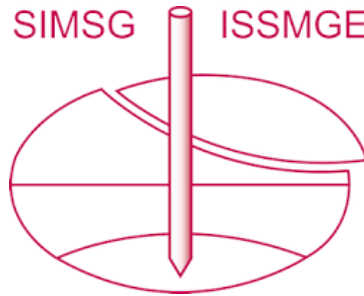


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# Behavior of Granular Media Subjected to Shear Stress

## Le Comportement d'un Milieu Granulaire dû aux Efforts de Cisaillement

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**SYNOPSIS** One of the most important features related to the behavior granular media is the strength of the limit of failure, which allows the analysis of the degree of stability of fill structures for a better zoning of construction materials. Adopting the maximum shear stress theory of Coulomb-Mohr, the shear angle  $\phi$  can be obtained experimentally, depending of the geometric characteristics of the medium, of the rock genesis and the state of stress. The series of experiments of triaxial tests with diameter  $D = 22\text{cm}$ . and of simple shear  $L = 15\text{cm}$ . and  $30\text{cm}$ ., lets general equations be obtained for  $\phi$  in the limit of normal stresses which do not cause the breaking of the particles when  $\sigma < 2 \text{ Kg/cm}^2$  and greater, considering the physical - mechanical factors of the media.

### INTRODUCTION

Besides the considerations related to minimum dimensions of the apparatus with respect to the weighted diameter of the fraction, it is well known that the value of  $\phi$  depends on the following factors : state of stress of the medium  $\sigma$  ; compressive strength of the grains,  $\sigma_c$  ; relative density,  $D_r$ ; coefficient of homogeneity,  $\eta$  ; roughness form,  $F_r$ ; and diameter  $d_{50}$  of the fraction. There is great agreement of opinions of the influence of each of the aforementioned factors on the value  $\phi$  , but not of the influence of the effect of the size of particles.

As a result of their works, Lewis (3), Roskasov, Petrov (1) consider that, as the size of the fractions grows,  $\phi$  also grows; Bishop, Vallerga (3), Gordienko, Sidorov (1) have the opinion that  $\phi$  does not change as the diameter of the fraction varies; Rowe, Leslie, Kirpatrick, - Marsal, Marachi and others (3) consider that the value of  $\phi$  increases as the size of the fraction decreases.

In order to obtain the general equation, it was necessary to analyze these three leanings in ranges for which the dimensions of the apparatus did not influence the experimental results, and afterwards ascertain the degree of compatibility of the obtained data.

### PRIOR TESTS

Tests were made in bigger size simple shear and triaxial apparatuses with fractions from 0.6 mm. to 40 mm. , in order to determine the influence of each of the factors, making constant the variables not being analyzed. In the first series, with small pressure ( $\sigma < 2 \text{ Kg/cm}^2$ ), at the end of the experiment particles of the medium are not modified. The relative influence of  $D/d_{50}$ , of the dimensions of the apparatus, and of the fraction on the value of  $\phi$  are shown on Fig. 1. For simple shear tests, it is noticed that for values of the  $D/d_{50}$  ratio greater

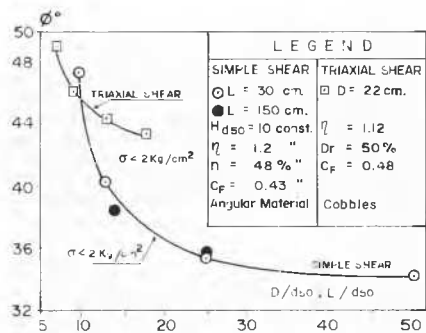


Fig. 1 Influence of the dimensions of the apparatus on  $\phi$

than 40 - 60, the value of  $\phi$  turns constant. The same tendency is seen in the triaxial tests - when  $D/d_{50}$  is greater than 18 - 20, the value of  $\phi$  is constant. These results give the minimum relative dimensions necessary to produce true results, while in the lower limits of these ranges, greater values of  $\phi$  than the real ones are obtained. For fractions having a large coefficient  $\eta$  , this relation is maintained, so it is indispensable to take this into account, besides of the well known ratio  $D/d_{\max} \geq 5$  (2).

For the series of experiments under pressures which break the edges of the grains and the grains themselves (diarita 5 mm. and 10 mm. fractions), keeping other factors constant,  $\sigma = 16 \text{ Kg/cm}^2$  was obtained and equal relative strains in the process of the experiment and equal modified  $\eta$  coefficient after the test. In the tests, it is frequently found that for fractions of the same rock genesis (Fig.2) when the fraction diameter is changed, the form coefficient

$C_F$ , also changes. This modifies the minimum porosity limit, allowing a greater degree of accommodation of the particles of the medium and, logically, influencing the value of  $\phi$ . In no case should it be considered as an influence on the fraction size, but only on its form.

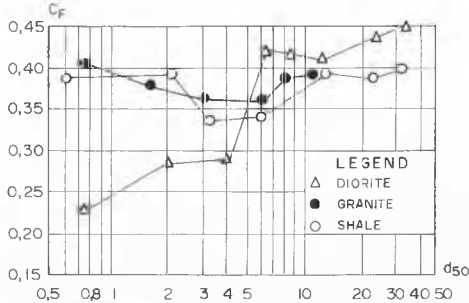


Fig. 2 Change of form of the particles of a fraction.

ANALYSIS OF THE TESTS

Taking as premise the results previously obtained, tests in triaxial apparatuses were carried out. From the results of normal stresses  $\sigma < 2 \text{ Kg/cm}^2$ , tendency curves were obtained for angular and semiangular materials (Fig.3), and rounded materials (Fig.4). It should be mentioned that the increment of  $\eta$  not always favors the value of  $\phi$ ; there are cases for small relative densities in which  $\phi$  decreases as  $\eta$  increases.

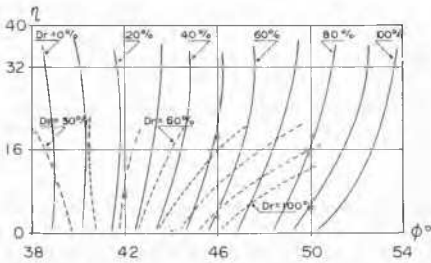


Fig. 3  $\phi = f(\eta, Dr)$  function for angular (—), and for semiangular (-----) materials.

The degree of compressibility is the most important factor affecting the behavior of the particle, thus confirming that selection of fractions is not basic for obtaining greater shear strength.

At great pressures, the granular medium has another behavior; for clean samples of angular materials and values of  $\eta > 15$ ,  $\eta$  has little effect on the value of  $\phi$ . Like -

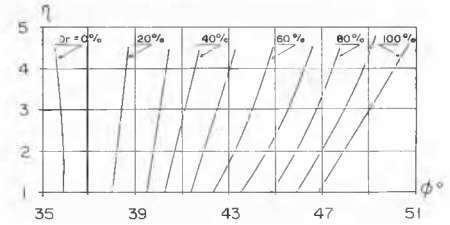


Fig 4  $\phi = f(\eta, Dr)$  function of cobbles.

wise for relative densities greater than 80%, which are difficult to attain in laboratory for values of  $\phi$  in practical cases, the results obtained fall within the limits of the experiments. For angular materials, with  $\eta \geq 15$ ,  $\sigma_c = 700 - 1000 \text{ Kg/cm}^2$ , having a compact state, the equation  $\phi = 44.5 - 0.18 \sigma + 12.2/\sigma$  was obtained. These values should be corrected by  $\Delta \phi(\sigma_c) = 19.2 (1000 - \sigma_c)/\sigma_c$  when the compressive strength of the grains of the medium has some influence.

CONCLUSIONS

Additionally to the  $D/d_{max} \geq 5$  ratio, the dependence of the weighted diameter  $d_{50}$  to the kind of apparatus being used should be considered.

The angle  $\phi$  stays constant as the fraction size changes, allowing the use of smaller fractions in test modelling and, thus, the use of medium range triaxial apparatuses.

ACKNOWLEDGEMENT

The author wishes to thank Professor Dr. P.I. Gordienko, of the Construction Engineering Institute of Moscow, for his advice and guidance.

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