Development of EC7 Malaysia National Annex for the Design of Embankment Stability on Soft Ground (Part 2 of 2)

by ***Ir. Tan Yean Chin***

Note: This is the continuation of Part 1 of the Eurocode Series paper published in the September 2010 issue on pages 32 to 37.

5. DEVELOPMENT OF THE MALAYSIA NATIONAL ANNEX (MY-NA) FOR THE DESIGN OF EMBANKMENT STABILITY

It is important that the MY-NA does not combine both Cut Slopes and Embankment into the same category to prevent making a fundamental mismatch of the loading mechanism and soil behaviour. A very clear distinction between the two can be found in past Malaysian practice, which is still being practised by adopting a factor of safety (FOS) of 1.2 to 1.3 for embankment during construction (*e.g.* total stress analysis), while for cut slopes, the FOS is 1.4 to 1.5 (*e.g.* effective stress analysis). The Malaysian practice is fundamentally correct and should be incorporated into the MY-NA by separating Embankment from Cut Slopes. We should also understand that in EC7, the fine grained subsoil materials the British are facing are mainly medium to stiff clay (*e.g.* London Clay), thus they are different from Malaysia and other ASEAN countries (*e.g.* Thailand and Indonesia) with many coastal areas underlain by very soft to soft alluvium clay. Therefore, the problems we face are different from that of the British especially in constructing embankment on very soft ground.

It is time for Malaysia to produce a code that truly reflects the engineering progress and development that we have achieved for the last 50 years instead of following the British National Annex (UK-NA), which is good in general, but in some situations, is not suitable for our country due to differences in geology, subsoil condition, requirements on infrastructure developments, practice and economy affordability, *etc*. The MY-NA to be used will have a great impact on the overall development of the nation as a conservative code will cause the cost to escalate (make many potential projects not viable thus hinder the infrastructure development of the country), while an optimistic code may trigger failures or even fatalities. Therefore, a balanced code that suits Malaysia's condition shall be formulated carefully and with proper processes including getting feedback from the various stakeholders, namely, the government, developers, contractors, engineering consultants, academics, etc, during the development of MY-NA. Malaysian practicing engineers should start to calibrate their conventional Malaysian practice with EC7 Annex A and with UK-NA so that they will be familiar with EC7 when imposed in Malaysia. Through calibration then only Malaysian engineers will understand and have the necessary engineering judgement on the implication of the potential values set in the MY-NA affecting their design in terms of safety and cost. In Europe, the practicing engineers there are just starting to use EC7 for design. It is also expected that further refinements of EC7 will surface within three to four years due to the problems faced by European engineers when using EC7 which, in the author's opinion, has to rely more on local practice, geological

(To be continued on page 31)

Table 2: Suggested Partial Factors for Actions, Soil Materials and Resistance in the MY-NA for Embankment

			Design Approach 1			Design Approach 2	
			Combination 2 - Embankment			Embankment	
			A1	M1	R2	A1	M=R2
Actions	Permanent	Unfav	1.00			1.00 ~ 1.20*	
		Fav	1.00			1.00	
	Variable	Unfav	1.00~ 1.30*			1.00 ~ 1.30*	
Soil	tan ϕ'			1.20			
	Effective cohesion			1.20			
	Undrained strength			1.20			
	Unconfined strength			1.20			
	Weight density			1.00			
Embankment	Earth Resistance (Short Term/Construction)				1.00 ~ 1.10*		1.20~ 1.30*
	Earth Resistance (Long Term / Drained Condition)				1.15		1.40

Notes * :

1. *Permanent* Actions (Unfavourable) (For Design Approach 2 : Embankment) :-
   = 1.00 if proper monitoring and control of filling can be executed effectively at site with instrumentation.
   = 1.20 if proper monitoring and control of filling cannot be effectively executed at site.
2. *Variable* Actions (Unfavourable) (For both Design Approach 1 and Design Approach 2) :-
   = 1.00 if proper control of variable load imposed on embankment can be executed effectively at site
   = 1.30 if proper control of variable load imposed on embankment cannot be executed effectively at site.
3. *Earth Resistance (Short Term / Construction)* (For both Design Approach 1 and Design Approach 2)
   = 1.00 (DA1-C2 Embankment) and 1.20 (DA2-Embankment) : For low risk to life (not likely to affect public safety) or not like to cause damages to adjacent important structures/services.
   = 1.10 (DA1-C2 Embankment) and 1.30 (DA2-Embankment) :For high risk to life (could affect public safety) or could caused damages to adjacent important structures/services.

Application of Earth Resistance :

1. To be applied to the Factor of Safety obtained from the stability analysis.

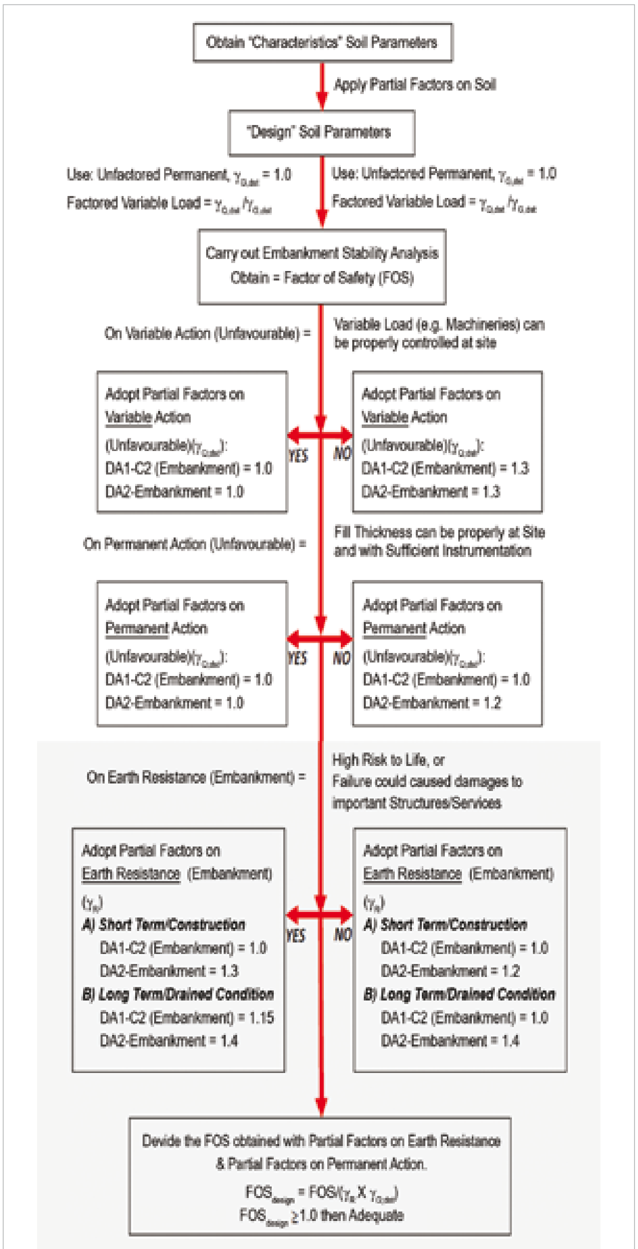

Figure 9: Simplified Flowchart for Stability Analysis of Embankment in EC7 using Suggested MY-NA

conditions, construction practice, history, etc, compared to EC1 to EC6 for structures.

It is also important that the MY-NA drafted should not use increased FOS values (*e.g.* increased partial factors values in EC7) as a way to compensate for the lack of proper engineering education, a systematic and proper on-the-job training, good engineering design and judgement, proper supervision and workmanship. If Malaysia were to fall into this trap of trying to increase the FOS due to the lack of confidence in the engineer's design, supervision and being afraid that the contractor will cheat, then we are definitely on the wrong track and this will hinder Malaysia from becoming a developed country in the future. The problems that the construction industry face shall be addressed separately by going into the root causes and finding relevant solutions that resolve the problems encountered. FOS is not a solution for most of the problems highlighted above, instead, it causes wastage of materials and unnecessary increase in cost without real safety or benefit.

EN1997-1:2004 (EC7) Section 2 - Basis of Geotechnical Design Section 2.4.7 Clause 2.4.7.1(4) stated that, "More severe values than those recommended in Annex A should be used in cases of abnormal risk or unusual or exceptionally difficult ground or loading conditions", while Clause 2.4.7.1(5) stated that, "Less severe values than those recommended in Annex A may be used for temporary structures or transient design situations, where the likely consequences justify it". Despite the freedom stated in the two clauses, it is recommended that the MY-NA be more specific to help practicing engineers. Therefore, in suggested MY-NA values listed in Table 2, specific differentiation between risk to life or possible damages to adjacent important structures/services are stated when selecting the partial factors for earth resistance.

In summary, the application of EC7 for embankment stability analyses needs rationalisation and harmonisation with currently established local practices that have been successfully adopted in the construction industry. The following are the main criteria that require rationalisation and harmonisation for the application of EC7 in Malaysia for the stability analyses of embankment over soft fine grained subsoil:

a) An understanding of the indirect comparison of load factors and partial factors adopted in EC7 with conventional FOS which local engineers are familiar with. The transformation of currently adopted overall FOS against embankment instability to partial factors used in the MY-NA of EC7 needs calibration.
b) For stability analyses of embankment over soft fine grained subsoil, the partial factor for permanent action (unfavourable), γ_G, which is referred to as the weight of the embankment (thickness of fill), shall be set equal to unity (1.0) in the MY-NA instead of 1.35 in the UK-NA. This is because the actual embankment weight and thickness of fill can be controlled at site as the filling works are carried out in layers. In addition, the filled height can be closely captured by settlement gauges, which are adopted for monitoring purposes. Therefore, the chances of overfill is unlikely and the uncertainties of the embankment weight is under control with proper monitoring and supervision.
c) It is recommended to set the partial factor for variable load equals to unity (1.0) in the MY-NA. Again, this is because the machineries loads are fairly consistent and controllable in earthwork constructions. Hence, the risk on the inconsistent variable load would not arise. Should there be no proper control, the partial factor for variable load could be applied.
d) As mentioned earlier, the stability of the embankment is most critical at the end of construction when the

embankment height is the highest (short term) and the undrained shear strength will gain in strength with time due to the dissipation of excess pore pressure. In view of this, it is impractical to apply a high partial factor of 1.4 on the undrained shear strength during stability analyses of the embankment over soft fine grained subsoil. In addition, currently available methods to obtain the in-situ undrained shear strength are generally reliable enough to be used in total stress analyses of an embankment. Therefore, the author recommends a partial factor of 1.2 to be adopted on undrained shear strength.

e) For suggested MY-NA, higher partial factors on earth resistance (embankment) (γ_R) are proposed if any failure of the embankment is high risk to life (*e.g.* fatalities and affects public safety) or causes damages to important structures/services. Using different partial factors on earth resistance is a rational way to differentiate the risk associated with embankment stability in different site conditions.

The suggested partial factors in the MY-NA for the design of embankment stability are listed in Table 2 for easy reference. Since DA1-C2 is likely to be adopted in Malaysia, the steps for embankment stability analysis following this approach are illustrated using the suggested partial factors of the MY-NA in Table 2:

1) Obtain the correct geometry of the embankment (including settlement magnitude), groundwater level, surrounding ground profile (*e.g.* any depression, channel or drains beside the embankment).
2) Select representative layers of "Characteristic" soil parameters of shear strength (*e.g.* undrained shear strength for fine grained soil [clayey materials] and effective shear strength parameters for coarse grained soil [sandy/gravelly materials])
3) Divide the "Characteristic" soil strength with the partial factors of soil strength (γ_M soil from Table 2 of suggested MY-NA) to obtain the "Design" soil strength.
4) Use "Characteristics" bulk unit weight of fill and subsoil materials that are classified as permanent actions (either favourable or unfavourable). In this step, the partial factors for all permanent actions (γ_G) (favourable and unfavourable) are set to unity (1.0). Thus the "Design" permanent action is the same as the "Characteristics" value.
5) On Variable Unfavourable Action (*e.g.* load from Machineries), it shall be multiplied by the ratio of partial factors on actions of (γ_Q;dst/γ_G;dst). Following DA1-C2 of Table 2, the value is either (a) or (b):
   (a) Able to control machineries load at site,
   use (γ_Q;dst/γ_G;dst)= (1.0/1.0) = 1.0
   (b) Unable to control machineries load at site,
   use (γ_Q;dst/γ_G;dst)= (1.3/1.0) = 1.3

(To be continued on page 35)

6) Carry out stability analysis to obtain the FOS using parameters obtained from Steps 1 to 5 for both Short Term/Construction and Long Term/Drained Condition.
7) Select the Partial Factors of Earth Resistance (γ_R) for Short Term/Construction from Table 2 based on either (a) or (b) from DA1-C2:
   (a) With low risk to life (not likely to affect public safety) or not likely to cause damages to adjacent important structures/services; use $\gamma_R = 1.00$
   (b) With high risk to life (could affect public safety) or could cause damages to adjacent important structures/services; use $\gamma_R = 1.10$
8) For Long Term/Drained Condition, the Partial Factors of Earth Resistance (γ_R) from Table 2 based on DA1-C2 is 1.15.
9) Obtain the "Design" FOS by dividing the FOS of Step 6 by both Partial Factors of Earth Resistance (γ_R) and Permanent Unfavourable Actions (γ_G;dst).

$$FOS_{design} = FOS / (\gamma_R . \gamma_G;dst)$$

10) If the $FOS_{design} \geq 1.0$ for both Short Term/Construction and Long Term/Drained Condition, then it is adequate and acceptable.

A simplified flowchart is shown in Figure 9.

6. CONCLUSION

This paper presents the Malaysian design methodology for embankment stability on soft fine grained subsoil and the way forward in converting to EC7. As there is no provision of partial factors specifically for embankment stability over soft fine grained subsoil in EC7 and the behaviour (*e.g.* pore pressure response, shear strength, *etc.*) of a cut slope is totally different from an embankment over soft fine grained subsoil, this paper presents the EC7 methodology with a suggested approach and value of partial factors for the development of the MY-NA.

From the case study of the Muar Test Embankment (which was constructed to failure in 1989), the allowable embankment height based on partial factors recommended by EC7 is about 24% to 28% lower than the current Malaysian practice. This implies that EC7 is too conservative in stability analyses of embankment over soft fine grained subsoil. Since currently adopted Malaysian practice on embankment stability has been successfully implemented, the suggested partial factors on embankment stability over soft fine grained subsoil for the MY-NA in the application of EC7 should rely on local experience. ■

REFERENCES

[1] Bishop, A. W., and Bjerrum, L., "The Relevance of the Triaxial Test to the Solution of Stability Problems", Proceedings of the ASCE Research Conference on the Shear Strength of Cohesive Soils, Boulder, Colorado, 1960, pp 437-501 (reprinted in Norwegian Geotechnical Institute Publication no. 34, 1960, pp 1-56).

[2] Brand, E.W., and Premchitt, J. , "Comparison of the Predicted and Observed Performance of the Muar Test Embankment", Proceedings of the International Symposium on Trial Embankments on Malaysian Marine Clays, Kuala Lumpur, Malaysia, November 1989, pp 10.1-10.29.

[3] Frank, R., Bauduin, C., Driscoll, R., Kavvadas, M., Krebs Ovesen, N., Orr, T. and Schuppener, B.,"Designer's guide to EN 1997-1 Eurocode 7: Geotechnical Design - General Rules", Thomas Telford, London, 2004, pp 1-216.

[4] Gue, S.S. and Tan, Y.C. (2005). "Failures of Ground Improvement Works in Soft Ground", In Indraratna, B. and Chu, J. (eds.), Ground Improvement (Vol. 3), Elsevier Science Ltd.

[5] Gue, S. S., Tan, Y. C. Liew and S. S. (2002), "Cost Effective Solutions for Roads and Factories Over Soft Marine Deposits", CAFEO2002, Cambodia, 2-5 September, 2002.

[6] Gue, S.S. and Tan, Y.C (2000). "Subsurface Investigation and Interpretation of Test Results for Foundation Design in Soft Clay". Seminar on Ground Improvement – Soft Clay (SOGISC-2000), 23 and 24 August 2000, UTM, Kuala Lumpur.

[7] Malaysian Highway Authority, MHA (1989), "Trial Embankments on Malaysian Clays. Vol. 1: Factual Report on Performance of the 13 Trial Embankments; Vol. 2: Part 1: The Embankment Built to Failure, Part 2: The Trials", Proc. of the Int. Symposium, 6–8 November 1989, Vol. 1 & 2.

[8] Neoh, C.A. (1999) "Planning of Site Investigation and Insitu Testing". Short Course on Soil Investigation and Design for Slope (SCOFG99), 11–12 May, 1999, Kuala Lumpur.

[9] Tan, Y.C., Gue, S.S. and Lee, P.T. (2010), " Rationalisation of Conventional Geotechnical Practice to EC7 on the Stability of Embankment on Soft Fine Grained Subsoil", The 17th Southeast Asian Geotechnical Conference, Taipei, Taiwan, 10–13 May 2010.

[10] Tan, Y. C. and Chow, C. M. (2009), "Current and Future Trends of Geotechnical Engineering in Malaysia – A Consultant's Perspective (2009)", Seminar on The State-of-the-art Technology and Experience on Geotechnical Engineering in Malaysia and Hong Kong, 25 February 2009, Hong Kong.

[11] Tan, Y. C., (2005), "Design of Embankment on Soft Clay", 2-days Course on Geotechnical Engineering 2005, The Institution of Engineers, Malaysia, 30–31 May 2005.

[12] Tan, Y.C. (1999) "Piezocone Tests and Interpretation". Short Course on Soil Investigation and Design for Slope (SCOFG99), 11–12 May, 1999, Kuala Lumpur.