International Conference on Case Histories in Geotechnical Engineering

(1988) - Second International Conference on Case Histories in Geotechnical Engineering

02 Jun 1988, 10:30 am - 3:00 pm

Prevision of the Bearing Capacity of Superficial Foundation on Jointed Rock

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Proceedings: Second International Conference on Case Histories in Geotechnical Engineering, June 1-5, 1988, St. Louis, Mo., Paper No. 2.61

Prevision of the Bearing Capacity of Superficial Foundation on Jointed Rock

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SYNOPSIS: The article describes the application, in Greece, of an approximate resolution of the prevision of the superficial foundation bearing capacity of a school building group on jointed granite. The method is based on the mechanics of the discontinuous media. On a sufficient number of a canvas points which is situated on the critical section under the foundation, the developing shear stresses are defined, based on the elastic theory, and they are compared with the variable -into the various directions- shear strength of the jointed rock. The resulted data conduct to the setting of boundaries of plastic zones which allow the approach of the failure form and of the sliding body. The limited load value is defined by successive appoximations.

1. INTRODUCTION. PROBLEM SETTING

There are sufficient solutions that calculate the bearing capacity in soil mechanics. This happens because of the homogeneous and isotropic character of the soil and of the easy way to define its mechanical characteristics.

The problem is not simple in case of jointed rock. The difficulties result because:

- The mechanical behavior depends mainly on the tectonic fabric of the rock mass. The joints devide the material and constitute low strength surfaces. Therefore, the failure form for a given loading, will be different from the form that is defined by the state of stress for a continuous-isotropic medium. So, according to the kind of the fabric and to the orientation of the main normal stresses, the failure tracks will follow partly or thoroughly the already existing joint surfaces and consequently the resistance will be differentiated to friction strength along the joint surfaces and to resistance of proper shear strength of the intact rock.

The approach of this "residual" strength presupposes the statistical measurement of the rock fabric and the knowledge of the stress distribution.

- The joints will have a great influence on the development of the shear fields that will result from the external loads. Deviations and local stress assemblies, till the failure limit, will appear in the stress paths with consequence the development of new stress fields in these places, which will conduct to progressive failure phenomena. The estimation of the fabric influence on the stress distribution meets insuperable difficulties practically,if we take into account the uncertainty that exists with reference to the orientation and the values of the pre-existing main stresses.

- The necessary mechanical characteristics for a bearing capacity calculation, and the quantitative parameters which characterize the fabric, require expensive investigation work.

Of course, we expect almost always that the bearing capacity of a jointed rock to be greater than a soil mass. But the problem is to find the permissible soil pressure as a magnitude that results from calculations in which to be able to take under consideration as much as possible the parameters from whom it depends.

The problem is complex in its origins and its approach seems to be possible only with assumptions.

Very simplified methods, where the jointed rock is characterized by a mean angle of friction and a mean cohesion, don't take into account the important influence of the joints on the rock behavior,conduct to great uncertainty regarding the value of the safety factor and they must be used with great prudence.

An approximate method for the study of the loading rock slopes has been proposed by Müller and Pacher. In this method for the determination of the stress distribution, the assumption of the elastic-isotropic semi-space is made but on the various points of the critical section the shear stress is getting under dependance from the orientation of the stress field and the orientation of the discontinuities that characterize the rock.

This article describes the application, in Greece, of an approximate resolution of the prevision of the foundation bearing capacity of a school building group on jointed granite, based on the principle of the method of Müller and Pacher. The great extension of the buildings, about 23.000 sq.m.,obliges to take advantage of the rock resistance for economy reasons.

2. GEOTECHNICAL DATA OF THE REGION

The rock that exists at the region is a strongly jointed granite. The determination of the fabric datas is based only on the measurement of the dips of the joints which have been observed in the cores of conventional coring boreholes of about 300 meters in total depth (core recovery about 100%). The statistical study of the joint planes conducted to the following fabric data. The rock mass is characterized by three joint sets J1,J2,J3 with dips α and frequences f (f = = number of joints per meter) equal to: J1:$\alpha=0^{o}$, f=4,0 m^{-1}, J2:$\alpha=30^{o}$, f=2,5 m^{-1}, J3:$\alpha=65^{o}$,f=2,0 m^{-1} The joints are filled by clay material at the majority of the areas with deverse mechanical characteristics.

3. PREVISION OF THE BEARING CAPACITY

In the adapted method, the assumption that the joint sets can have the most unfavourable combination of strikes -that lies on the safety side- is made. Hence, it is based on the statistical measurement only of the dips of the joint planes, abolishing the costly sampling of orientated core.

The investigation is focussed in the determination of the limit load which in case of its application can give a sliding body able to move.

This method follows the following steps:

- Determination -for various loads successively-

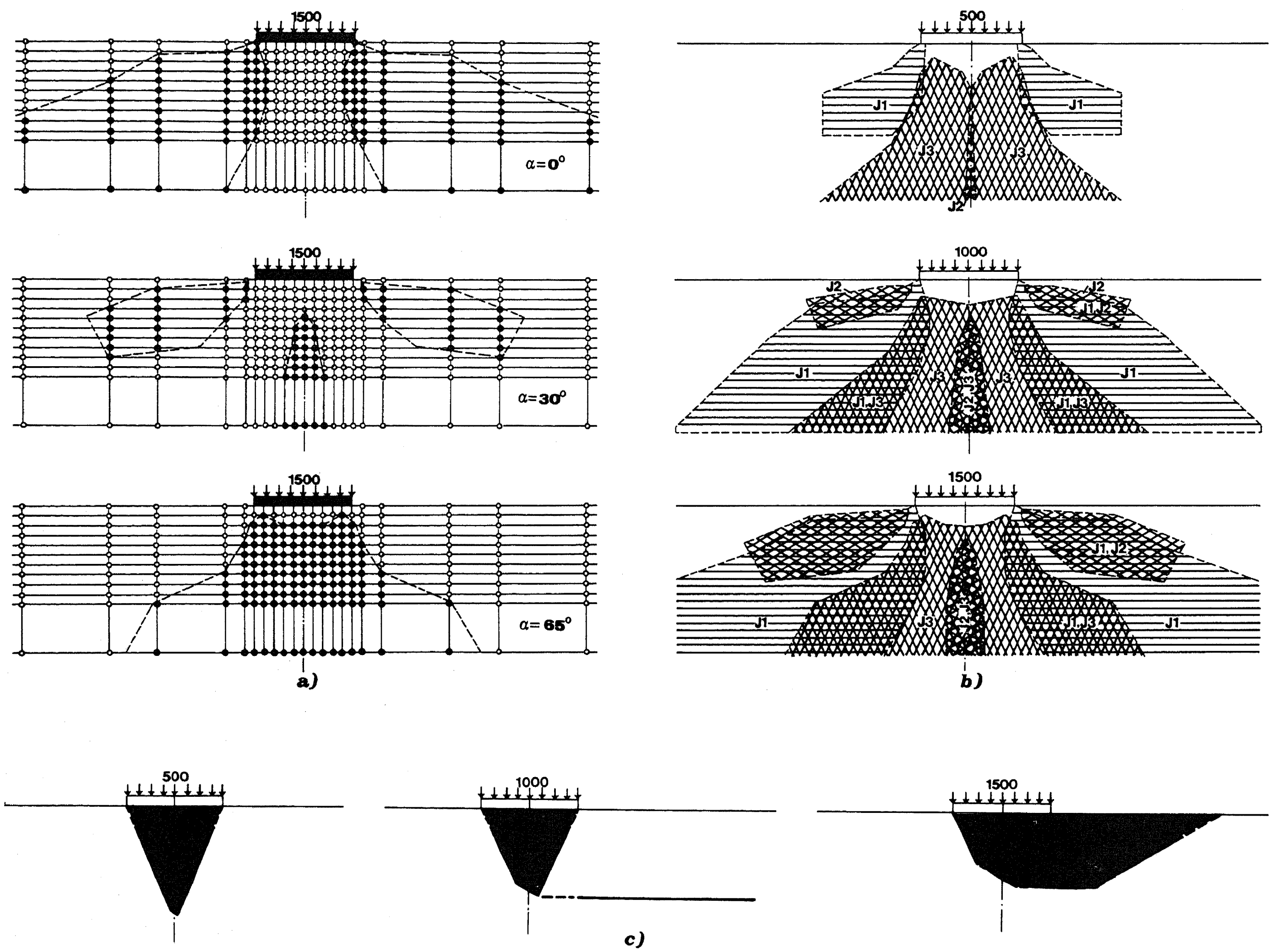

Fig. 1. Static analysis of the superficial foundation bearing capacity on jointed rock.

a) Partial safety factors R=t/τ and plastic zones, separately for each of the joint sets J1,J2,J3 in points of canvas situated on the critical section for load p = 1.500 kN/m^2. • = R≤1,0, ○ = R > 1,0. b) Plastic zones, under the footing of all the joint sets J1,J2,J3 for loads p = 500, 1.000, 1.500 kN/m^2. c) Approximation of the limit load. Failure form and sliding body. ---- = progressive failure.

Geotechnical data: Jointed granite. Fabric: three joint sets:J1: $\alpha=0^{o}$, f=4,0 m^{-1}, J2: $\alpha=30^{o}$, f=2, 5m^{-1}, J3: $\alpha=65^{o}$, f=2,0 m^{-1}.Joint sets filled by clay filling material with parameters f=17°, c_f = 45,0 kN/m^2. Form data: Rigid strip footing, B = 2,80 m in width. Superficial foundation.

of the state of stress that results from the self weight and from the transported loads on a sufficient number of points of a canvas that is situated on the critical section under the footing, with the assumption that the rock consists elastic-isotropic semi-space. That is, we don´t take into account deviations that result from the fabric in the development of the shear fields.

- Calculation on the points of the canvas of the shear strength t and of the shear loading τ along all the joint sets and comparison between the shear stress and shear strength. The resulting stability factors $R = t/\tau$ -they are also called partial safety factors- conduct to the setting of the boundaries -for every load and every joint set separately- of zones where the shear strength along the joint set will be exceeded. The position and the extension of these critical zones (plastic zones) give information regarding to the form of the sliding body and the moving possibilities and allow the determination of the limit load.

The state of stress has been determined for canvas points with distances equivalent to the statistical mean value of the distance of the horizontal joints, that is 0,25 meters. The calculation has been made for the case of the plane strain state (strip footing = the most unfavourable case). The shear strength has been calculated for the three joint sets for the case where the joints are filled by clay material or not, respectively, by the relations:

$$t = c_f + \sigma . tg\varphi_f \quad \text{and} \quad t = \sigma . tg\varphi_R \ ,$$

where c_f, φ_f = the cohesion and the angle of friction of the filling clay material of the joints, φ_R = the angle of friction of the rock, σ = the normal stress on the joint plane.

The following cases are investigated:

- The joints don´t contain filling material. The angle of friction of the jointed granite was determined -by triaxial tests- equal to φ_R=240.000 kN/m^2.

- The joints are filled by clay material 1-3 cm in thickness. The strength characteristics, in the various areas, are illustrated in the figures 1-3.

The results of the calculations of the examined cases are given in the figures 1-3.

The zones of the joint sets, where exceeding of the shear strength is observed, have been plotted in the figures for various loads. They have been plotted based on the values of the partial safety factors R and contain all the points of the section where $R \leq 1,0$. The critical zones for every joint set are characterized by delineation with the same dip as the dip of the concerned joint set. The lack of the strike values of the discontinuities imposes the assumption that the joint sets can have as dips α^o and $\alpha+90^o$. The number of joints which will fall in the critical zones will depend on the statistical mean value of the joint distance of every joint set.

We observe the increase of the extensions of the

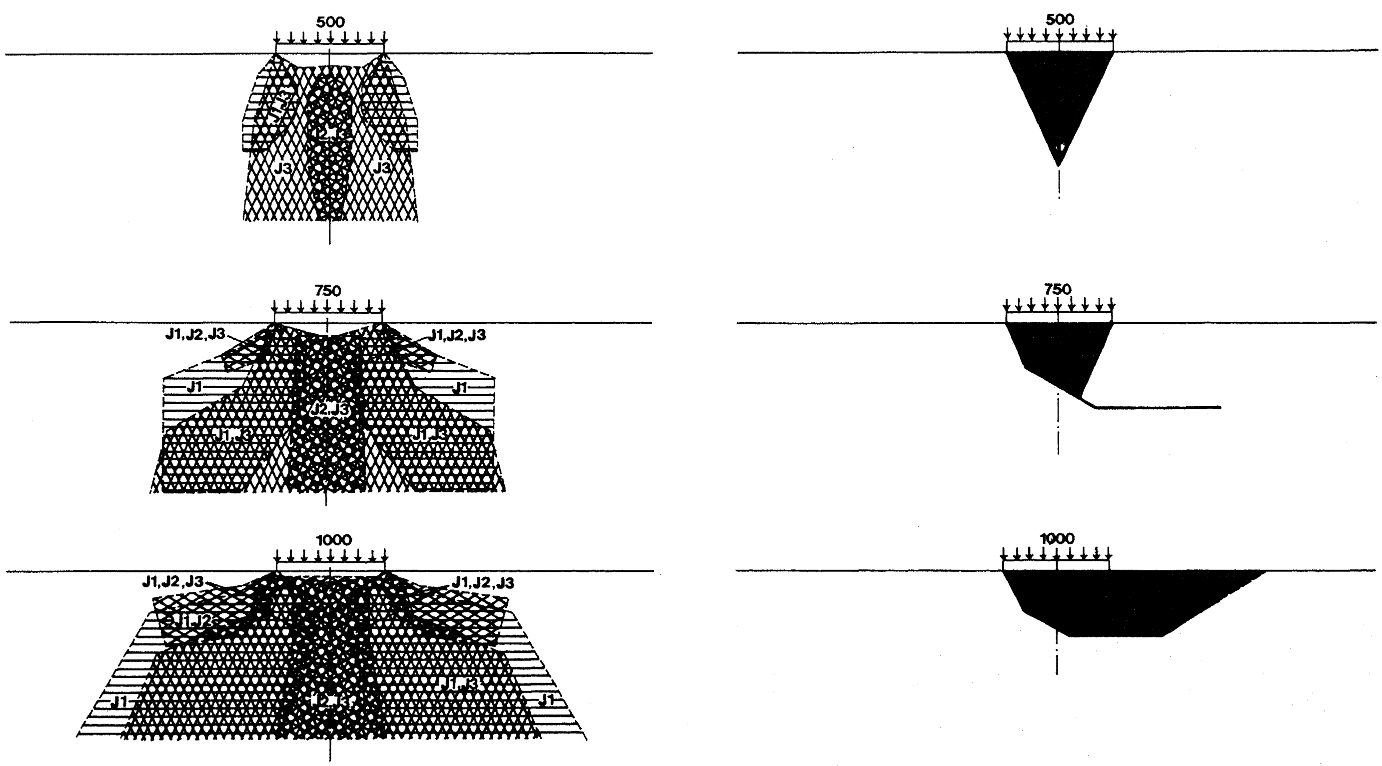

Fig. 2. Plastic zones of joint sets in the critical section. Failure form and sliding body. The joint sets are filled by clay filling material with mechanical parameters $\varphi_f = 0$, $c_f = 95,0$ kN/m^2.

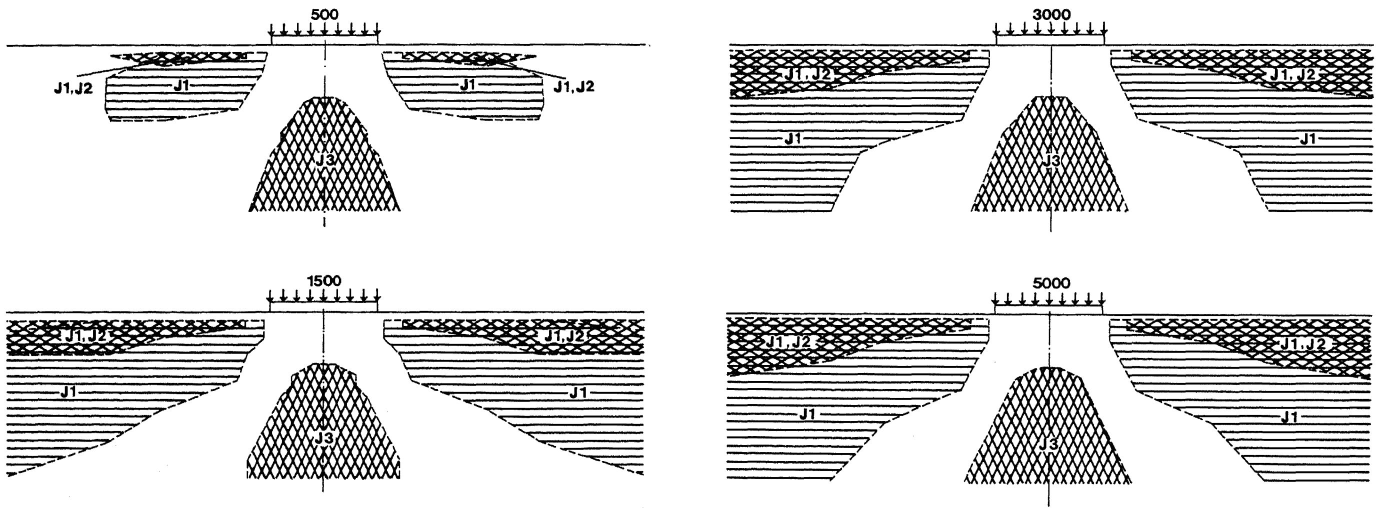

Fig. 3. Plastic zones in case where the joints of rock mass don´t contain clay filling material.

plastic zones with the size of the load in the figures. Plastic zones, which have common areas, are developed for relatively bigger loads for the two or for the three joint sets (Fig. 2). The further load increase conducts finally to unfavourable combination of the plastic zones of the joint sets with consequence the creation of a sliding body and the failure of the foundation.

The limit state would be determined considering that the bearing capacity is getting exhausted for the load for which a continuous failure surface is created. The shear stresses must have the moving direction along all the parts of this failure surface.

Tha partial safety factors R have been computed for the state of stress which is caused by the foundation loads. It is certain that the creation of wedges under the footing will conduct to more unfavourable loading conditions of the lateral parts with consequence the development of additional stresses on these and of progressive failure phenomena which have to be taken under consideration for the evaluation of the limit load. The failure forms and the limit loads that are illustrated in the figures have been estimated according to the above.

4. CONCLUSIONS

The following general conclusions are resulted from the carried out investigation:

- The bearing capacity decreases considerably for the same strength parameters with the increase of the number of joint sets. The control of the bearing capacity is judged as necessary in case where the rock is characterized by more than two joint sets which are filled by clay filling material.

- The presence of clay filling material of the joints conducts to a considerable decrease of the bearing capacity, until more than ten times.

- The presence of only one joint set, indipedently of joint density and filling material, doesn´t decrease considerably the rock resistance, because in this case the high shear strength of the intact rock will considerably contribute in the bearing capacity.

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