Pile lateral support based on P-y curves

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Introduction

Pile lateral support may be modeled using P-y curves. P-y curves, typically provided by the geotechnical engineer, describe the lateral soil resistance along the depth of a pile or drilled pier. For each layer of soil along the depth, the P-y curve represents a nonlinear relationship in which lateral pile displacement \( y \) mobilizes lateral soil reaction \( P \) per unit length.

The modeling of lateral soil support proceeds as follows:

- Define links, and their associated properties, which will represent lateral support from the soil.
- Draw discrete links at pile joints. For non-gapping soil behavior, draw one link per joint (Figure 1), and for gapping soil behavior, draw two links per joint, one on each side (Figure 2).
- Fully restrain the grounded end of each link, which is away from the pile, as shown in Figures 1 and 2:

![Figure 1 - Non-gapping soil behavior](image1)

![Figure 2 - Gapping soil behavior](image2)

Link definition

Define nonlinear link properties, available through Define > Section Properties > Link/Support Properties, as follows:

- Add a new link property of Multi-Linear Plastic type, then specify the nonlinear link stiffness for the axial (U1) DOF such that it matches the stiffness of the P-y curve, as described through the following process:
  - Define the P-y curve as a force-deformation (F-D) relationship in which \( F \) is total force acting along the tributary length of a pile joint.
  - Use the minimum number of points to characterize the P-y curve such that computation time may remain efficient.
For soil with non-gapping behavior, link definition should extend stiffness through both sides of the F-D relationship, and the hysteretic model should be selected as Kinematic, as shown in Figure 3:

![Figure 3 - Non-gapping link definition](image)

For soil with gapping behavior, only compression should be specified. Tensile stiffness should be set to zero, and the hysteretic model should be selected as Takeda, as shown in Figure 4:

![Figure 4 - Gapping link definition](image)

**Link assignment**

These link definitions should be assigned to link objects through Assign > Link/Support > Link/Support Properties.
Hysteretic behavior

To demonstrate hysteretic behavior, an increasing cyclic-displacement load is applied to a pile joint during nonlinear displacement-based quasi-static time-history analysis. Hysteretic response for the Kinematic and Takeda models are shown in Figures 5 and 6:

Figure 5 - Kinematic model simulates non-gapping behavior
Distributed springs

Rather than drawing links as discrete elements, *line springs* may expedite the modeling process when assigned as follows:

- **Mesh** the piles within each soil layer.
- Define link properties using the tributary length assumed for the F-D relationship.
- For each soil layer, select the pile frame elements and assign the corresponding P-y curve to its link using Assign > Frames > Line Springs.

Ground-displacement loading

The process for applying ground-displacement load along pile length is as follows:

- Model discrete links within each soil layer along the depth of the pile.
- For each layer with a common *displacement history*, define a single *load pattern* per loading direction, and a corresponding number of time functions.
- For each load pattern, select the joint at the grounded end of each link, then assign a unit ground-displacement load along a single direction.
- Create time-history *load cases* as needed to combine load patterns with time-history functions. Additional information is available in the *Manual multi-support excitation* article.

See Also

- *Line and area springs* test problem
- *Displacement time-history record* article
- *Manual multi-support excitation* article