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FINITE ELEMENT MODELLING OF THE PULL-OUT TEST OF GEOSYNTHETICS

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Summary. *A numerical investigation of the pull-out test of a geotextile has been carried out using 2D and 3D finite element simulations. The results obtained show the limitations of the 2D analysis in capturing the complex stress redistributions reproduced by the 3D model.*

1 INTRODUCTION

The pull-out test is the current experimental procedure for determining the interface resistance in cases where the geosynthetic tends to be pulled out of the surrounding soil, even though test results are difficult to interpret and substantially affected by the boundary conditions and other experimental factors [1].

A numerical investigation has been carried out involving 2D and 3D finite element simulations of the pull-out test with the objective of assessing the importance of the three-dimensional effects.

2 THE PULL OUT TEST PROCEDURE

The pull-out box prototype developed at FEUP (Figure 1) has the following internal dimensions: 1.53m (length); 1.00m (width); 0.80m (height).

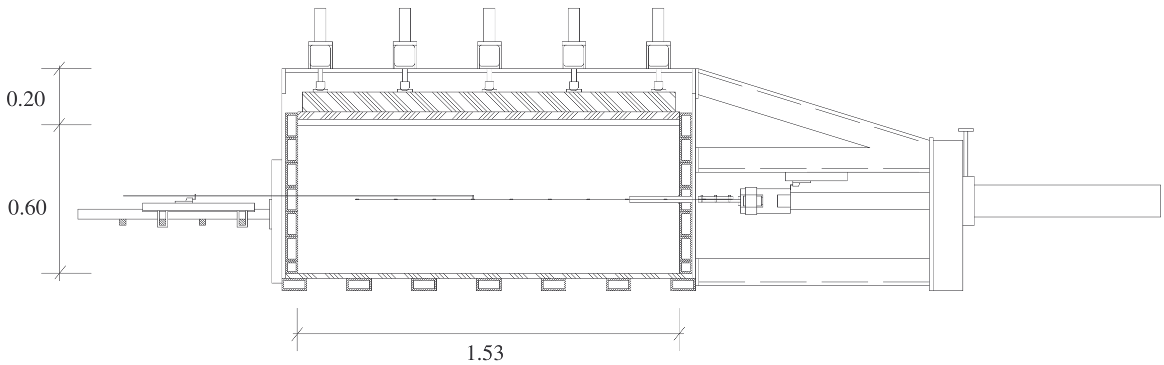

Figure 1 – Pull-out box geometry

The test specimen is placed horizontally, sandwiched between two layers of soil, a uniform vertical pressure being applied to the top soil surface. The specimen is pulled out through a horizontal slit in the frontal wall which may be provided with a stainless steel sleeve protruding 0.20m into the box.

2.1 The testing procedure

The pull-out test procedure comprises the following steps:

- The lower half of the box is filled with two soil layers, each one 0.15m thick after compaction. The soil is poured from a distance of 0.40m to the previous layer surface. Each layer is levelled and compacted with a hand-held vibratory device until reaching the target soil density, as checked with a gamma densimeter.
- When the sleeve level is reached the test specimen is laid flat on the compacted soil and passed into the sleeve out through the front slit.
- After installing various measuring devices for monitoring the specimen displacement at a number of locations, the two top soil layers 0.15m thick are placed and compacted.
- The soil is covered with a 0.025m thick soft neoprene sheet and a plywood board on which will be applied the selected vertical confining pressure.
- All monitoring devices are set to zero and the specimen is then pulled out 0.20m at the adopted test rate.

3 FINITE ELEMENT MODELLING

The basic features of the finite element programs utilized are:

- 8-noded plane or 20-noded brick finite elements for discretizing the soil and the test specimen.
- 6-noded or 16-noded zero thickness joint elements for modelling the soil-geosynthetic interface.
- Gauss-Legendre and Gauss-Lobatto rules for numerical integration.
- Mohr-Coulomb (and several other) elastoplastic material models, with apex and edge singularity indicators and forward Euler stress integration.
- An incremental-iterative procedure with consistent linearization and non-proportional loading.

The 2D mesh has 453 nodes, 117 8-noded plane elements and 23 6-noded joint elements (Fig.2), with the soil-box contact admitted on rollers.

The 3D mesh has 3795 nodes, 702 20-noded brick elements and 52 16-noded joint elements. The soil-box contact is admitted frictionless and the frontal sleeve has not been included.

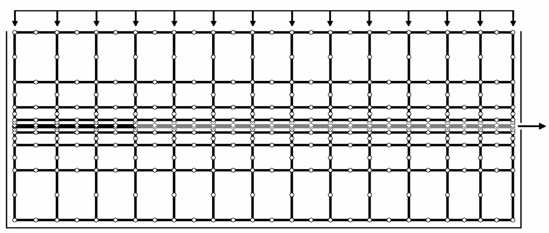

Figure 2 – Pull-out test 2D mesh

Table 1 shows the material and interface parameters adopted in the analyses.

Soil	
γ (kN/m^3)	16.45
Friction angle (°)	35.7
E (kPa)	10000

Geotextile	
Mass/m^2 (g/m^2)	800
Thickness (mm)	6
E (kPa)	10500

Interface	
G (kPa)	3846
Peak friction angle (°)	25
Residual friction angle (°)	9.3

Table 1 – Material and interface parameters

4 2D FINITE ELEMENT RESULTS

The frontal sleeve is a 0.20m long steel device which is placed inside the pull-out box in order to increase the distance from the frontal wall to the zone where stress interaction starts between the test specimen and the soil, thereby reducing the so called frontal boundary effect.

Figure 3 shows how the sleeve has been modelled in the 2D mesh [2,3]. The principal stress plots of Figure 3 correspond to the end of the pull-out, the result of the inclusion of the sleeve being readily apparent.

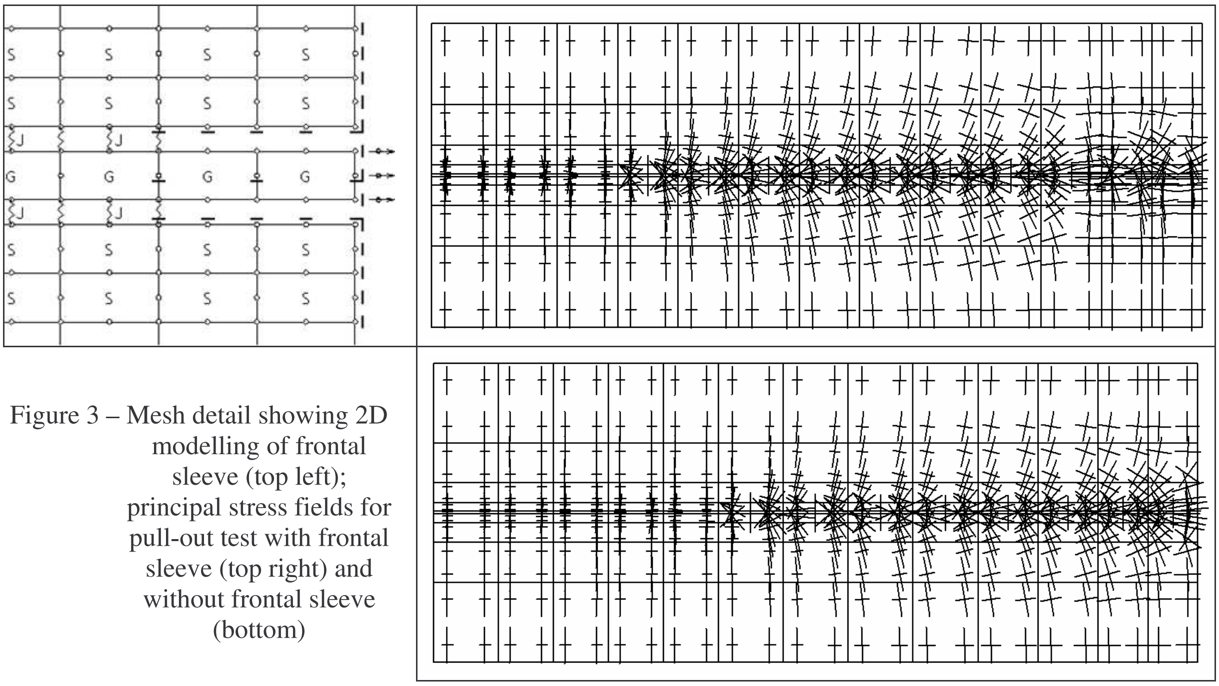

Figure 3 – Mesh detail showing 2D modelling of frontal sleeve (top left); principal stress fields for pull-out test with frontal sleeve (top right) and without frontal sleeve (bottom)

5 3D FINITE ELEMENT RESULTS

The 3D mesh configuration along the yz-plane is identical with that of the 2D meshes (compare Figures 2 and 4). The vertical stress fields of Figure 4 (top) indicate that, in addition to the principal stress rotations on the yz-plane already detected by the 2D analyses, there is an important arching effect involving stress rotation on the xz-plane, as shown by the shear stress τ_{xz} plot and the vertical displacement field of Figure 4.

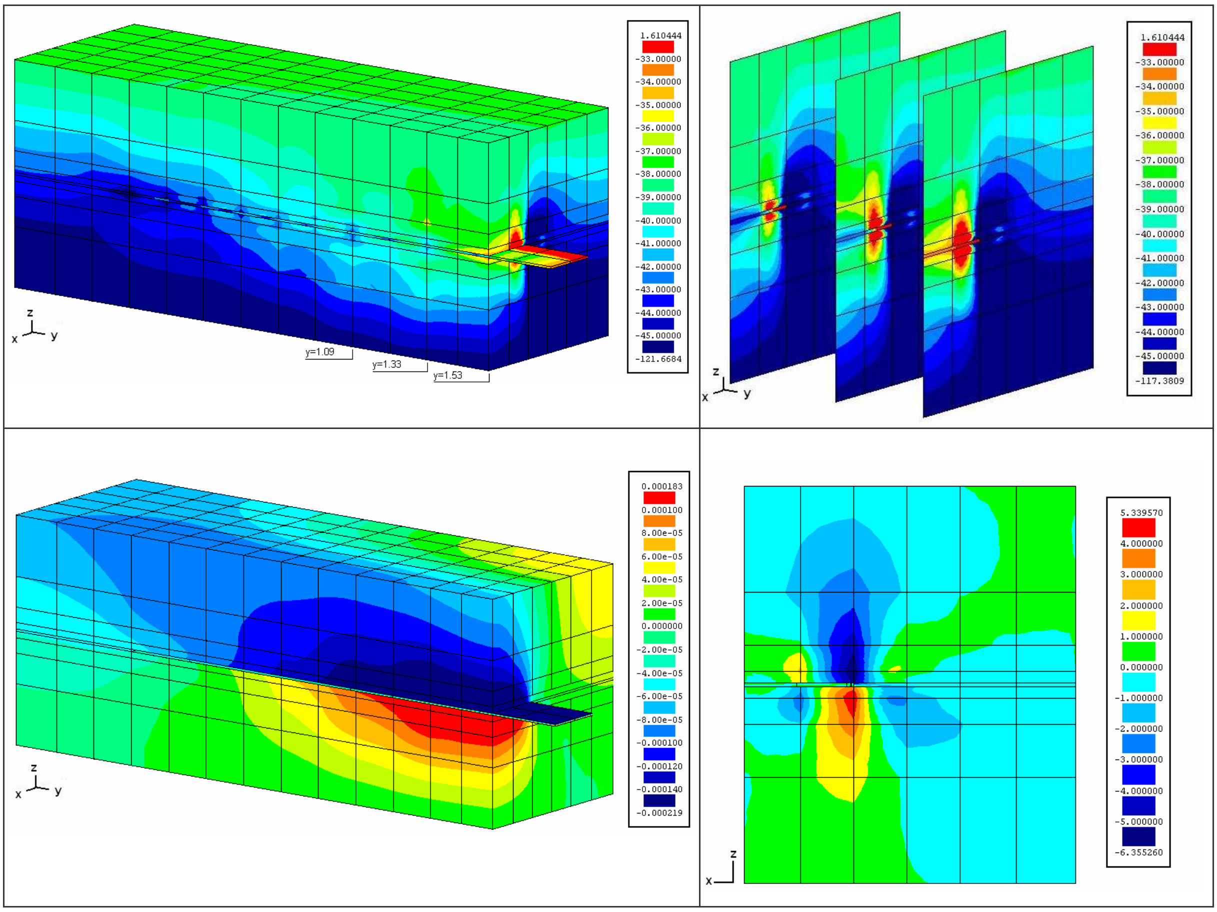

Figure 4 – Clockwise from top left: (i) Overall σ_{zz} distribution; (ii) Distribution of σ_{zz} on three planes normal to the y axis (at y= 1.09, y=1.33 and y=1.53); (iii) Shear stress τ_{xz} (on plane y=1.53); (iv) Vertical displacement d_{zz}.

6 CONCLUSIONS

- The complex stress redistributions of the pull-out test are best captured by resorting to 3D finite element analysis. Such features are only partially revealed by the 2D simulations.

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