BULLETIN

PLAXIS

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**Bulletin of the**
**PLAXIS**
**Users Association (NL)**

**PLAXIS bulletin**
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## IN THIS ISSUE:

# Editorial

*We are pleased to announce the release of the new Plaxis Version 7 at the end of this month. In the past months the Plaxis team has re-written the user documentation, as well as Beta-testing the new Version. The new version has been tested by a substantial group of selected users. In addition, the new version has been used during some user meetings and also during the course on Computational Geotechnics in Noordwijk last January.*

"During this course, existing users, as well as people who had no previous Plaxis experience used the new Version. The participants were very enthousiastic with respect to the new concept of mesh generation. In Version 7, the user only needs to enter the relevant geometry (project contour, soil layers, construction phases, loads and structural elements). This information is used by the automatic mesh generator to propose a finite element mesh (see fig 1). Several options exist to refine the proposed mesh in a convenient manner. Needless to say the Windows Version offers many other new

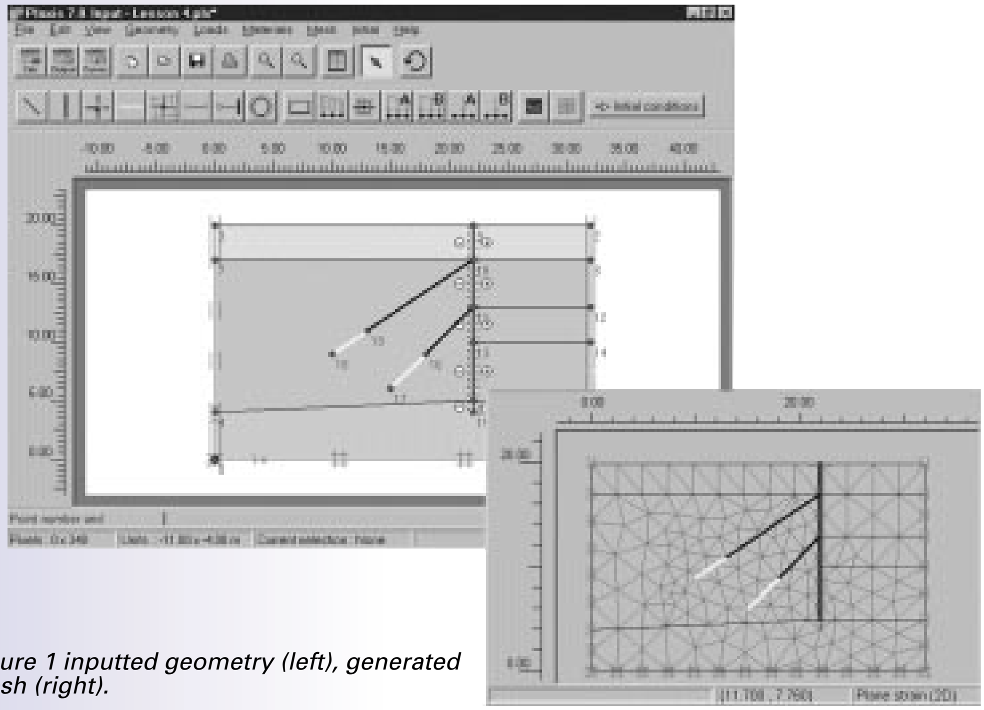

*Figure 1 inputted geometry (left), generated mesh (right).*

features as well. In this issue of 'New developments' one of these features, namely the Tunnel Designer, is described.
All existing users will receive detailed upgrade information on the new Version by separate mail.

As for the previous bulletin, two contributions have been accepted for the column Plaxis Practice. In this bulletin the Users Forum is temporarily discontinued. In the next bulletin the Users Forum will continued for Version 7.

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Nisa Nurmohamed, chief editor
Eric Sluimer, chairman Plaxis Users Association (NL)
Peter Brand, Plaxis bv

Scientific committee:
Prof. Pieter Vermeer, Stuttgart University
Dr. Ronald Brinkgreve, Plaxis bv

# Column Vermeer

***Being involved in deep excavations in clay soils, I had to answer the question whether we needed a drained or an undrained analysis. I happen to possess an excellent book entitled "Deep Excavations" by Malcolm Puller (1996) and I thus did some reading. Indeed, this practical manual gives excellent information and for clarity I will repeat some of it:***

The undrained shear strength $c_u$ is only correctly used when load is applied immediately and it is strictly illogical to use it as soon as pore pressures change. In clay soils, where the retaining wall structure deforms and attempts to move away from the retained soil bulk, negative pore pressures (underpressure) are generated in the retained soil as excavation proceeds in front of the wall. In highly fissured or laminated overconsolidated clays the reduction in underpressure may proceed relatively quickly and the original value of $c_u$ quickly becomes inapplicable. The use of $c_u$ in such analyses can therefore become over-optimistic."

I fully agree! For excavations we have unloading and then the drained long-term stability is decisive, rather than the undrained short-term stability. Most textbooks tend to concentrate on loading problems in embankment or foundation construction, when consolidation improves the stability of a structure, and one might get the false impression that the undrained analysis always leads to a conservative estimate of the factor of safety.

For soft soils, which do not benefit from drainage paths due to fissuring, Malcolm Puller states that it is prudent to undertake analysis for both drained and undrained soil conditions. Here I would like to add that one might also decide on the basis of a back-of-the-envelope calculation. To judge the degree of consolidation, most textbooks provide the function U(T), where T is the dimensionless consolidation time.

$$T = \frac{k\, E_{oed}}{\gamma_w D^2}\, t$$

where:

$k$ = soil permeability
$E_{oed}$ = oedometer modulus
$\gamma_w$ = specific water weight
$D$ = drainage length
$t$ = consolidation time

No doubt, available functions for U relate to one-dimensional consolidation, but we often have near-vertical drainage of deep layers to the bottom of the excavation and similar conditions for shallower clay layers behind an impermeable retaining wall.

Considering one-dimensional consolidation, we have a well-known relationship between the degree of consolidation, U, and the dimensionless time T. For $T = 0.01$ we have $U \approx 0.1$ and thus little consolidation, as $U = 0.10$ implies an average dissipation of excess pore pressures of only 10%. In such cases I would suggest undertaking the undrained analysis and forgetting about the drained analysis. On the other hand, if construction takes a very long time, with T > 0.4, giving U > 0.7, we have nearly drained conditions and I would suggest undertaking only a drained analysis. For intermediate consolidation times, the PLAXIS code offers the possibility of taking consolidation properly into account. I like to continue with this subject in a coming bulletin.

**P.A. Vermeer, Stuttgart University**

# PLAXIS Practice I

## SETTLEMENT BEHAVIOUR OF A LARGE CLINKER SILO ON SOFT GROUND

*A heavy circular clinker silo with storage capacity of about 9000 MN (see Figure 1) had to be founded on clay at Beremend in Hungary. The upper 21.0 m subsoil consists of soft to medium stiff clay followed by quaternary silty sand down to a depth of about 33.0 m below ground surface. Tertiary sediments of stiff to hard clay with thin sand layers are found under the quaternary sand. The groundwater table is 5 to 6 m below ground surface. The conducted soil exploration and in-situ tests such as the cone penetration test (CPT) show that the subsoil layers are almost horizontal and nearly homogeneous.*

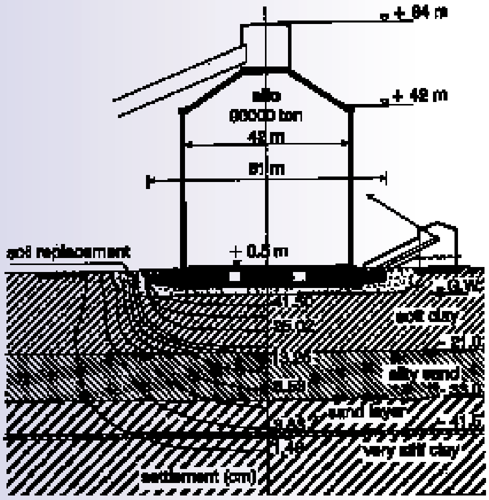


Figure 1 Layout and calculated contour lines of settlement.

Due to the soil homogeneity a traditional raft was chosen to support the heavy silo on the soft soil. The raft thickness is 5.5 m in the middle part and decreases to 2.5 m at the edges. A reliable prediction of the total and differential settlements under the working loads was the main basis of the foundation design. The PLAXIS program was used to simulate the behaviour of the silo under both undrained (short term) and drained (long term) conditions. An axisymmetric finite element analysis was conducted using isoparametric triangular elements with 15 nodes. An elasto-plastic constitutive law applying the Mohr-Coulomb yield condition was employed to model the behaviour of the different soil types. Table 1 summarizes the required soil parameters which are based on the conducted laboratory and in-situ tests as well as on the gathered experience of similar projects. Here, the conventional option of using $\nu_u = 0.495$ is applied to simulate undrained behaviour for clay layers. Note that Plaxis has a more convinient option to model undrained behaviour. This option is to set the material type to 'Undrained' behaviour, which also allows for the generation of excess pore pressures. This option is always used in combination with effective stiffness properties $(E', \nu')$ . The settlements of the silo have been observed in detail since about 2.5 years to ensure the serviceability requirements.

Figure 2 demonstrates the development of the applied loads and the corresponding measured settlements of two points at the center and the edge of the raft. Although the maximum total settlement is about 30.0 cm, the maximum differential settlement within the silo walls is less than 2.0 cm. The maximum measured tilting of the silo reaches about 1 : 3200.

The calculated load settlement relationships of the raft under undrained as well as drained conditions in comparison with the measured behaviour are shown in Figure 3. It can be seen that the development of the applied load was fairly quick to a silo load of about 900 MN (see

*Table 1a Short term condition material properties (Undrained).*

| soil | $\gamma_{dry}/\gamma_{wet}$ [kN/m³] | φ [°] | c [kN/m²] | E [MN/m²] | ν [-] |
|---|---|---|---|---|---|
| soft clay | 19/9 | 0 (= $\varphi_u$) | 100 (=$c_u$) | 50 | 0.49 |
| silty sand | 19/10 | 30 | 1 | 80 | 0.35 |
| hard clay | 20/10 | 0 (= $\varphi_u$) | 150 (=$c_u$) | 80 | 0.49 |
| soil replacement | 20/10 | 35 | 1 | 50 | 0.35 |

*Table 1b Long term condition material properties (Drained).*

| soil | $\gamma_{dry}/\gamma_{wet}$ [kN/m³] | φ [°] | c [kN/m²] | E [MN/m²] | ν [-] |
|---|---|---|---|---|---|
| soft clay | 19/9 | 20 | 40 | 12.7 | 0.35 |
| silty sand | 19/10 | 30 | 1 | 61.5 | 0.35 |
| hard clay | 20/10 | 25 | 25 | 61.5 | 0.35 |
| soil replacement | 20/10 | 35 | 1 | 50 | 0.35 |

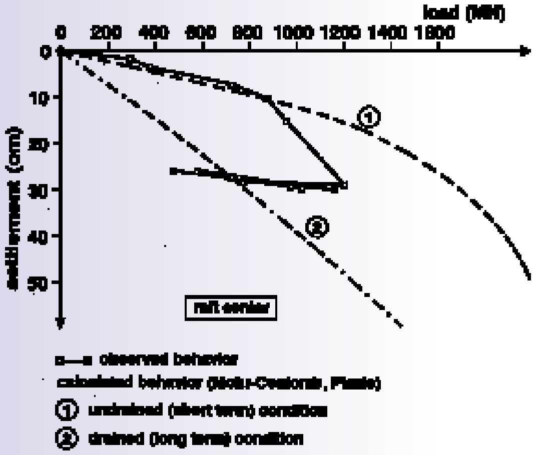


*Figure 2 Development of loads and setllements with time.*

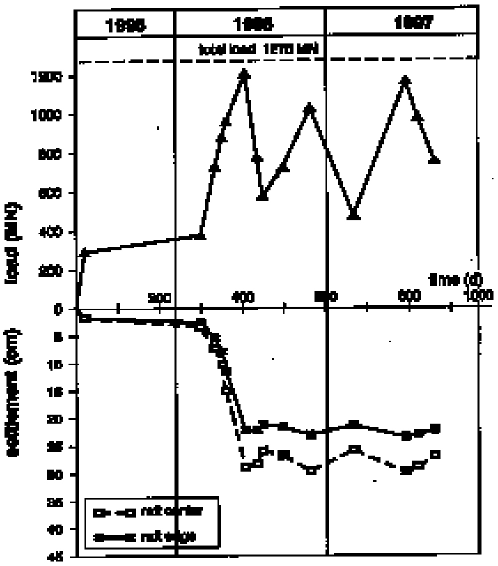


*Figure 3 Comparison between observed and calculated load-settlements behaviour.*

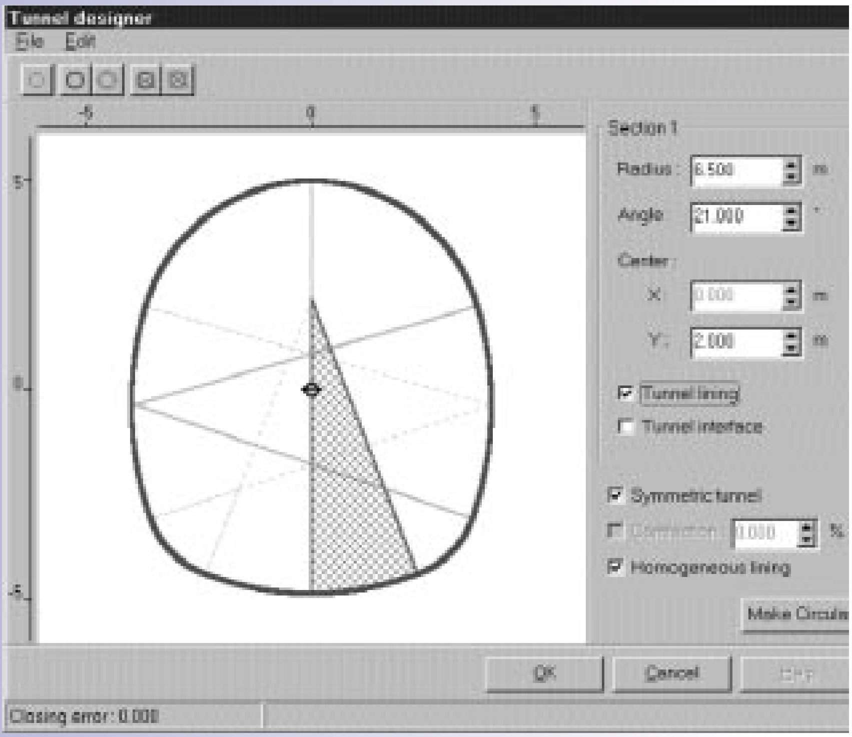
Figure 2). Therefore, the raft behaviour is close to the undrained behaviour in this range. Due to the stress release caused by the pit excavation, the behaviour of the soil during reloading it by the weight of the raft is still stiffer than its behaviour under the subsequently applied larger loads. Up to 900 MN subsoil consolidation takes place and the raft behaviour tends towards the drained behaviour. It can be seen that the raft has an adequate factor of safety against failure. More than 70 % of the settlement occurs in the soft clay layer (see Figure 1). Due to the more or less cyclic filling and emptying the silo, the maximum applied load does not reach its designed limit value. The duration of the reached maximum load is very short (see Figure 2). Therefore, the maximum measured settlements are still smaller than the predicted settlement under completely drained conditions.

This comparison shows the reliability of the Mohr-Coulomb Model to simulate the soil behaviour under both short and long term conditions. This case history demonstrates how PLAXIS, as a special geotechnical finite element program, helps the practising engineers to achieve more reliable predictions of the soil deformation as well as of its bearing capacity. Last but not least more economic designs are accessible.

**Dr.-Ing. El-Mossallamy, Yasser**
**Assistant Prof., Ain Shams University, Cairo, Egypt**
**Trischler und Partner GmbH, Darmstadt, Germany**

## New developments

*The new Windows version of Plaxis has special options for the creation and analysis of tunnels. The creation of a circular or non-circular tunnel shape has become very easy with the new Tunnel Designer. Moreover, a new calculation option is available to simulate the arching effect in the soil around temporarily unsupported tunnels.*



Section 1
Radius : 6.500 m
Angle 21.000 °
Center :
X: 0.000 m
Y: 2.000 m
☑ Tunnel lining
☐ Tunnel interface
☑ Symmetric tunnel
☐ Contraction : 0.000 %
☑ Homogeneous lining
Closing error: 0.000

*Figure 1 Tunnel Designer.*

### Tunnel Designer

The Tunnel Designer is a separate window in which the shape of a tunnel can be created on the basis of circle sections. The "Tunnel Designer" with an example of a tunnel shape is presented in Fig. 1.

A tunnel is composed of sections. Each section is an arc (part of a circle), which is defined by a centre point, a radius and an angle. By default, the tunnel is circular and composed of 6 sections (3 sections for half a tunnel). The first section starts at the lowest point on the local y-axis (-90°) and runs in the anti-clockwise direction.

The position of this lowest point (starting point of the first section) is determined by the "Centre" coordinates and the "Radius". The end point of the first section is determined by the "Angle". The starting point of a next section coincides with the end point of the previous section. In this connection point, the two sections have the same radial (normal of the tunnel section), but not necessarily the same radius (see Fig. 2). The centre point of the next section is located on this common radial and the exact position follows from the section radius. The radius and the angle of the last section are determined such that the ending radial coincides again with the y-axis.

After the creation of the full tunnel shape, the tunnel can be included in the geometry model of the environment.

### Arching

In addition to the Contraction method for the simulation of soil volume loss around shield tunnels, it is now possible with Plaxis to simulate the construction pocess of tunnels with a sprayed concrete lining (NATM). The major point in such an analysis is to account for the arching effect and the deformations that occur in the soil around the unsupported front of the tunnel. A method that takes these effects into account is the so-called ß-method (Ref.1), but others have presented similar methods under different names. The idea is that the initial stresses $p_k$ acting around the

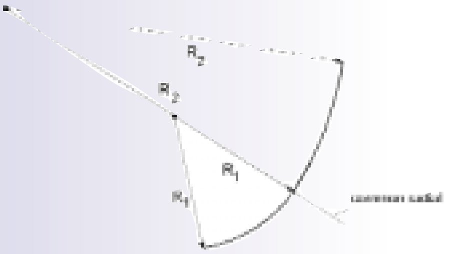


*Figure 2 Detail of connection point between two tunnel sections*

location where the tunnel is to be constructed are divided into a part (1-ß)$p_k$ that is applied to the unsupported tunnel and a part ß$p_k$ that is applied to the supported tunnel (see Fig.3). The ß-value is an 'experience value', which, among other things, depends on the ratio of the unsupported tunnel length and the equivalent tunnel diameter.

Instead of entering a ß-value in Plaxis one can use the staged construction option with a reduced ultimate level of ∑Mstage. In fact, when deactivating the tunnel cluster(s) an initial out-of-balance force occurs that is comparable with $p_k$. In the beginning of the staged construction calculation, when ∑Mstage is zero, this force is fully applied to the active mesh and it will be stepwise decreased to zero with the simultaneous increase of ∑Mstage towards unity. Hence, the value of ∑Mstage can be compared with 1-ß. In order to allow for the second step in the ß-method, the ultimate level of ∑Mstage should be limited to a value of 1-ß while deactivating the tunnel cluster(s). The third step in the analysis is again a staged construction calculation in which the tunnel construction is completed by activating the tunnel lining while ∑Mstage increases towards unity. Hence, the remaining out-of-balance force will be applied to the geometry including the tunnel lining.

## Conclusion

In addition to the analysis of shield tunnels, the new options in the Windows version make Plaxis very suitable for the analysis of NATM tunnels. On the other hand, the "Contraction" procedure, as generally used to simulate the soil volume loss due to shield tunnelling seems to overpredict the width of the settlement trough. This defect is being examined at the University of Delft and a modified procedure is under development. Meanwhile, adequate use of advanced soil models may already improve the results of deformation effects around shield tunnels (Ref. 2).

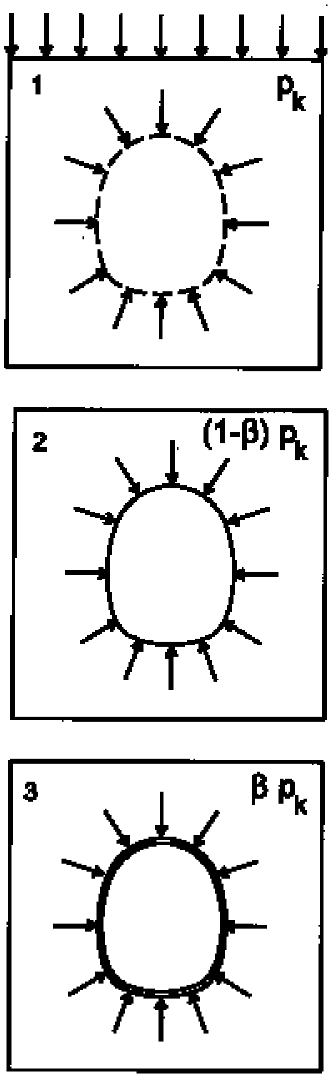


*Figure 3 Schematic representation of the ß-method for the analysis of NATM tunnels.*

Literature:
[1] Schikora K., Fink T. (1982). Berechnungsmethoden moderner bergmännischer Bauweisen beim U-Bahn-Bau. Bauingenieur, 57, 193-198.
[2] Vermeer P.A. (1996). Tunnelling with the Hard Soil model. PLAXIS Bulletin No. 1.

**Ronald Brinkgreve, Plaxis BV**

# PLAXIS Practice II

## THE UPLIFT OF RETAINING WALLS

In PLAXIS bulletin no. 4 1997 Schweiger and Freiseder present an interesting numerical study of the uplift of a diaphragm wall supported by horizontal struts. They conclude that a reduction of the strength reduction factor reduces the uplift tendency of the wall in the PLAXIS analyses.

GeoVita has studied the uplift of an unsupported sheet-pile wall, and came to the opposite conclusion. To explain this, it is necessary to study the overall soil/wall behaviour of both cases.

As soil is excavated in front of an unsupported or horizontally supported wall, the vertical swelling of the subsoil in front of the wall and swelling at larger depths have a tendency to drag the wall upwards along with it, while the settlement of the terrain behind it has a tendency to drag the wall downwards in the analyses.

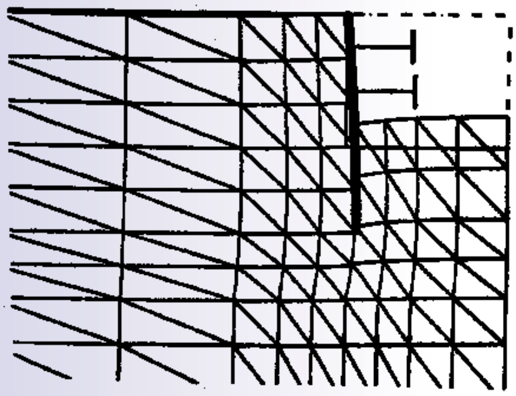


*Figure 1 The deformed diaphragm wall.*

In our opinion, the behaviour of the extremely stiff wall in the study of Schweiger and Freiseder is governed by a soft soil layer at the base of the wall in combination with stiff struts. This allows the wall to kick out at the base, see Figure 1, and thereby causes a rotation of the principal stresses and shearing in front and at the base of the wall, while little happens at shallow depth behind the wall. Thus, the primary action is the heave of the excavation bottom in front of the wall, while the requirement of vertical equilibrium gives the shear reaction behind the wall.

In our model, the sheet-pile wall moves most horizontally outwards at the top of the wall and hardly moves at the tip, see Figure 2. This deformation pattern causes a rotation of the principal stresses at both sides of the wall, but the shearing is more pronounced at shallow depth behind the wall than in front of it. In this case, the primary action is the settlement of the terrain surface behind the wall, while the vertical equilibrium gives the shear reaction in front of the wall.

The uplift tendency of a wall depends on the actual shear stiffness of the soil at both sides of the wall. A softer shear behaviour in front of the wall allows more heave of the excavation bottom compared to the uplift of the wall, and thereby reduces the uplift tendency. On the other hand, a softer shear behaviour behind the wall allows more settlement of the terrain compared to the uplift of the wall, and thereby increases the uplift tendency.

Thus, it can be concluded that the influence of the strength reduction factor on the uplift tendency of a wall depends on the problem analysed. A reduced strength reduction factor

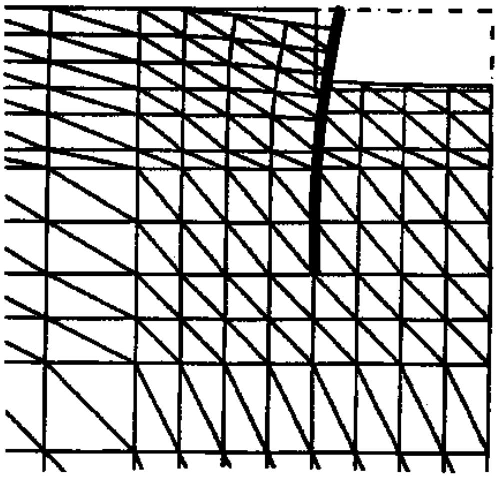


*Figure 2 The deformed sheet-pile wall.*

tends to increase the uplift tendency if the shearing is most pronounced at shallow depth behind the wall, while it tends to reduce the uplift tendency if the shearing is most pronounced in front of the wall.

In addition Schweiger and Freiseder investigated the use of beam elements versus continuum elements for the modelling of the wall. In our opinion, modelling of walls by continuum elements is likely to cause a much too stiff wall behaviour unless several element rows are used over the height of the beam (thickness of the wall).

**Dr. S. Kirkebø, GeoVita as, Norway**

## ACTIVITIES

### 30, 31 MARCH AND 1 APRIL, 1998

Short course on Computational Geotechnics (German), 'Finite Elemente Anwendungen in der Grundbaupraxis', Stuttgart, Germany

### 6 APRIL, 1998

Release date of Plaxis Version 7.0

### 16 APRIL, 1998

Users meeting (Dutch) Plaxis User Association (NL), Barendrecht, the Netherlands

### 20-22 MAY, 1998

Short course on Computational Geotechnics (English), Cairo, Egypt

### 25-27 MAY, 1998

International course for experienced Plaxis users (English),
Noordwijkerhout, the Netherlands

### 8-10 JUNE, 1998

Short course on Computational Geotechnics (English), Boston, U.S.A.

### AUGUST, 1998

5th European Users meeting (English),
Karlsruhe, Germany

### OCTOBER, 1998

Short course on Computational Geotechnics (English), Bandung, Indonesia

### NOVEMBER, 1998

Users meeting and Short course on Computational Geotechnics (Norwegian)
Trondheim, Norway

### JANUARY, 1999

Standard course on Computational Geotechnics (English), Noordwijkerhout, the Netherlands

### 18-19 MARCH, 1999

"Beyond 2000 in Computational Geotechnics" Symposium to celebrate 10 years Plaxis international. Amsterdam, the Netherlands

For more information on these activities, please contact:

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