INTERNATIONAL SOCIETY FOR
SOIL MECHANICS AND
GEOTECHNICAL ENGINEERING

SIMSG ISSMGE

This paper was downloaded from the Online Library of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE). The library is available here:

https://www.issmge.org/publications/online-library

This is an open-access database that archives thousands of papers published under the Auspices of the ISSMGE and maintained by the Innovation and Development Committee of ISSMGE.

INTERACTION OF NEIGHBOURING FOUNDATIONS

INTERACTION DES FONDATIONS AVOISINANTES
ВЗАИМНОЕ ВЛИЯНИЕ СОСЕДНИХ ФУНДАМЕНТОВ

A. MYSLIVEC, Professor Ing. Dr. Sc. Corresponding Member of the Czechoslovak Academy of Sciences
ZDENEK KYSELA, Ing., CSc Institute of Theoretical and Applied Mechanics, Czechoslovak Academy of Sciences, Prague, (Czechoslovakia)

The article deals with the influence of the neighbouring foundations on their ultimate loads for various distances, depths and widths of both foundations. The work is the result of the laboratory test with sands, carried out for various distances, depths and widths of foundations, in the course of which the forms of failure zones below foundations were investigated.

It was ascertained that neighbouring foundations influence each other until a certain distance between them has been attained, and that the ultimate load of each foundation is different from that of individual foundations. The problem of interaction of neighbouring foundations was studies by Stuart /1962/, Biarrez /1963/, Mandel /1963/, Hanna /1963/, West and Stuart /1965/, Kos /1967/, Myslivec and Kysela /1968 and 1969/, Dembicki and coll. /1971/. As a rule these authors investigated the problem of foundations of equal widths and equal depths.

So far no attention was afforded to the problem of neighbouring foundations of different widths, different depths and different mutual distance. The solution of this problem is the aim of the presented work.

For this purpose model tests with EJF sand of particle size varying from dia. 0.05 mm to 0.2 mm were carried out. To ensure a good quality of the results of the investigation of failure zones below the foundations the NII sand /with particle size from 0.2mm to 2.0mm/ was used, which makes it possible to obtain good quality photographs. The sand was compacted to the density of 1.62 g/ccm in a rigid metal container sized 30 x 30 x 30 cm or 50 x 50 x 50 cm. The porosity of every compacted layer was investigated in several places by means of a penetrometer designed especially for this purpose. In selected evaluated tests the apex angle of repose of the sand was determined at $\phi'_f = 32^o12' \pm 1^o03'$ with the probability of 90%. The foundation models were made of metal; their dimensions were 1 x 10 cm, 1.5 x 10 cm and 2.0 x 10 cm. The surface of the foundations was provided with different finishes. The angle of friction of the soil with the foundation sides varied in the individual test series at $0.36\,\phi'_f$, $0.5\,\phi'_f$, $0.66\,\phi'_f$ and $1.0\,\phi'_f$. In the course of the tests also the influence of the relative particle size of sand with regard to the foundation width was followed. Nondeviations among the read values of the ultimate load of the same groups of foundations were observed, when different types of sand were used, if the maximum particle size of the sand used has not exceeded 1/25 of the foundation width B.

The foundations were pressed into the sand at the rate of 0.0066 mm per sec. The load applied to each foundation and the respective values of vertical displacement were measured. The ultimate load was attained, when the increment of foundation settlement became high; this occurred, when the foundation was pressed into the sand by 0.5 to 1.5 mm, which agrees with the data ascertained also by Dembicki and coll. /1971/.

In the course of our research 147 tests were evaluated, in the course of which the form of the failure zones was photographed. Another 253 tests of ultimate loads of couples of foundations of different sizes and arrangements were evaluated statistically.

When the foundations were of equal depths and the reduced S/B distance was in excess of 8 to 10, the failure zones below each foundations were the same as that below a separate foundation. The ultimate load of each foundation was identical with that of separate foundations. When the reduced S/B distance between the foundations was inferior to 6 to 8, the sliding surfaces of both foundations intersected and the soil between the two foundations was pressed upwards by the forces generated by both foundations /Fig.1/. The upward thrust of the soil follows the way of the least resistance; therefore, no

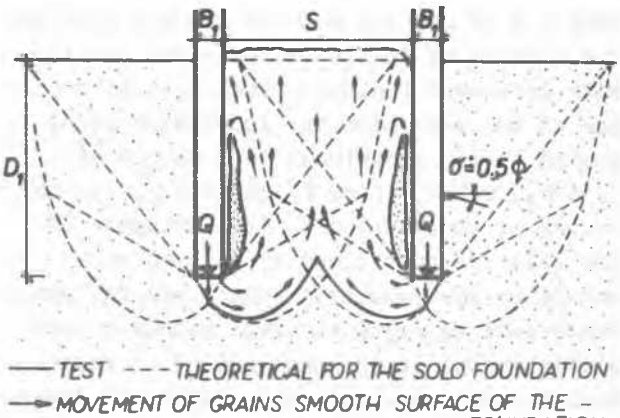

Fig. 1

sliding surfaces outside the foundations originated. Near the foundation sides the soil is displaced downwards by the friction of the soil with the foundation surface. The upward thrust of the soil between both foundations is the more intensive, the smoother the foundation sides are. The ultimate load of both foundations was lower than it would be, should both foundations be situated separately. In the case of very coarse-faced foundations no reduction of the load bearing capacity was observed.

When the reduced distance between the foundations S/B was inferior to 5, the sliding surfaces originated outside both foundations only. Due to the friction with the foundation sides the soil between the foundations was displaced downwards, moving together with the foundations, thus ensuring the cooperation of both foundations and the soil in between them. At the base level of both foundations this soil exerted a pressure on the subbase not only due to its weight, but also due to the friction with the foundation sides. The generated failure zones below the foundations were larger than it would be the case below separate foundations. The ultimate load of both foundations in this case is higher than the sum of ultimate loads of both separate foundations.

Furthermore tests with foundations of different widths B_1 and B_2 were carried out considering also different depths of both foundations $\Delta D = D_1 - D_2$. /D_1 is the depth, B_1 the width of the investigated foundation, D_2 and B_2 being the depth and width respectively of the neighbouring foundation/.

In the case of foundations of different widths and depths, e.g. when $\Delta D/B_1 = 2$ and in the case of the distance of the neighbouring foundations S/B = 2 /when $B = 1/2 (B_1 + B_2)$ / a failure zone originates below the shallower foundation base which extends also below the deeper foundation base /Fig. 2/.

Due to the friction the soil between

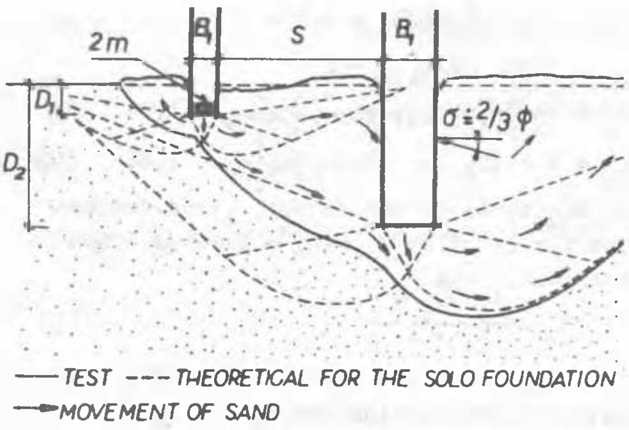

Fig. 2

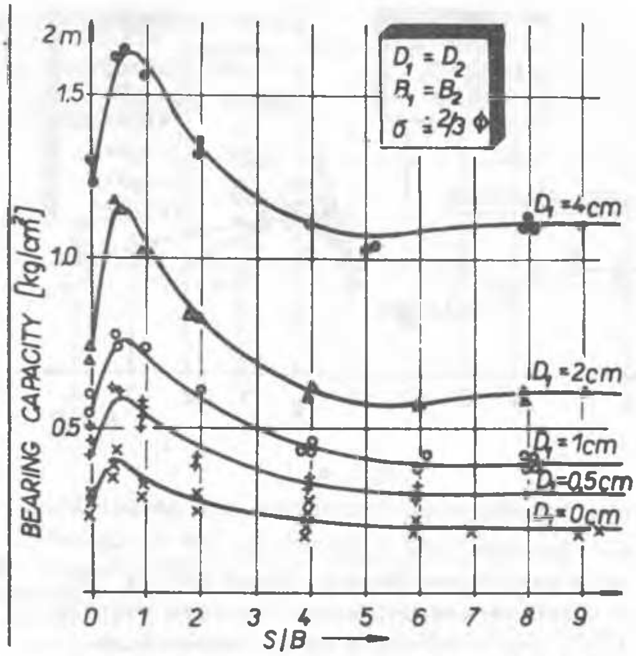

Fig. 3

the two foundations is displaced downwards and the resistance on the sliding surface between both foundations is lower than it would be the case, if the shallower foundation be separate. The horizontal forces generated by the shallower foundation increase the friction on the surface of the deeper foundation and the failure zone below the deeper foundation is larger than it would be the case, should the foundation be separate. For this reason the ultimate load bearing capacity of the deeper foundation was higher than it would be, should the foundation be separate. On the other hand, the load bearing capacity of the shallower foundation was considerably lower than it would be in the case of a separate foundation, uninfluenced by the neighbouring foundation.

In all tests the ultimate load bearing capacity of a coupled foundation was found identical with that of separate foundations, when the failure zone was equally large and of equal form as that of a separate foundation.

From the ultimate load-bearing capacity Q the ultimate load $Q_m = Q/A$ was calculated. The measured values of ultimate load of foundations of equal widths and equal depths are shown in Fig.3. The greatest increase of the ultimate load of a couple of foundations situated at a mutual distance of S/B = 0.6 amounted to 160% of the ultimate load of a separate foundation. This ultimate load increment decreased with the increasing depth, sinking to 50% at the depth of D/B = 6. The greatest reduction of ultimate load was ascertained for the mutual distance of both foundations of S/B = = 7.5 and the depth of D/B = 2.5. This reduction amounted to 60% of the ultimate load of a separate foundation when the angle of surface friction of the soil and foundation sides was 0.66 ϕ_f.

The results of one series of tests of the foundations of the widths of $B_1 = 0.5\ B_2$, mutual distance S/B = 0.5, different depths and different difference between the depths of both foundations $\Delta D = D_1 - D_2$ are shown in Fig. 4. The ascertained coefficient α shows how many times the ultimate load of the investigated foundation exceeds that of a separate foundation. When the investigated foundation was shallower than the neighbouring foundation, its load-bearing capacity was lower than that of a separate foundation, if the difference of the foundations depths $\Delta D/B_1 < -1$. The reduction of the ultimate load amounted to as much as 40% ascertained for $\Delta D/B_1 = -3$. When

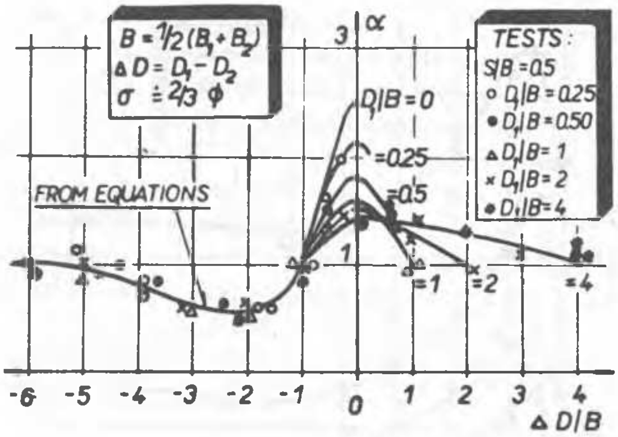

Fig. 4

the investigated foundation was deeper than the neighbouring foundation, its ultimate load was higher than it would be, if the foundation was separate, the more so, the lower the difference in the foundation depths ΔD and the smaller the depth of the investigated foundation.

The ascertained relations were mathematically formulated by means of the factors α_γ, α_q and α_c in the equation for the determination of ultimate load. These factors express the influence of the neighbouring foundation on the magnitude of the ultimate load of the investigated foundation. For the foundations of a depth D = 0 to D = 6B and for the angle of surface friction between the soil and the surface of foundations $\delta_f \geqq 2/3\ \phi_f'$ the ultimate load is

$$q_m = 1/2\ B_1 N_\gamma \cdot \alpha_\gamma + \gamma D_1 N_q \alpha_q + c N_c \alpha_c \qquad /1/$$

$$\alpha_\gamma = \left[1 - \frac{\sin(0{,}6S/B + 0{,}2 - \pi)\,\mathrm{tg}\,\phi}{e^{(0{,}6S/B + 1{,}3 - \pi)}} \cdot (1 - \beta_1) - \beta_2\right] (B/B_1)^\psi \qquad /2/$$

$$\psi = 1{,}5^{-S/B} \qquad /3/$$

$$\beta_1 = 1 \ \dots \text{ for } \Delta D/B_1 \leqq -1 \qquad /4/$$

$$\beta_1 = \left(\frac{|\Delta D|}{B_1}\right)^{3/2} \dots \text{ a/ for } -1 < \Delta D/B_1 \leqq 0; \text{ b/ for } \Delta D/B_1 > 0, \text{ when } D_1/B_1 \leqq 1 \qquad /5/$$

$$\beta_1 = \left(\frac{\Delta D}{D_1}\right)^{3/2} \dots \text{ for } \Delta D/B_1 > 0, \text{ when } D_1/B_1 > 1 \qquad /6/$$

$$\beta_2 = 0 \ \dots \text{ for } \Delta D/B_1 > -1 \qquad /7/$$

$$\beta_2 = \frac{\sin(0{,}5\,\Delta D/B_1 + 0{,}5 + \pi)\,\mathrm{tg}\,\Phi}{10 + 0{,}08\,(S/B)^3} \cdot e^{(0{,}5\,\Delta D/B_1 + 0{,}5 + \pi)} \quad \text{for } \Delta D/B_1 \leqq -1 \qquad /8/$$

$$\alpha_q = \frac{0{,}54\,\alpha_\gamma}{(B/B_1)^\psi} \ \dots \text{ for } \frac{\alpha_\gamma}{(B/B_1)^\psi} \geqq 1{,}86 \qquad /9/$$

$$\alpha_q = 1 - \beta_2 \ \dots \text{ for } \frac{\alpha_\gamma}{(B/B_1)^\psi} \quad 1{,}86 \qquad /10/$$

The magnitude of the factor α_c was deduced from the relation $N_c = (N_q - 1)\mathrm{cotg}\,\phi$. After transformations

$$\alpha_c = \frac{N_q \alpha_q - 1}{N_q - 1} \qquad /11/$$

D_1 is the depth and B_1 the width of the investigated foundation and D_2 and B_2 the depth and width respectively of the neighbouring foundation. The difference of foundation depths $D = D_1 - D_2$ and the average depth of both foundations $B = 1/2(B_1 + B_2)$, γ is the density, c cohesion and N_q, N_γ and N_c are the coefficients of the load bearing capacity.

When the foundations are of different depths and spaced at different mutual distances, the bearing capacity of both foundations may be calculated with Eq. 1 to 11, when the angle of surface friction between the soil and the foundation sides is $\delta_f = 0.66\,\phi_f'$. The introduction of the influence of interaction of both neighbouring foundations and the cooperation of the soil between them into the calculation of the 653
load bearing capacity of the foundations can result inconsiderable economy.

B I B L I O G R A P H Y :

BIARREZ, J. (1963), "Nosnosc graniczna fundamentów", Archiwum inzynierii ladowej, Wawa

MANDEL, J. (1963), "Interference plastique de fondations superficielles", Proc. of the Conf. on Soil Mech. and Found., Budapest

MYSLIVEC, A., KYSELA, Z. (1968), "Effect of adjacent found. on bearing capacity", Proc. of Conf. on Soil Mech. and Found., Budapest

STUART, J.G. (1962), "Interference between foundations, with special reference to surface footings in sand", Géotechnique 1/XII, London.