KARI AVELLANIN ESITELMÄ
Ultimate Limit State Design of a Strip Foundation
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Ultimate Limit State Design of a Strip Foundation

Kari Avellan / KAREG Consulting Engineers, Helsinki, Finland

ABSTRACT

A practical design procedure is suggested for geotechnical and structural Ultimate Limit Design of a strip foundation, which is resting on frictional soil. The procedure takes into account the Serviceability Limit State by using the mean settlement of the total foundation and by using the criterion of angular distortions.

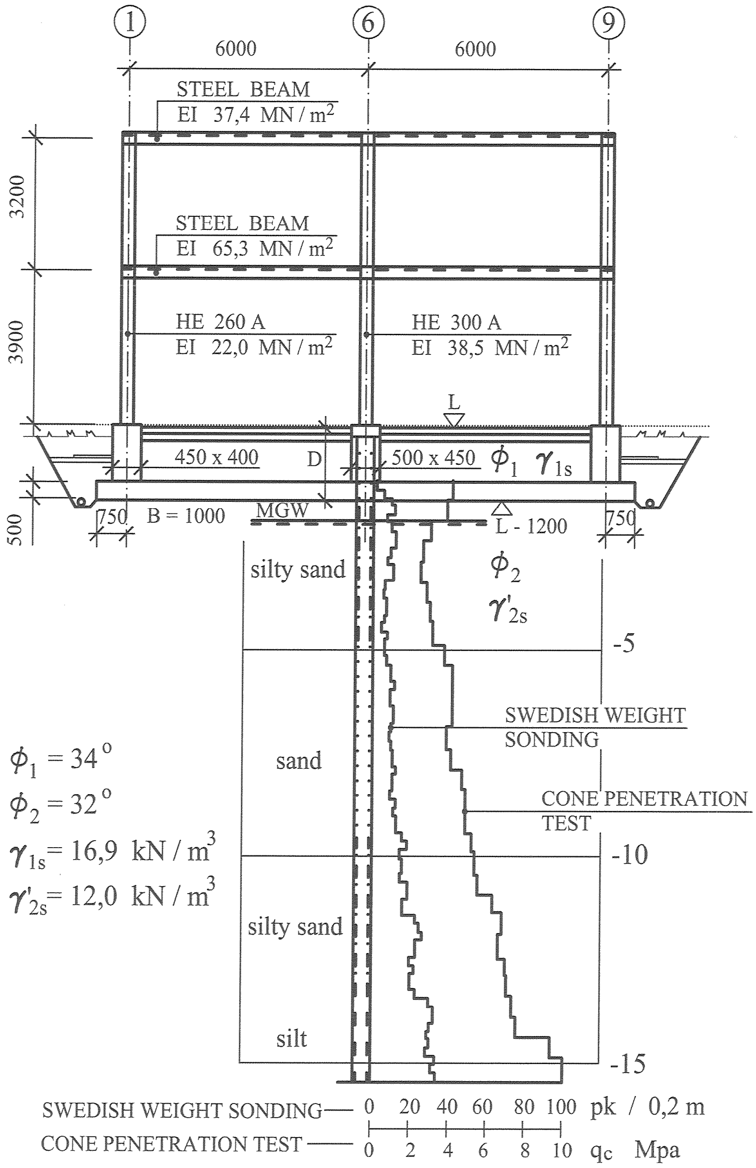

Figure 1. Light industrial building founded on silty sand.

This paper is based on the practical experience of the author. A light industrial building founded on silty sand is used as an example. The skeleton of the building consists of a two storey, two portal steel frame structure (figure 1). For the geotechnical part of this article, results from soil investigations and tests with large model foundations by Bergdahl et al. (1986) were used as a comparative base.

The strip foundation of the frame is dimensioned in projected Ultimate Limit State, when the contact pressure distribution and the soil bearing pressure are calculated as Ultimate Soil Bearing Pressure. The acting forces of the superstructure are calculated in projected Ultimate Limit State (ULS); the acting forces including the normal forces as well as the moments of the frame columns.

The bearing capacities are determined using the formula of Brinch Hansen. The contact pressure distribution in projected Ultimate Limit State is roughly determined according to the settlement calculations of theoretically separated minimum foundations (figures 2 and 3). To obtain real knowledge of settlements, an elastic-plastic empirical model law, according to Horn (1972) (figure 4), has been used.

Settlement calculations have been made using a 3-dimensional Deformation Modulus E_d, according to the tests made by Bergdahl et al. (1986), and the Schultze and Sherif method (1973) based on the SPT-test.

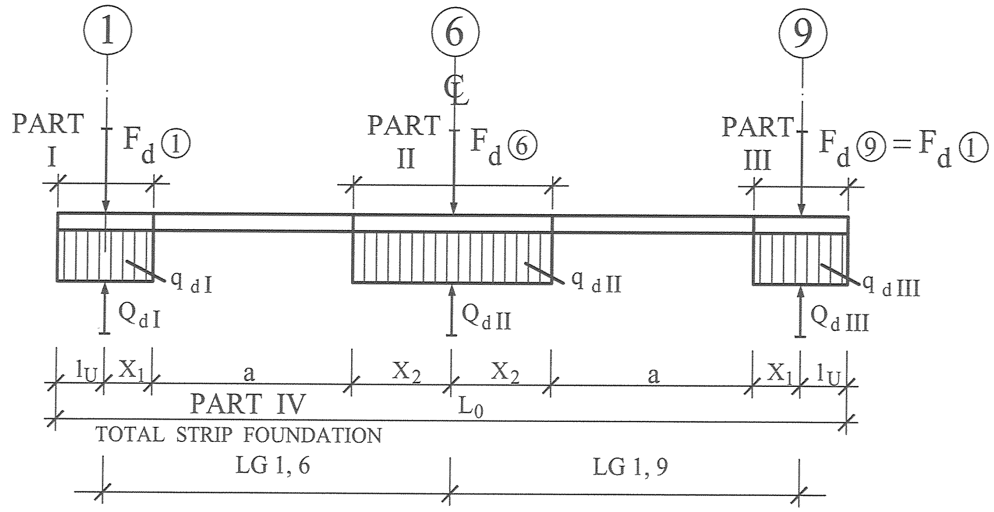

Figure 2. Total Strip Foundation and separated minimum parts I II and III. Acting forces in ULS (F_d) from the superstructure and opposing force Q_d are subjected to soil pressure in ULS (q_d).

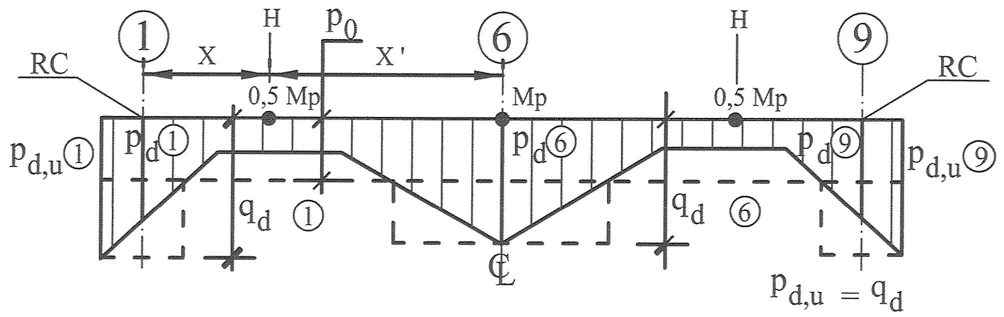

Figure 3. Contact pressure distribution (p_d), Rotational Centers (RC), Plastic Hinges (H) and Plastic Moments (Mp).

The plastic moments (M_p) of the structure are calculated with the Kinematic Method of the Theory of Plasticity. Sufficient ductility for the plastic rotation has been verified to be in accordance to Eurocode 2 (1992), and FIP recommendations (1984). The angular distortions are calculated by using settlements of the separated foundations which are estimated by applying the contact pressure distribution in the projected Ultimate Limit State divided by a safety factor according to the acting building code.

Thus the settlement and the angular distortions are considered the criteria of the Serviceability State. The calculated Ultimate Limit State moments divided by the same safety factor, as earlier mentioned, are close to the Serviceability Limit State (SLS) moments. These are determined using the Modulus of Compressibility Method and using the Modulus of Subgrade Reaction Method. The contribution of the groundsoil has been analyzed in Serviceability Limit State by Subgrade Reaction Method using Winkler's springs as well as by Compressibility Method with help of Sherif's and König's tables(1975).

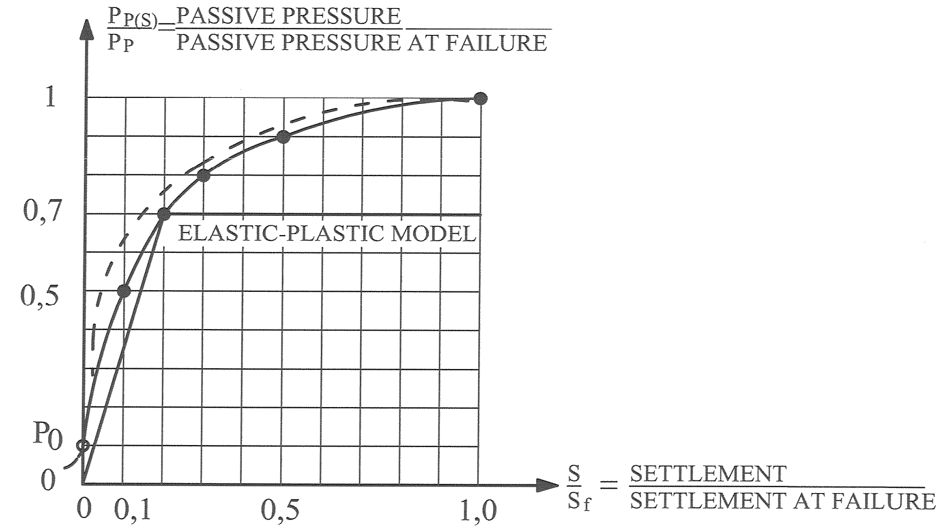

Figure 4. Elastic-Plastic Model.

The results of the Plastic Moments (Mp) of the foundation of the light industrial building are presented in figures 5 and 6. The numerical results are shown in graphic form and represent cases in which the superstructure is loaded by maximum vertical forces (fig. 5) and by minimum vertical forces with wind loading (fig. 6).

In figure 7, the design procedure in geotechnical and Structural Ultimate Limit State is explained. Using the mentioned procedure the engineer can design the strip foundation in ULS and at the same occasion, can check the serviceability in SLS. Control of cracking can be designed by using tables for maximum bar diameters and maximum bar spaces (ENV 1992-1-1).

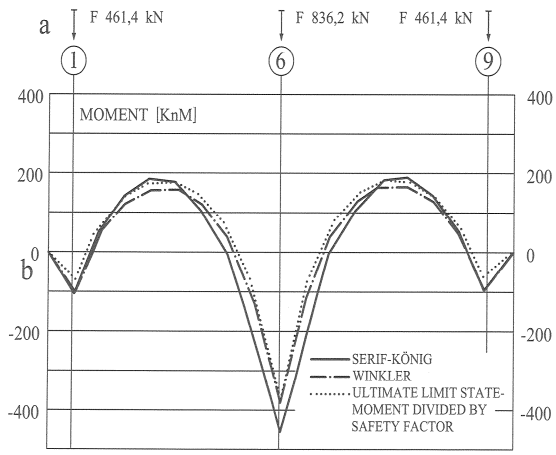

Figure 5. Strip Foundation. a) Acting forces from superstructure. b) Moment Diagrams.

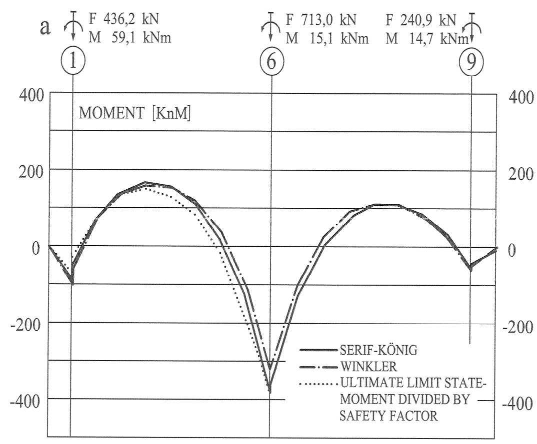

Figure 6. Strip Foundation. a) Acting Forces and Moments for superstructure. b) Moment Diagram.

These results demonstrate that even though the soil pressure and the settlements estimated by different approaches and theories differ slightly from each other, this has no significant bearing for the design moments of the foundation. The design moment $Mp_{l\psi}$ is the sum of the moments Mp and $M\psi$ ($Mp_{l\psi} = Mp + M\psi$).

Should the engineer make a general assumption that the soil pressure is distributed evenly on the total length of the strip foundation, this would lead to an overdesign of the strip foundation of approximately 50 to 80 percent.

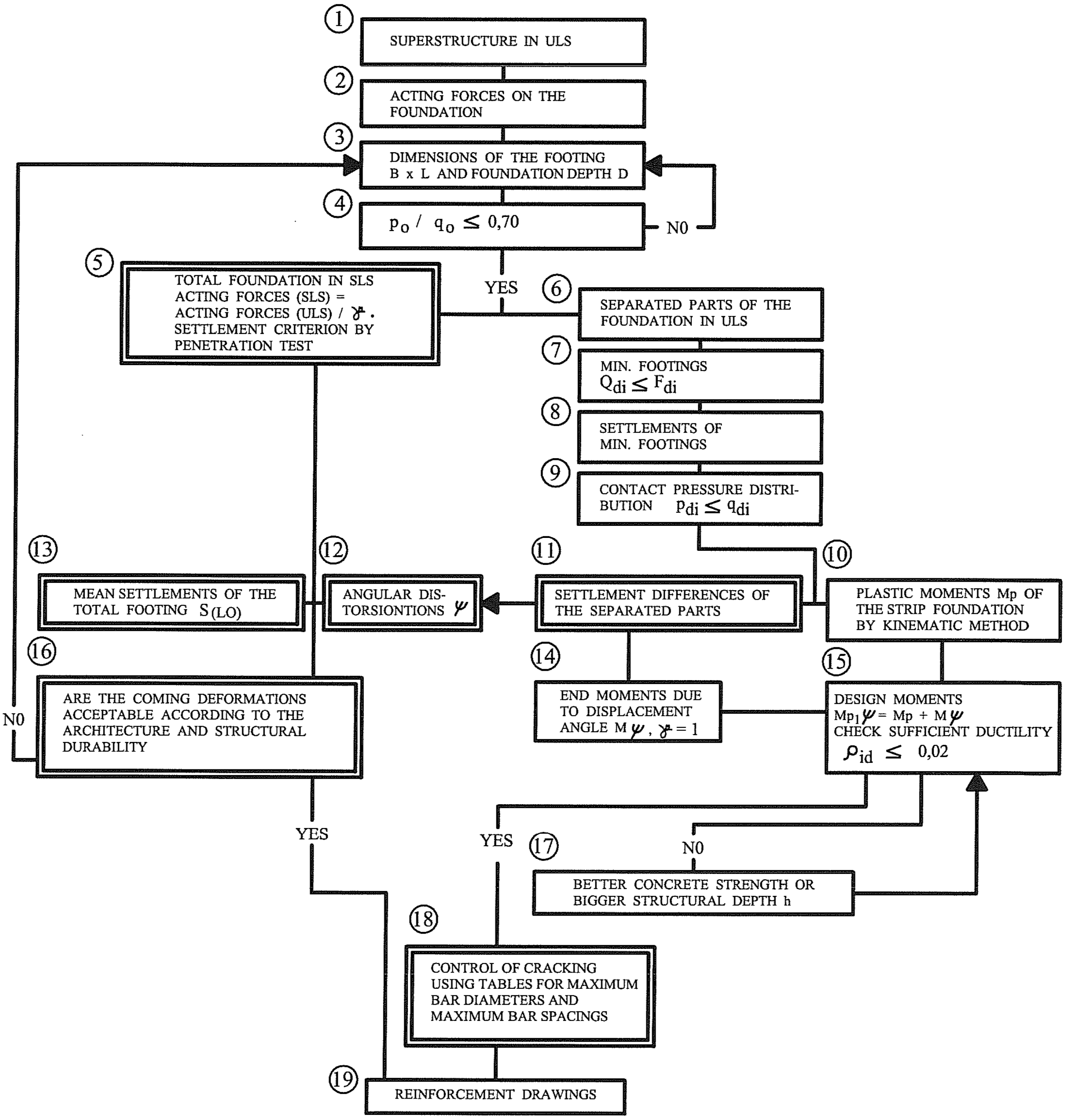

Figure 7. Geotechnical and structural design procedure in ULS for Strip Foundation.
Double line for Boxes represent Serviceability State (SLS).

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