Using 2D Finite Element Analysis to create a sub-surface plane/curve in Xdisp

1. Introduction

Carrying out a two dimensional (2D) finite element (FE) analysis specific for the proposed installation of a retaining wall and subsequent retained cut excavation is one method to enable the user to create sub-surface ground movement plane in Xdisp.

A 2D analysis would typically calculate ground movements considering either a plane strain or axi-symmetric assumption.

One of the main advantages of importing sub-surface planes of displacement from FE analysis is that the ground movement results can be combined with movements from other excavations such as those from tunnels calculated by Xdisp. The combined effect can then be appraised and impacts on 3rd party assets such as buildings, utilities or tunnels appraised. Other uses could be to generate an estimate of three dimensional displacements around a deep basement excavation from a two dimensional analysis based upon an empirical methodology that has been programmed into Xdisp.

The term 'ground movement plane' in this section of text is used to describe a vertical plane or grid of settlement or horizontal ground movement results. These can be tabulated in terms of the x and y co-ordinate of the displacement calculation point and magnitude of displacement.

2D FE analyses generally model a number of construction stages and any of these could be input into Xdisp dependent upon the desired ground movement results required. Sub-surface planes of displacement from different stages can be imported into Xdisp, for instance to reflect the effect of installing piles or completion of the excavation.

Care should be taken if using results from two or more stages from the FE analysis that the cumulated displacements proposed for use in Xdisp are appropriate. For instance, unless displacements are zeroed at a given stage of a FE analysis, displacements are carried through from previous stages.

Consideration should also be given to the use of appropriate soil models in the FE analysis that has been calibrated to the ground conditions and enable appropriate calculation of ground movements.

Several common applications are anticipated for importing sub-surface planes of displacement from a 2D finite element analyses. These include:

- Modelling installation of an embedded retaining wall. Often a stage is included in a finite element analysis prior to installing the retaining wall for relaxation of the ground as a consequence of wall installation. The user of Xdisp could then apply the calculated plane to the length of wall specified in Xdisp
- Modelling excavation induced displacements from an axi-symmetric shaft analysis. The user of Xdisp could then apply the calculated planes of displacement around the defined shaft position in Xdisp.
- Modelling excavation induced displacements from a basement or embedded retaining wall analysis. Where a plane strain 2D analysis has been carried out and the corners of an excavation are considered to have a stiffening effect, the empirical method proposed by Fuentes & Devriendt (2010) has been programmed into Xdisp to allow an estimate of three dimensional displacements to be calculated around the proposed excavation.

Procedures are provided below for the import of displacements from a 2D FE analysis for import of pile installation and excavation induced embedded retaining wall analysis.

These would be used to create the sub surface curves as detailed below.

2. Procedure for generating a 'Sub surface plane' for the installation of the wall

1. Progress to the construction sequence showing the installation of the wall
2. Query the x and y displacements at a grid of points behind and below the retaining wall
3. Create an Excel file with the following columns:
   - Point number
   - x co-ordinate
   - y co-ordinate
   - vertical displacement
   - horizontal displacement
4. Calculate the distance from wall and depth of the points using the co-ordinates
5. For the vertical sub-surface curve, calculate:
   a. Distance from wall/wall depth
   b. Depth/wall depth
   c. Vertical displacement/wall depth
6. For the horizontal sub-surface curve, calculate:
   a. Distance from wall/wall depth
   b. Depth/wall depth
   c. Horizontal displacement/wall depth

The values required for one point are shown graphically in Figure 1.
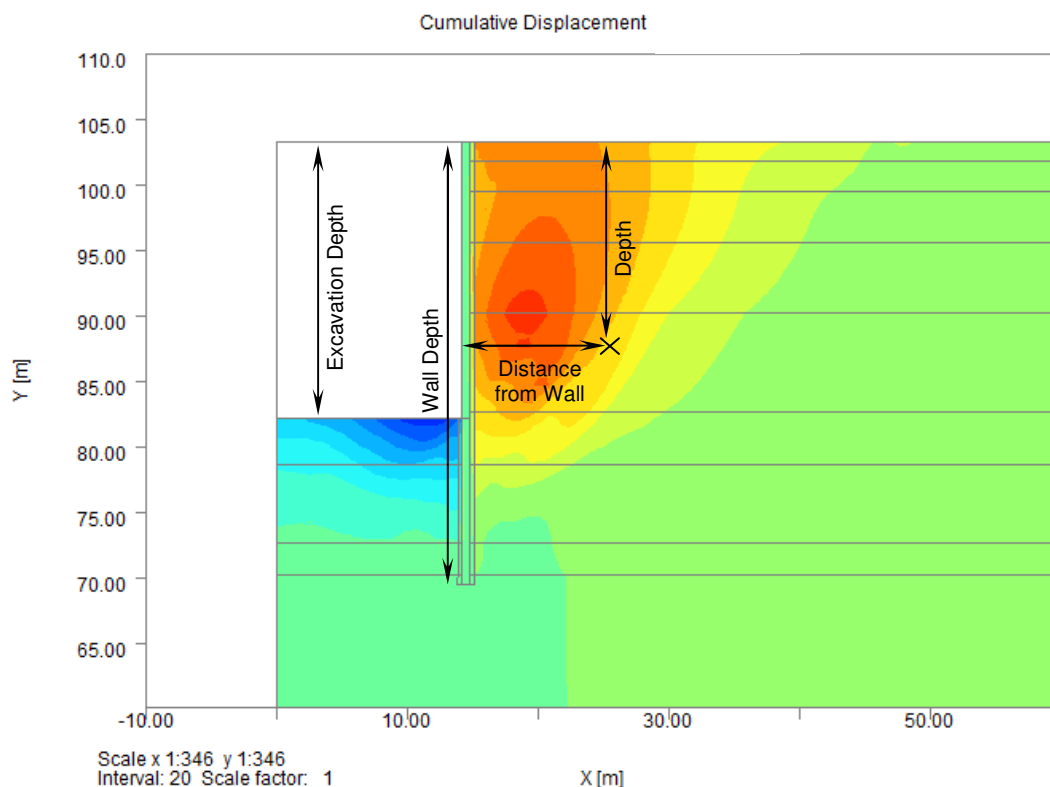
The values from **5**. and **6.** would be pasted into the 'Ground Movement Curves' tab in gateway to create the ground movement plane (Figure 2).

This uses the ratios created in the sub-surface plane and applies them to walls of any depth, as per the base level specified in the 'Polygonial Excavations' tab. To model the installation, the base level specified in Xdisp would be the toe of the installed wall..

An appropriate order of x and y polynomial should be selected to obtain an appropriate fit to the imported data. A check should be carried out to confirm the polynomials proposed in Xdisp adequately replicate the input data.

Figure 2 – Xdisp input for sub-surface curve

3. Sub surface curve for the excavation

1. Progress to the construction sequence showing the excavation
2. Query the x and y displacements at a grid of points behind and below the retaining wall
3. Create an Excel file with the following columns:
    - point number
    - x co-ordinate
    - y co-ordinate
    - vertical displacement
    - horizontal displacement
4. Calculate the distance from wall and depth of the points using the co-ordinates
5. For the vertical sub-surface curve, calculate:
    a. Distance from wall/excavation depth
    b. Depth/excavation depth
    c. Vertical displacement/excavation depth
6. For the horizontal sub-surface curve, calculate:
    a. Distance from wall/excavation depth
    b. Depth/excavation depth
    c. Horizontal displacement/excavation depth

The values required for one point are shown graphically in Figure 1.

The values from **5**. and **6.** would be pasted into the sub-surface curve tab in gateway to create the curve (Figure 2).

To model the excavation, the base level specified in Xdisp would be the base of the excavation (not the installed wall).

An appropriate order of x and y polynomial should be selected to obtain an appropriate fit to the imported data. A check should be carried out to confirm the polynomials proposed in Xdisp adequately replicate the input data.