Panel discussion: Strip footing – Partial factors design concept

Débat de spécialistes: Semelle filante – Dimensionnement aux coefficients de sécurité partiels

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ABSTRACT : This contribution is related to the problem of harmonization of the partial factors of safety for loading (actions) from superstructure and partial factors of safety for foundation subsoil material strength parameters. Attention is given to clarification of partial safety factors relationship resulting from two codified limit states : case "B" and case "C" stipulated in EUROCODE 7 . The simple example of strip footing has been elaborated with the aim to highlight the essentials of the design based on the partial safety factors, and the necessity for partial factors of safety harmonization.

RESUME : Cet article présente la problèm de convenance entre les coefficients de sécurité partielles pour actions (chargements) dans la superstructure et pour les paramètres de résistance dans les sols de fondations. L' attention est accordée aux éclairci sscements de relations entre les coefficients de sécurite codifiée par EUROCODE 7 (les cas "B" et "C"). Une exemple simple de semelle filante est examinée et les resultats obtenue ont été utilisée pour une analyse critique de principes du calcul basée sur le conception des coefficients de sécurité partielles, et pour une éclairage du besoin d'assurer leur conformité.

1. INTRODUCTION

The partial safety factors related design of shallow foundations depends on the selection of the partial safety factors values for actions (loadings) on the one side and also partial safety factors values for soil strength parameters on the another side. The interrelations of these two sets of "apparently independent" partial safety factors needs to be carefully examined.

2. PRESENTATION OF THE PROBLEM

In order to highlight the interrelations of partial safety factors for actions (loadings) to those for soil strength, a rather simple example consisting of a strip foundation situated on horizontal cohesionless soil has been selected for the presentation. The partial safety factors listed in EUROCODE 7 have been used in order to demonstrate the required relationship for harmonization between those used in superstructure and those used for foundation subsoil strength.

One may consider that the basic limit state design concept of concrete foundation structure is related to the cases when the unfitness of the structure may arise either due to a collapsing state in its subsoil or due to excessive cracking or/and crushing of concrete . Following this design concept the "net values" of actions which has to be obtained from the design analysis of the superstructure (usually related to serviceability limit state) are : $Pn = Pp + Pv$ where :

Pp are permanent and Pv are variable design actions (loadings) acting on the strip foundation (force / lin.m.). The ultimate state design concept requires the formulation of an ultimate action $Pu = Pp \cdot \Upsilon p + Pv \cdot \Upsilon v$

where :Υp and Υv are partial safety factors for actions (loadings) , which values are prescribed in the structural codes in order to control the ultimate limit state of the superstructure and the concrete footing .

The ultimate limit states in foundation subsoil are formulated by division of the subsoil strength parameters such as defined by Coulomb - Mohr criterion using another pair of material strength partial safety factors :

$\Upsilon\varphi$ and Υc related to the frictional and cohesion components. Similarly as for partial safety factors related to actions, these material strength related partial safety factors shall define the conditions of the foundation subsoil states of stresses for serviceability and failure limit states.

The selection of the codified values for cited partial safety factors presumably has to be based on economy and safety consideration, and these values shall ensure a consistent balance of safety margin throughout whole structural design i.e. for the superstructure and its subsoil foundation space.

3. EXAMPLE OF STRIP FOOTING DESIGN

In order to explain in more obvious way the cited problem the simplest foundation structure design is selected , consisting of a strip footing situated on the horizontal noncohesive subsoil with its unit weight γ and shear resistance angle φ' . The footing with its width " B " is centrally loaded and following stipulations of EUROCODE 7 its design foundation pressure is defined by : $q_u = Pu / B$. The corresponding limit state design foundation pressure depends on the mobilized shear strength i.e. on the partial factor of safety $\Upsilon\varphi = tg\,\varphi / tg\,\varphi_m$, and can be defined by :

$$q_{ul} = 0.5\,\gamma\,B\,N_\gamma \{ e^{\pi\, tg\,\varphi_m} tg^2(45 + 0{,}5\,\varphi_m) - 1 \} tg\,\varphi_m$$

Under provisions of EUROCODE 7 for the limit states one can obtain :

$0{,}5\,B^2\,\gamma\,N_\gamma\,(\Upsilon_\varphi) = Pp\,\Upsilon p + Pv\,\Upsilon v$, and considering limit cases " B " and " C " the interrelationship :

$$\frac{N_\gamma(\varphi, \Upsilon_{\varphi b})}{N_\gamma(\varphi, \Upsilon_{\varphi c})} = \frac{Pp\,\Upsilon pb + Pv\,\Upsilon vb}{Pp\,\Upsilon pc + Pv\,\Upsilon vc} = \text{is a variable}$$

This interrelationship confirms that one can not preselect the unique preselected values for all partial factors of safety (Υ_φ ,Υ p, Υv).

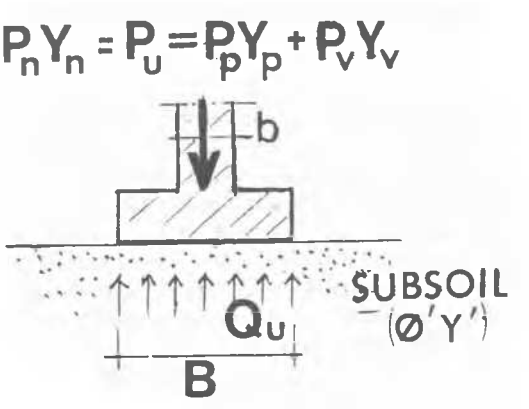
Similarly an another interrelationship can be derived in case of differing values of Bb and Bc i.e. :

$$\frac{(Bb)^2}{(Bc)^2} = \frac{N_\gamma(\varphi, \Upsilon_{\varphi c})}{N_\gamma(\varphi, \Upsilon_{\varphi c})} = \frac{Pp\,\Upsilon pb + Pv\,\Upsilon vb}{Pp\,\Upsilon pc + Pv\,\Upsilon vc}$$

therefore, the condition Bb ≅ Bc can be met only in the case of :

$$N_\gamma(\varphi, \Upsilon_{\varphi b})\,(Pp\Upsilon pc + Pv\Upsilon vc) \cong N_\gamma(\varphi, \Upsilon_{\varphi c})\,(Pp\Upsilon pb + Pv\Upsilon vb)$$

as the necessary condition for attaining approximately same values for foot width "B" for both considered design limit state cases, i.e. for a harmonized safety margin in the superstructure and its subsoil. Therefore, this kind of interrelationship has to be introduced in the design procedure for the determination of balanced foundation structure dimensions.



4. CONCLUDING REMARKS

The consistent balance of the safety margins throughout the superstructure and its foundation subsoil space depends on the harmonization of the partial safety factors for two considered limit states and to demonstrate this requirement such an additional condition for a simple case of strip footing has been derived and highlighted hereabove.
Similar conditions can be derived in less simple cases of spread foundations and they can be considered as additional requirement to that which may be found in the design procedures related to the harmonized formulation s for selection of the footing dimensions based on the functions defining failure conditions of shallow foundations.

REFERENCES

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