Finite Element Analysis of Deep Excavation Problems

by Ir. Mak Wai Kin

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An evening technical talk was delivered at Tan Sri Prof. Chin Fung Kee Auditorium by Ir. Dr Law Kim Hing, and chaired by Ir. Mak Wai Kin on 23 August 2016. The talk was attended by 53 participants. The objective of this presentation is to gain insight into the mechanisms of soil-structure interaction in deep excavations through 2D and 3D finite element analyses and calibration with field data from well-documented case histories.

The presentation started with discussion on general considerations in deep excavation modelling using finite element analysis. The influence of several important aspects such as excavation symmetry, geometry of the model, groundwater modelling and undrained/drained analyses were presented.

Dr Law highlighted that “half-section” analysis would not have predicted asymmetrical behaviour for non-symmetrical excavation work, e.g. retained height is higher at one side than the other. In such case, the displacement shape of both walls will be different which is important for determination of wall forces. Dr Law reminded that no analysis can model excavation geometry in detail or for that matter every construction activity. He cautioned that care must be taken when making simplifying assumptions on any forms.

The sensitivity check on the effect of finite element mesh depth between linear elastic-plastic model and small strain stiffness model was presented. It was found that the depth of mesh has higher dependency for linear elastic-plastic model compared with small strain stiffness model. The extent of finite element mesh will depend on the problem being analysed, the adopted constitutive model, etc. Figure 1 shows the general suggestions of the depth and lateral extent for the finite element model.

Dr Law presented types of groundwater table condition commonly encountered at site, i.e. wall toe socketed into rock, wall toe found in permeable soil and where clay layer is presence within the wall depth. The distribution of water pressure in difference conditions was discussed. He highlighted that commonly adopted Z-profile groundwater method is often unrealistic as pressure distribution is very sensitive to the relative permeability of layers.

On the undrained/drained analysis consideration, Dr Law provided illustration on the stress path in t-s plot for soil element located behind the wall on retained side which subjected to excavation work. He summarised that the illustration clearly indicates that for deep excavation or unloading problems, drained condition is the most critical condition. Figure 2 presents the recommendation when to use undrained behaviour based on time factor for consolidation.

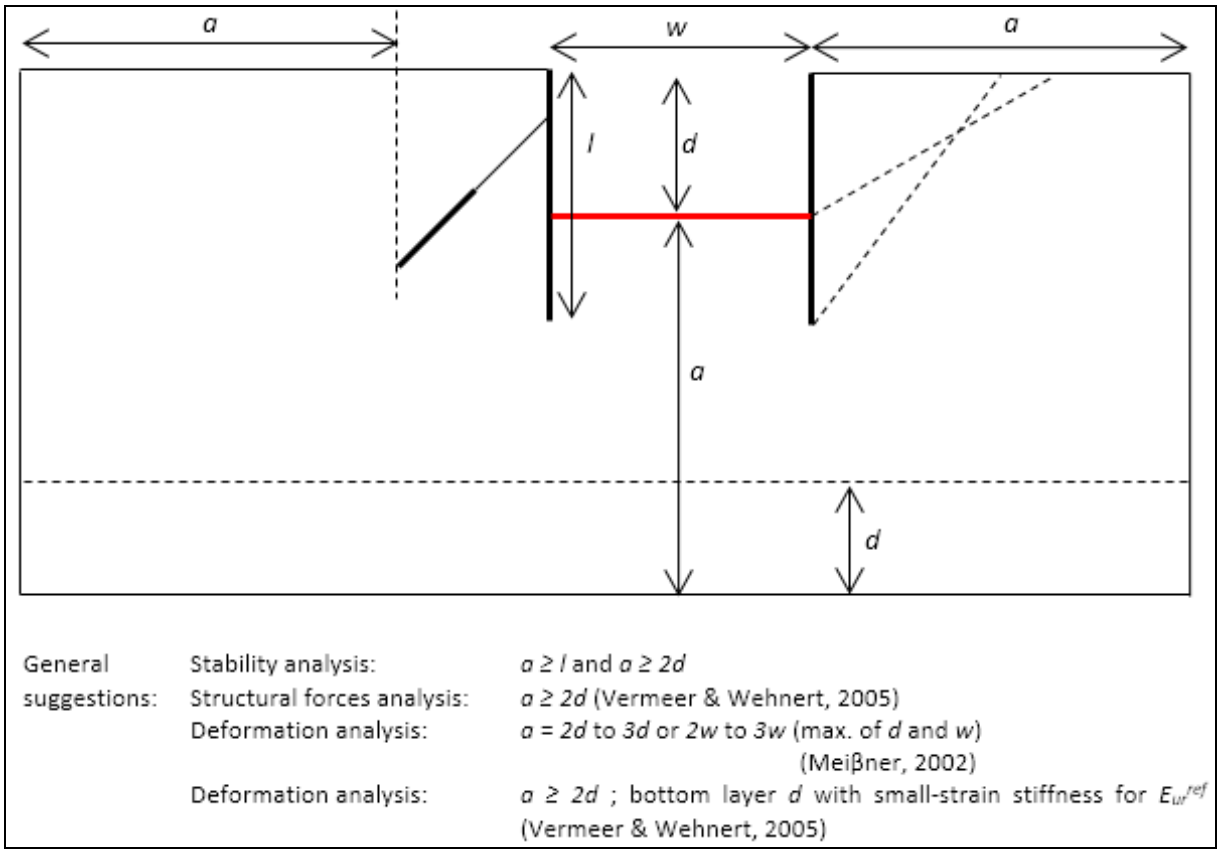

Figure 1: General Suggestions on Depth and Lateral Extent of Finite Element Model.

When to Use UNDRAINED BEHAVIOUR

Evaluation based on Time Factor for Consolidation

$$T = \frac{kE_{oed}}{\gamma_w D^2} t$$

k = permeability
E_{oed} = oedometer modulus = $1/m_v$
γ_w = water unit weight
D = drainage length = depth of wall on passive side
t = consolidation time

Vermeer's Recommendation:
For $T < 0.01$ (U<10%): Use Undrained Behaviour
For $T > 0.40$ (U>70%): Use Drained Behaviour

Figure 2: Recommendation on When to Use Undrained Behaviour

Prior to the conclusion of the talk, Dr Law presented some interesting case histories he had been involved to the participants of the followings:

1. 2D & 3D finite element analysis of rectangular sheet pile cofferdam in soft clay.
2. 3D finite element analysis of deep excavations considering the effect of anisotropic wall stiffness.
3. Wall behaviour under unbalance loading condition.
4. 3D numerical modelling and investigation of collapsed corner sheet pile wall.
5. Application of buttress diaphragm wall in reducing ground movements.

After the Q&A session, the evening talk ended with the presentation of momento and certificate of appreciation to Dr.Law by the Technical Division chairman, Ir. Yee Thien Seng .

Question & Answer Session in Progress