the tendon outside of the bounding box of any object where you want it to be external or specify a group of object that can be loaded by the tendon to exclude objects for which the tendon is external. This could be useful for modeling tendons in a box section that is modeled as a frame.
- It is assumed that the tendons do not slip over the deviator blocks. Alternatively, slippage at deviator blocks could be modeled using partial Equal constraint (for no friction condition) or friction pendulum links (for a condition with friction).
- Friction losses (due to wobble and curvature) should be either neglected by specifying zero losses, or external and internal portions of the tendons would need to be modeled by a separate tendon objects with the actual losses specified separately for each portion of the tendon.