28 May 2010, 2:00 pm - 3:30 pm

Diaphragm Walls Seismic Design According to the Eurocodes

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Fifth International Conference on
Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics
and Symposium in Honor of Professor I.M. Idriss
May 24-29, 2010 • San Diego, California

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ABSTRACT

Although one can think that it is very low the probability of a seism occurrence during the execution of an excavation in an urban lot protected by a diaphragm wall curtain, reality shows that whenever a seism occurs in an urban area several diaphragm walls will be affected by it. So it is advisable to consider the seismic action when designing a diaphragm wall curtain.

The Eurocodes consider the seismic actions in Eurocode 8 (EC 8) and recommend the use of the Mononobe-Okabe method when dealing with soil retaining structures.

The Eurocodes consider the possibility of each European country to adopt their own seismic parameters as the seismic risk is different in each country.

Thus the so-called National Document of Application prescribes the seismic local parameters.

In Portugal the Portuguese Standard ENV 1998-1-1 considers four seismic zones: A, B, C and D.

Zone A is the one of greater seismic risk and includes the Lisbon area and the coastline South of Lisbon down to the Algarve.

The paper presents the general approach of diaphragm walls design under EC 8 and the application to the case of a diaphragm wall located at Coimbra, near the local Stadium, with an height of 21,5m and four levels of anchorages, each one with a 1.200kN prestress.

EUROCODES PRESCRIPTIONS

Although one can think that it is very low the probability of a seism occurrence during the execution of an excavation in an urban lot protected by a diaphragm wall curtain, reality shows that whenever a seism occurs in an urban area several diaphragm walls will be affected by it. So it is advisable to consider the seismic action when designing a diaphragm wall curtain.

According to Eurocode 8 – Part 5 (pr EN 1998-5) seismic actions on soils should be quantified adopting the Mononobe-Okabe method that gives good approaches when compared with reality.

The horizontal seismic coefficient k_h will be:

$$k_h = a_{gr} \cdot \gamma_I \cdot \frac{S}{g \cdot r} \qquad (1)$$

or

$$k_h = a_g \cdot \frac{S}{g \cdot r} \qquad (2)$$

where:
a_{gr} – reference peak ground acceleration
a_g – design ground acceleration: $a_g = \gamma_I . a_{gr}$
S – soil factor
g - acceleration of gravity
r – factor for the calculation of the horizontal seismic coefficient

and the vertical seismic coefficient k_v will be:

$$k_v = \pm 0,5 . k_h \qquad (3)$$

However normally k_v is neglected which means that for practical applications it is considered: $k_v = 0$.

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The values of the seismic acceleration prescribed by ENV 1998-1-1 are:

	Values of maximum acceleration a_g (m/s^2)	Values of maximum acceleration a_g (m/s^2)
Seismic Zone	Seismic Action Type 1	Seismic Action type 2
A	2,7	1,6
B	1,9	1,1
C	1,3	0,8
D	0,8	0,5

Where type 1 means a seism of moderate magnitude acting from a short focal distance, and type 2 means a seism of greater magnitude acting from a larger focal distance.

For instance for type 1 seismic action and seismic zone A:

$a_g = 2,7$ $\qquad$ $S = 1,0$

$g = 10,0\ m/s^2$

For flexible curtains such as anchored diaphragm walls the EC 8 considers r = 1. So from equation (2) comes $k_h = 0,27$.

Also from EC 8 we have:

$$\theta = \text{ang tg } k_h = \text{ang tg } 0,27 = 15º$$

When the soil on the top of the diaphragm wall curtain is horizontal this means that we have $\beta = 0$ so:

$$\beta = 0 < Ø - \theta \qquad (4)$$

where Ø is the soil internal frictional angle.

According to the Mononobe-Okabe method the active pressure coefficient (static + dynamic) is:

$$K_{a(s+d)} = \frac{sen^2(\psi+\phi-\theta)}{\cos\theta\, sen^2\psi\, sen(\psi-\theta-\delta)\left[1+\sqrt{\frac{sen(\phi+\delta)\, sen(\phi-\beta-\theta)}{sen(\psi-\theta-\delta)\, sen(\psi+\beta)}}\right]^2} \qquad (5)$$

where:

Ψ = angle of the curtain with the horizontal (for vertical curtains $\Psi = 90º$)
δ = soil-curtain frictional angle (in general $\delta = 0$)

The passive pressure coefficient (static + dynamic) is:

$$K_{p(s+d)} = \frac{sen^2(\psi+\phi-\theta)}{\cos\theta\, sen^2\psi\, sen(\psi+\theta)\left[1-\sqrt{\frac{sen\phi\, sen(\phi+\beta-\theta)}{sen(\psi+\beta)\, sen(\psi+\theta)}}\right]^2} \qquad (6)$$

For cohesive soils it is important to know how the value of cohesion changes when a seism occurs.

According to [I] the value of cohesion under dynamic loads is about 80% of its static value. This is confirmed by EC8 that considers reduction factors of 1,3 and 1,2 respectively for c_u and for c.

When a seism occurs it is also necessary to consider the seismic action due to the curtain weight:

$$q = k_h . P$$

Where k_h is the horizontal seismic coefficient and P is the curtain weight/m^2.

It is important to refer that the Mononobe-Okabe method, that was initially applied to rigid earth-retaining walls (gravity walls, etc.) considered the application point of the soil dynamic pressure resultant located at midheight of the walls. However, according to [II], for flexible curtains as the diaphragm walls, the application point can be the same as for the static actions.

APPLICATION TO A REAL SITUATION

Applying these procedures to the Coimbra Euro Stadium diaphragm wall design [III], see Photo nº 1, an increase of about 40% in the anchorages reactions due to the seismic action was obtained and it was necessary to increase downwards the curtain height calculated by the static design to ensure its stability under the seismic action.

Photo Nº 1

CONCLUSIONS

Although there is a low probability of a seism occurrence during the excavation phase for basements location protected by a diaphragm wall curtain, it can happen and, in this case, it is mandatory for the curtain design particularly for high curtains.

So it is highly recommended that judges can be aware of this fact when they decide to suspend such excavation when a neighbourhood complaint comes to court, to avoid an inconvenient increase of the construction time.

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