Piles and Forepoles

Introduction

This document describes the implementation of pile or forepole structural support elements in *RS3*. Piles in *RS3* are based on beam elements, with additional parameters to account for the properties of the rock/soil interface with the pile, as well as the end bearing capacity.

Embedded Element

In *RS3*, a special type of element is used called an embedded element, which can be used to model structural support such as beams, piles or forepoles. Embedded elements are elements which do not conform to the mesh. This simplifies meshing requirements and increases computational speed. Nodes are introduced at the intersections of the embedded element and a tetrahedral element. The formulation of the embedded element is similar to the original element except that virtual nodes are linked to the solid element.

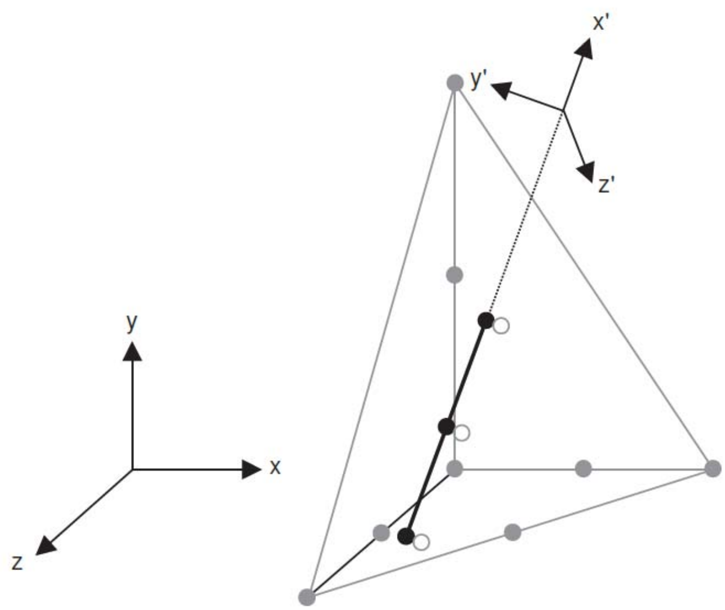

Figure 1 - Geometry of an embedded beam element.

Embedded Beam

The strain-displacement matrix (B) of an embedded beam element is derived from the B^b matrix of the beam element by the relation:

$$B = N^{bs} B^b$$

where B^b is the strain-displacement matrix of the beam element

N^{bs} is the mapping matrix from the beam element to the solid element

$$N_i^{bs} = \{N_i^s 1 \quad 1 \quad 1\}$$

where N_i^s are the shape functions of the solid element at node i

The stiffness matrix of the embedded beam element is then derived using the following expression:

$$K = \int B^T E B$$

where E is the stress-strain material matrix.

The stiffness matrix can then be calculated numerically using Gauss integration or Lobatto integration scheme.

Embedded Piles

The finite element discretisation of a pile is similar to an embedded beam element. In addition, the interaction of the soil and the pile at the skin of the pile is described by embedded interface elements. These interface elements are constructed based on joint elements which have pairs of nodes instead of single nodes (please refer to the joint element formulation document). One node of each pair belongs to the beam element and the other belongs to the solid element (see Figure 1).

A similar procedure to the embedded beam element is employed to derive the formulation for the embedded interface. The interaction can be used to represent skin traction between the pile, and the rock or soil.

In addition to the interaction along the length of the pile, an embedded spring is added at the bottom of the pile to represent the end bearing capacity of the pile. A similar procedure to the embedded interface element is used to derive the formulation of the end spring element.

Embedded Forepoles

The implementation of a forepole is the same as described above for a pile element, except that only skin traction along the length of the forepole is considered. The bearing capacity and stiffness at the ends of the forepole are not considered, since forepoles are usually installed horizontally to provide tunnel roof support.

References

1. Sadek, M. and Shahrour, I. (2004). “A three dimensional embedded beam element for reinforced geomaterials”. International journal for numerical and analytical methods in geomechanics, 28:931-946.

2. Sethna, E., Yacoub, T., Dang, K., and Curran, J. (2013). “Finite element parametric analysis of vertically loaded pile in clay”. Presented in DFI, September 2013.