Comparison of Eurocode7 and Japanese standard approach on the design of deep excavation with temporary embedded walls

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1. Introduction

From 2010, Eurocodes (the European structural design standards) became mandatory for EU civil engineering works. Moreover, in terms of unification of international design standards in the global construction industry, Eurocodes may have substantial expectation as a world de-facto standard, but there are various problems to be solved at present. This paper has focused on Eurocode7 (Geotechnical design) on the design of deep excavations with embedded walls and conducted sensitivity analysis regarding the multi-struts embedded wall to compare Eurocode7 with Japanese standard approach.

2. Eurocode7 approach

Eurocodes introduce limit state design for geotechnical structure, even though it is for temporary. They give little detailed guidance on the design of embedded retaining walls. Traditional practice will therefore still have a significant role to play in their design. Recently, FEM (Finite Element Method) has been used in practical for the assessment of embedded walls design due to progress of analytical software. Safety load factors are taken into account by which is called design approach. These factors are applied as partial factors to the actions and/or the material properties. Then, in ultimate limit state, the effects of factored actions need to be ensured not to exceed the corresponding design resistance values.

3. Japanese standard approach

The basic concept of Japanese standard analysis of temporary embedded walls design is differing from Eurocode7. Subgrade reaction spring model which assumes that the wall is a beam and the soil would be a series of liner-elastic perfectly plastic springs is mainly used for deep excavation. Bending moments, shear forces and strut reactions are calculated from deformation of the wall. The soil spring reaction coefficients ‘k’ will be estimated by the stress-strain behaviour of the soil. The earth passive pressure mobilized on the wall can be found out from the soil spring reaction.

4. Methodology of sensitivity analysis

The multi-struts temporary embedded wall with 25m retaining height was considered. Homogeneous sand (a range of friction angle from 25° to 40°) and clay (a range of undrained shear strength Cu from 30+3z kPa to 150+3z kPa, depth z in metres) soil conditions were chosen with the intension of investigating the drained and undrained condition respectively. Reinforcement concrete continuous diaphragm walls were chosen with 800mm thickness. In order to simplify comparison of the results, the embedment of the wall was fixed, and total wall length was 60m from the ground level. The width of the excavation was 20m, and thus struts were assumed to 20m length. Each property of the walls and struts are listed in Table 1 and Table 2. The basic geometry of the case study is depicted in Figure 1.

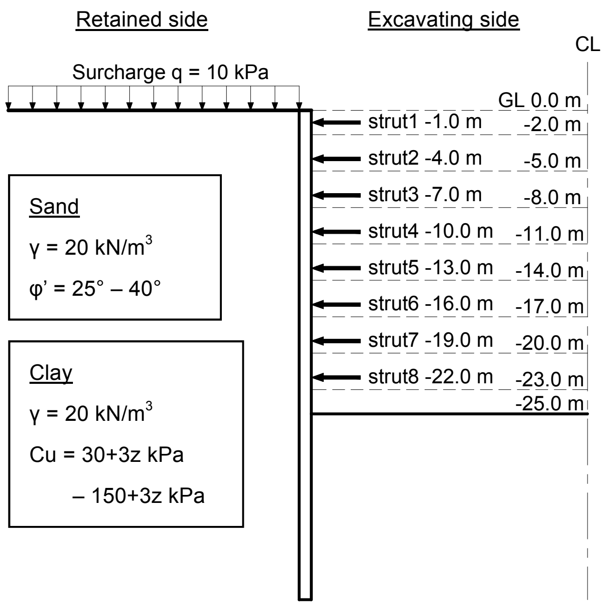

Figure 1: Geometry of excavation model

Table 1: Wall parameters

Parameters		Meaning	Value
γc	[kN/m^3]	Unit weight	25
E	[kPa]	Elastic modules	2.5×10^7
EA	[kN]	Normal stiffness of the wall	2.0×10^7
EI	[kNm^2]	Flexural rigidity of the wall	548720
v	[-]	Poasson's ratio	0.2

Key wards: *Eurocode7, Geotechnical design, Temporary retaining wall, Deep excavation*
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Table 2: Strut parameters

Parameters		Meaning	Value
γs	[kN/m^3]	Unit weight	77
E	[kPa]	Elastic modules	2.0×10^8
EA	[kN]	Normal stiffness of the strut	3954000
$L_{spacing}$	[m]	Strut spacing out of plane	3.0

The computer software ‘PLAXIS ver.2016’ was used for FEM analysis. A simple elastic-perfectly plastic model, namely a Mohr Coulomb constitutive law was used. Japanese standard analysis was conducted against same conditions as Eurocode7 by using ‘Kasetsu5X ver.13.0’.

5. Result and discussion

Figure 2 represents one of examples of contour diagram of total displacement by FEM analysis.

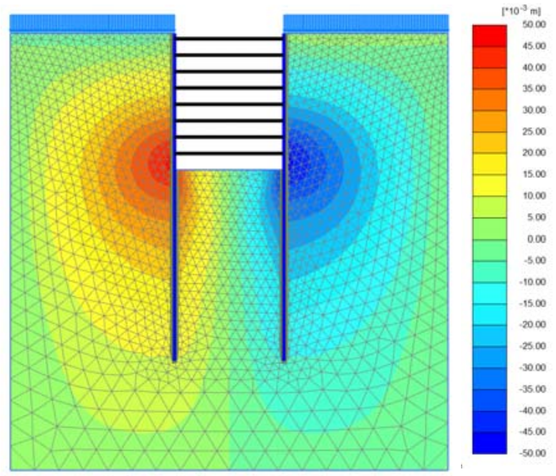

Figure 2: Disp. contour diagram example of FEM

Figure 3 and Figure 4 show comparisons of maximum bending moments by ‘Design Approach 1’ from sand and clay conditions respectively. In sand conditions, Japanese standard gives a higher value than Eurocode7 in the case of softer soil and the maximum difference was approximately 13%. The difference had decreased gradually as friction angle increased. Namely, Japanese standard provides more conservative effects in the sand soil condition.

On the other hand, in the clay conditions, Eurocode7 gives a higher value than Japanese standard regardless of differences of undrained shear strength. Huge gaps were created between Eurocode7 and Japanese standard in the soft conditions and Eurocode7 was roughly 64% higher than Japanese standard at the case of undrained shear strength Cu=30+3z kPa.

As an additional study will be required, this result might be derived from a fundamental problem of Eurocode7 with FEM analysis. There is a possibility that failure mechanism of the soft clay soil might be overestimated. Eurocode7 may not be easy to be interpreted due to a number of clauses which have ambiguity. Regarding FEM design, this paper has used only Mohr Coulomb constitutive law, but advanced constitutive law model (such as Hardening Soil model) might be more reliable than Mohr Coulomb model.

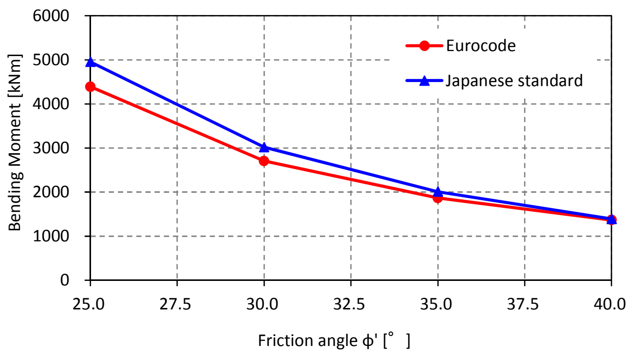

Figure 3: Maximum Bending Moment in Sand

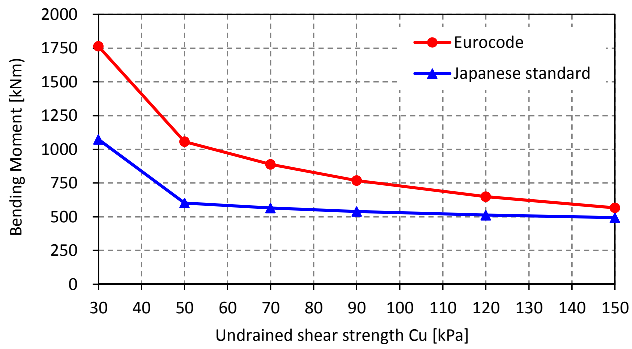

Figure 4: Maximum Bending Moment in Clay

5. Conclusion

This paper revealed several useful conclusions.

1) Soft soil condition provides larger differences than stiff soil regarding the effects of temporary retaining wall.

2) General tendency indicated that Eurocode7 provides more economically advantageous design outputs than Japanese standard in the sand conditions, but more conservative in the clay conditions.

3) Designers need to keep remembering that the soft soil condition may cause oversensitivity of the effects regarding soil failure mechanism with FEM analysis.

However, reasonable care is required that these conclusions might be applicable only on specific choices of analytical models and soil conditions.

REFERENCE

BS EN 1990: 2002 Eurocode - Basis of structural design

BS EN 1997-1: 2004 Eurocode 7: Geotechnical design - Part 1: General rules