

INTERNATIONAL SOCIETY FOR SOIL MECHANICS AND GEOTECHNICAL ENGINEERING



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.

MECHANICAL PROPERTIES OF ROCKFILL AND GRAVEL MATERIALS

PROPRIETES MECANQUES DES ENROCHEMENTS ET GRAVIERS

R. J. Marsal
Comisión Federal de Electricidad
Asesoría Técnica
Ródano No. 14, 5o. Piso
México 5, D.F., México.

MINUTES OF SPECIALTY SESSION N° 13

The Session took place in two parts, on the 27th and the 28th August, from 14:30 to 17:30 hours. One hundred and five members registered, of which 90 attended, approximately. About a year before the Conference, the Organizer invited through the Special Bulletin and by personal communications to those interested on the subject, to present brief contributions on the mechanical properties of rockfill and gravel materials. Six papers were received prior to the meeting and they were published as pre-prints; these were sent to pre-registered members on July 1969. With minor modifications to improve presentation, they are reproduced in the report on the Specialty Session N° 13 (chapter 2, Contributions). For reference purposes, this report will be designated with the initials SS13 to which a number separated by a dash will be added to indicate the corresponding chapter.

In June 1969, the Organizer mailed to those pre-registered a letter outlining the procedure for the Specialty Session. Six topics were selected, three for discussion at each meeting, as follows:

Part I	Part II
Theoretical models	Testing equipment
Index properties	Shear strength
Particle breakage	Compressibility

Several researchers and engineers were invited to submit written discussions with in the above mentioned topics. In response, thirteen discussions were received before the Conference and some participants submitted summaries of their presentations during the Session. This material classified by subjects appears in chapter 3, Written Discussions.

Opening of the Session. Mr. Fernando Hiriart,

Sub-Director General of the Comisión Federal de Electricidad (CFE), opened the Session. Hiriart referred to the development of the design and construction of earth and rockfill dams in Mexico, with emphasis on the evolution of studies on granular media carried out both by the CFE and the Secretaría de Recursos Hidráulicos (SRH). The second part of the Session, on August 28, was preceded by a brief talk by Prof. A. Casagrande, relative to the general recommendations formulated by him in 1960 for testing rockfill specimens (maximum particle size 20 cm), which were the basis for the design of the triaxial compression apparatus built by the CFE (specimens one square meter in cross section and 2.50 m high), at present in operation at the Institute of Engrineering of the Universidad Nacional Autónoma de México (UNAM). The English version of the address by F. Hiriart is included in chapter SS13-3.

Theoretical Models. The first part of the Specialty Session was started with presentations by Takeo Mogami and Raúl J. Marsal on the theoretical models that these researchers consider adequate for the interpretation of the behavior of granular media. Their approaches have in common the theory of probability, but the fundamental variables under analysis are different. Mogami focuses his attention on the probabilistic distribution of the void ratio, a parameter which he correlates in a simple manner with the angle of internal friction of the material. On the other hand, Marsal regards as essential the study of contact forces between the particles; through the number of grains per unit of total area and the number of contacts per particle, he estimates the average value and the coefficient of variation of the contact forces; moreover, Marsal concludes that effective stresses in a discrete body are variables with a normal statistical distribution. Several concepts were clarified by the authors at the request of members of the au-

dience; their written presentations appear in SS13-3.

Index Properties. Characteristics such as those deriving from the grain size distribution (effective diameter and coefficient of uniformity), are regarded as acceptable for a partial description of the granular mass and are used by various investigators. However, John Lowe III pointed out that

D. H. Burmister, approximately fifteen years ago, introduced the parameter C, obtained from the straight line best fitting the grain size curve and that, in his opinion, can be useful for establishing correlations with the mechanical properties (SS13-3). Lowe mentioned that in order to determine the shear strength of the rockfills for Tarbela dam in Pakistan, Burmister's parameter C was being used. The principal aim is to test in triaxial compression a material with a grain size distribution that reproduces to scale the characteristics of the actual rockfill. This observation promoted an interesting discussion on the variables affecting certain properties of granular materials, the following two tendencies being observed: 1) For a rock with a given shape and angularity of the grains, the problem is solved by reducing to scale particle sizes; and 2) grains are affected by other factors such as particle breakage, thus the above mentioned criterion is not sufficient. For the first group, the relative density of the material is the determinant factor in substantial changes of shear strength; on the other hand, for the second group, the grain size distribution and the quality of the rock constitute the main characteristics, in view of their implications in particle breakage which in turn influences both the shear strength and the compressibility of the material. This subject was again reviewed by A. Bishop and A. Vesic when discussing the shear strength of gravels and sands.

On the desirability of carrying out tests to determine the soundness of the rock components of a rockfill, it was agreed that abrasion tests (Los Angeles) and water absorption tests can be useful to judge the quality of the material and it is anticipated that as more information becomes available, it will be possible to establish practical criteria for the selection of rockfill and gravel materials. However, Lowe and Marsal are inclined to consider other types of tests (unconfined compression, tension, crushing of particles) as more directly connected to the mechanical behavior of the rock grains.

Particle Breakage. Kenneth L. Lee presented evidence of the effects of the grain size distribution and the stress level on particle breakage, through anisotropic compression tests run in a triaxial apparatus. He also mentioned the results obtained in a device similar to that used in the Los Angeles abrasion test, concluding that breakage is larger when the size of the particles increases. In addition, Lee referred to the importance of particle breakage on the selection of soils to be used in filters, since breakage changes one material into another. This information is shown in the written discussion presented by Lee in SS13-3.

Marsal proposed a simple test to determine the variation of the load which causes grain crushing as a function of the average particle dimension, taking into account not only the characteristics of the rock, but also the loading conditions (bending, shear, etc.) and the grain defects (see SS13-3). Test results are best fitted with a function of the form $P_a = \eta d_m^\lambda$, in which P_a is the crushing load, η and λ characteristics of the rock, and d_m the average dimension of particles. This formula coincides approximately with the equation derived bearing in the mind the effects of stress concentration in the contacts (Joisel) and the theory on the propagation of cracks in a solid with defects (Griffith).

About the question of how to measure particle breakage, Lee indicated that the ratio of the initial d_{15} to the final d_{15} , is an adequate and simple parameter for this purpose. Marsal described the procedure he uses to estimate particle breakage, based on the sum of positive differences between the initial and final percents retained in the various sieves of a standard series; in addition, correlations between the parameter thus defined (B) and the stress level, void ratio and dry unit weight of the material were presented. Results of tests carried out by both Lee and Marsal are shown in SS13-3. It was pointed out that according to the formula proposed by Marsal, the crushing load of the grains increases appreciably with the average dimension, since the exponent λ varies between 1.2 and 1.8 for the rocks tested; this apparently contradicts the results on particle breakage obtained in compression tests. Marsal explained that actually there is no contradiction, since contact forces grow as a function of the square of d_m (see discussion in SS13-3).

Testing Equipment. In the second part of

the Specialty Session, based on the experience of the first meeting the day before, it was decided to free participants to present their information, treating simultaneously several of the topics selected. However, the previously established order was kept for this report.

Clarence Chan described the rockfill testing equipment installed at the University of California, the way the specimens are prepared, the type of membrane and the devices used to measure stresses and deformations (SS13-3). In his presentation, A. Bishop briefly showed the characteristics of the triaxial apparatus built at Imperial College for the testing of gravels. A. Vesic referred to the high pressure tests run with sands and pointed out the advantages of the equipment used at Duke University's laboratory in order to induce axial strains larger than 20 percent, by reducing friction at the base and cap of the specimen. Mention was also made of the triaxial apparatuses used by the U. S. Corps of Engineers and the U. S. Bureau of Reclamation, both for 12 in. diameter specimens. Simple shear devices built at the University of Tokyo, Japan, at the University of Liege, Belgium, and at the VODGEO Research Institute, USSR, are described by T. Mogami, A. Fagnoul, and A. A. Nitchiporovich in their respective presentations in SS13-3. Facilities available in Mexico for testing rockfill specimens were shown to Conference members that visited the Institute of Engineering, UNAM.

Shear Strength. J. Kérisel was invited to discuss on relationships between shear strength and index properties. In his opinion, the parameters d_{10} and C_u are not sufficient to characterize the material, thus being necessary to take into account the maximum particle size d_{100} . Based on results published by R. J. Marsal (1966 and 1967) of triaxial compression tests carried out on El Infiernillo silicified conglomerate and granitic gneiss from Mica, Kérisel concludes that the shearing strength increases for decreasing maximum particle size, the coefficient of uniformity being kept constant. This conclusion is not in agreement with the information presented by T. Mogami (SS13-3), who correlates parameter k of the formula $\sin \phi = \frac{k}{1+e}$, with the coefficient of uniformity; in this equation, ϕ is the angle of internal friction measured in direct shear tests and e is the initial void ratio.

A. Vesic presented results obtained in testing granular materials under confining pressures up to 50000 psi. Tests were

carried out with quartz, feldspar, calcite and chlorite fragments of various sizes produced by crushing in a ball mill; the finest material tested had $d_{10} = 1\mu$. The influence of several variables on the shear strength was investigated, namely: particle size, grain shape, relative density and saturation. Corresponding experimental data are shown in Vesic's contribution included in SS13-3. He also provided evidence supporting the conclusion that the residual shear strength depends only on the void ratio at failure.

A. W. Bishop briefly described tests on gravel and equipment developed at Imperial College since 1948, the latest apparatus being a triaxial cell for testing specimens 12 in. diameter under a maximum confining pressure of 600 psi. Results of tests run in this device were compared with those obtained in a standard cell for specimens $1\frac{1}{2}$ in. diameter. Three materials were used, namely: mudstone, gneiss and chert particles. In order to test the first two materials in the above mentioned triaxial cells, the gradations were scaled. After comparing shear strength envelopes for the mudstone and gneiss samples, and in view of uncertainties in the determination of relative densities, Bishop decided to use the rate of dilatancy at failure ($\Delta \epsilon_v / \Delta \epsilon_a$), as a basis for comparison of test results. A plot of ϕ vs $\Delta \epsilon_v / \Delta \epsilon_a$ values obtained for several materials, shows that points fall within a narrow band, although particle breakage was important at high pressures. The speaker referred also to the effect of D/d_{max} , D being the diameter of the specimen and d_{max} the maximum particle size, and to the influence of grain breakage on the dilatancy of samples made of chert particles of tuberos and rounded shape.

The Organizer had invited H. B. Seed to discuss on shear strength of rockfill samples. In his absence, Clarence Chan presented information which was obtained at the University of California Rockfill Testing Facility. Tests have been run in 2.8, 12 and 36 in. specimens. Initially, in order to check the large scale equipment, Monterey sand specimens of the three sizes mentioned were tested. The modelling technique consists in adopting a parallel displacement of the gradation curve. The speaker showed data of three rockfill materials (Pyramid, Oroville and Napa Basalt), tested under a maximum σ_3 of 650 psi. For Pyramid Dam material, the shear strengths obtained in 12 and 36 in. diameter specimens are very close. Similar results were found for the Oroville material and the Napa Basalt (SS13-3). The ϕ -value does not decrease for σ_3 higher than 350

psi; thus, the envelope tends to become straight. A plot of ϕ vs maximum grain size disclosed that it is feasible to extrapolate laboratory tests to field conditions, since there are only slight changes in ϕ for particles over 2 inches and the changes are predictable. A comparison between triaxial compression and plain strain results has been made only in small specimens of Monterey sand. Little difference was found for the loose state and for high confining pressure.

Dana D. Leslie presented a brief account of relationships between the shear strength, gradation and index properties of rockfill materials, as determined in the triaxial apparatus of the U. S. Army Corps of Engineers (see SS13-3). Leslie emphasizes the importance of 1) establishing a classification system to correlate engineering properties and 2) carefully determining the accuracy of the testing equipment in use.

Questions by Lowe, Webster, Poulos and Fumagalli to the above speakers, as well as additional observations made by Mogami, Brauns, Ramírez de Arellano and Marsal, contributed to the discussion on shear strength.

Compressibility. Due to lack of time, it was not possible to cover this subject during the Session. Several participants referred to it while discussing particle breakage. Undoubtedly this aspect is of great interest for its practical implications. Written contributions on this topic were presented by E. Fumagalli and R. Floss (SS13-2 and 3).

COMMENTS BY THE ORGANIZER

The Organizer present here his comments on the more relevant aspects discussed in the Session. It is not intended to be a complete evaluation of information discussed but rather an effort to orient studies on the selection of materials, scale effects and compaction. In addition, short notes are included on the contributions submitted to the Session, a list of the written discussions and brief impressions on the development of the Session.

Selection of Materials. In order to decide which of the available materials to choose in the preliminary design stage of a particular job, the performance of simple tests to enable the identification with respect to a catalogue of typical materials is required; these materials have to be classified on the basis of intervals of index values and the corresponding orders of magnitude of the pertinent mechanical properties. K. L. Lee commented on the parallelism between Atterberg limits of fine soils

and particle breakage in granular media. Such catalog does not exist at present and further research work on rockfill samples will be required before the engineer is able to estimate the shear strength and the compressibility of these materials, with fair confidence. From the discussion on the above mentioned identification tests it is concluded that the water absorption and abrasion tests may be used to evaluate the quality of the component rocks of the material. On the other hand, it was agreed that the soundness test (ASTM C88) is of doubtful value for the purpose, while unconfined compression and particle breakage tests can be useful. The geological evaluation of the rock in a potential quarry, particularly in relation to fracturing and other defects, is essential as a starting point. In important projects, this evaluation can be supplemented with blasting tests to predict approximately the behavior of the rock upon explosive action.

Representative Samples. One of the subjects attracting more attention during the Session was the "scale effect" on the shear strength of granular media. The subject was covered when discussing index properties, afterwards in connection with particle breakage, and more extensively, in the presentations on shear strength. There are some doubts about the value of results obtained with various equipments, including those capable of testing large size specimens, because even in the latter, it is not possible to include the largest particles and reproduce characteristics of rockfill materials currently been used. Moreover, the costs of construction and operation of such devices, make in many cases prohibitive the direct determination of the mechanical properties of rockfills. Hence, the trend to study representative samples in devices of smaller dimensions.

But, how to "model" a rockfill with fragments varying in dimensions between 1 cm and 2 m? Even when the void ratio and the grain size distribution in the field are known, there are other factors affecting the behavior of these materials which are not reproduced in samples constituted by the same rock, with a grain size distribution having some similarity with that of the prototype (for instance, with the same coefficient of uniformity) and in which by some ingenious procedure, the shape and angularity of the particles have been duplicated. Among the most significative factors are: 1) the defects in the particles, and 2) the law of variation of the granular interaction (contact forces) as a function of the respective acting stresses. They have a direct

bearing on particle breakage, which implies a substantial transformation of the solid skeleton both in the prototype and in the laboratory specimen; these changes lead to grain size distributions in the prototype and in the specimen which do not necessarily maintain similarity in any given stage of the loading process. On the other hand, it must be kept in mind that particle breakage is a complex process which varies from the formation of powder by crushing of the contacts to the rupture of grains in two or more fragments; in addition, many particles are cracked but their fragments remain together, without relative displacement. Depending on the grain size distribution and the compactness, the new fragments and particularly the fine ones, can remain idle, without participating in the granular skeleton. In view of these facts, it becomes problematic to accept that it is sufficient to start with a grain size distribution fulfilling the laws of geometrical similarity, and hold that the results provided by the laboratory specimens be applicable to the rockfill mass which the engineer endeavors to represent.

The problem posed above in connection with shear strength, is even more significant for the compressibility of the material. This aspect becomes of paramount importance for high dams, in which it is necessary to associate materials of widely different properties, such as clays, sands and rockfills. The occurrence of differential settlements between the impervious core and the adjacent granular masses is the cause of important changes in the stress distribution and can lead to cracking and displacements of the structure not anticipated in the design. Lack of time prevented the discussion of rockfill compressibility during the Session.

Specimen Size. Another of the "scale effects" discussed during the Session, is related to the influence of D/d_{\max} in the shear strength, in which D is the minimum dimension of the specimen and d_{\max} is the maximum particle size. Some researchers sustained that the effect of D/d_{\max} is important, while others felt that it is of little significance. Actually, the first ones based their position on results of tests carried out with specimens having a D/d_{\max} ratio smaller than 6, and the second group operated with values D/d_{\max} of 10 or larger. From the discussion it is concluded that the variation of, for instance, the angle of inclination of the straight line tangent to Mohr's failure circle and passing through the origin (ϕ_0) in terms of

D/d_{\max} is as indicated schematically in Fig. 1. It seems that the effect is of particular importance in the interval $3 \leq D/d_{\max} \leq 6$, ϕ_0 growing when D/d_{\max} diminishes;

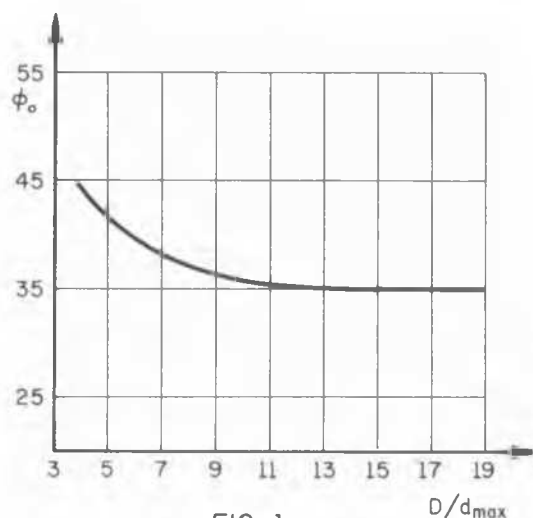


FIG 1

ϕ_0 remains almost constant for values of D/d_{\max} larger than 10. Pending a verification of the previous conclusions with further studies on the subject, it is necessary that the engineer know the details of the tests carried out with a given material in order to estimate "scale effects" described in this and the preceding paragraph, when selecting the strength parameters to be used in the design. Note that both the reduced-to-scale-sample and the specimen diameter-to-grain size factor may give results that are on the unsafe side.

Compaction. Regarding the variables which have a larger influence on the shear strength of a granular medium, taking into account "scale effects" discussed above, conclusive evidence was presented that compaction is always beneficial, its effects being of less importance above a certain stress level beyond which the material undergoes appreciable particle breakage, or else, does not exhibit dilatancy at failure. On this aspect, A. Bishop presented experimental information of several materials for which well defined linear correlations exist between shear strength in triaxial compression and the rate of dilatancy at failure ($\Delta\epsilon_v/\Delta\epsilon_\sigma$). This fact concurs with the results of triaxial tests (compression and extension) on rockfills run at the Institute of Engineering, UNAM, and confirms that the Mohr envelope is curved in its initial portion;

from a certain value of the normal stress onwards, the envelope becomes a straight line not concurring to the origin (Fig. 2).

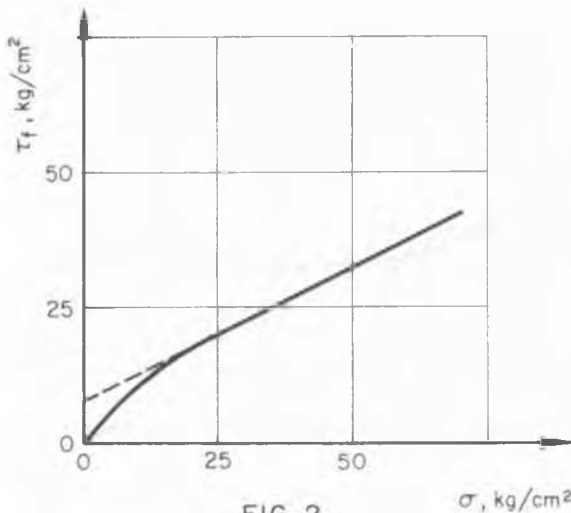


FIG 2

It must be pointed out that plane strain tests run at the above Institute, interpreted by means of Hill's (1960) criterion lead to the same conclusion as shown by Marsal in his contributions of SS13-2 and 3.

Stress-Strain Relationships. This important aspect of dam design was mentioned only incidentally. Measurements carried out in the prototypes during the last decade, claim for the study of the fundamental laws governing the behavior of granular masses. Very preliminary experimental data in rockfills indicate that the design can be conditioned by limitations in the deformation of the structure and not simply by a given safety factor with respect to failure. I. Holubec and You-Tan Tong sent to the Organizer a copy of their paper "Graphical Presentation of the Stress-Strain Behaviour of a Cohesionless Soil", submitted to *Geotechnique* on March 1969, in which they discuss the subject of deformation of granular materials. Due to time limitations it was not possible to discuss this interesting topic.

Contributions. (See SS13-2). T. Mogami and H. Yoshikoshi of Tokyo University, Japan, found experimental correlations between the coefficient of uniformity and the angle of internal friction of a material, based on direct shear tests. These were run with a shear box 2x2x0.5 m, loaded with ballast to

apply the normal load; the rate of displacement during the tests was of 3 mm/min. The separation between the two halves of the shear box and its ratio to the maximum particle size, in this case 10 cm, is not indicated. Unfortunately, the reduced normal load applied to the specimens ($\sigma \leq 1.4 \text{ Kg/cm}^2$) limits the applicability of this study.

H. Leussink and J. Brauns of the University of Karlsruhe, Germany, present the results of triaxial compression tests carried out with equidimensional spheres, arranged in two types of packings (quadratic and hexagonal), formed by materials of well known mechanical properties (smooth and rough glass, ceramic). The purpose of these tests is to study the influence of particle breakage on the shear strength and to compare the respective principal stress ratios at failure with theoretical predictions.

E. Fumagalli of the Instituto Sperimentale Modelli e Strutture (ISMES), Italy, describes triaxial and one-dimensional compression tests carried out with equipment designed at ISMES. In order to minimize the effects of wall friction, instead of a steel cylinder for one-dimensional compression tests, a series of rigid rings and deformable ones glued together is used. The confining cylinder is 50 cm in diameter and 1 m high. Specimens are tested with their natural gradation, or else, with a sample of the material scaled geometrically. The protecting cover for triaxial compression tests is formed by several layers of hexagonal pads 7 mm thick, placed between two rubber membranes, 5 mm thick the inner one and 2 mm thick the outer one. Specimens tested in triaxial compression are 35 cm in diameter and 70 cm high. The author presents results obtained in both types of tests.

With the principal aim of studying scale effects, A. Fagnoul and F. Bonnechere of Liège University, Belgium, discuss test data furnished by direct shear apparatuses with a cross sectional area varying between 20 and 2500 cm² and by triaxial cells with specimens 3.5, 10.3 and 22.8 cm diameter. Tests were run with samples of porphyritic material produced by crushing. After analyzing the various parameters affecting the shear strength at the peak, Fagnoul and Bonnechere conclude: 1) The shear strength of granular materials of uniform gradation and with the same porosity, does not vary appreciably with the average dimensions of the grains. 2) The influence of the porosity is very important in the shear strength. 3) The behavior of samples constituted by very small grains is different from that shown

by coarser materials.

R. J. Marsal of the Universidad Nacional de México, UNAM, suggests a way of evaluating the frictional resistance of a granular body, based on the statistical analysis of contact forces, measurements of rock-to-rock friction and the hypothesis that the mean path of the particles during a loading process, approximately corresponds to the direction determined by the ratios $\Delta\epsilon_z/\Delta\epsilon_x$, $\Delta\epsilon_z/\Delta\epsilon_y$ and $\Delta\epsilon_y/\Delta\epsilon_x$ between recorded strain increments. From the expression for the frictional resistance, Marsal determines the failure condition and explains the difference in results obtained in triaxial compression and plane strain.

The need to determine the modulus of deformation and Poisson's ratio for the application of the finite element method when computing stresses and strains in a granular structure, suggested the desirability of performing K_0 tests in triaxial compression reported by W. Ellis and R. R. Ledzian of the Bureau of Reclamation, USA. In their paper, the testing procedure and results for two gravels placed with various relative densities are described, the maximum axial pressure being 200 Kg/cm². The authors point out that the K_0 and Poisson's ratio values vary little for axial pressure between 10 and 100 Kg/cm²; while the modulus of deformation increases with the applied pressure, the increment rate being related to the gravel content of the specimen.

List of Written Discussions. In chapter 3 of the report SS13, discussions submitted to the Organizer are included. The corresponding list follows:

1. Fernando Hiriart, Opening of the Session
2. Takeo Mogami, Theoretical Models
3. Hans Leussink and Josef Brauns, On Regular Sphere Packings as Models for Cohesionless Soils
4. Raúl J. Marsal, A Statistical Model for Granular Materials
5. Takeo Mogami, Index Properties
6. Wesley G. Holtz, Some Thoughts about Index Properties for Evaluating the Mechanical Properties of Rockfill and Gravel Materials
7. Kenneth L. Lee, Particle Breakage during High Pressure Testing
8. Raúl J. Marsal, Particle Breakage in Coarse Granular Soils
9. Clarence K. Chan, University of California - Rockfill Testing Facility
10. Hans Leussink and Josef Brauns, Testing Equipment

11. Georges R. Post et Pierre Bonnardel, Boite de Cisaillement Direct de 1.20m x 1.20m pour L'etude des Matériaux Graveleux ou Rocheux
12. A. Fagnoul, Shear Strength of a Weathered Phyllite Material
13. Dana D. Leslie, Relationships between Shear Strength, Gradation and Index Properties of Rockfill Materials
14. A. A. Nitchiporovitch, Shearing Strength of Coarse Shell Materials
15. N. Marachi, H. Bolton Seed and C. K. Chan, Strength Characteristics of Rockfill Materials
16. R. J. Marsal, Shear Strength of Rockfill Samples
17. R. Floss, Compaction and Deformation of Coarse-grained Naturally Mixed Soils

Development of the Session. The general impression is that discussions were useful for those interested in research on the mechanical properties of rockfills and gravel materials and its applications. Language continues to be an almost unsurmountable barrier in these sessions, due to the need of interchanging impressions, clarifying concepts, and supplying information in a spontaneous manner. Long presentations trying to cover too many aspects of the subject are self-defeating; the attention of the participants is diluted and the discussion automatically declines. The system of questions prepared beforehand by the participants, selected and ordered by the Organizer, can result in a most adequate way of promoting a discussion of benefit to engineers. For this purpose it is required that the Organizer prepares a summary of the state-of-the-art on the subject of the Session and send it to those pre-registered at least two months in advance of the meeting. Preliminary contributions and personal communications with the Organizer are very desirable for this purpose. Questions to the Organizer may be of two kinds: 1) To clarify concepts or data that are misleading. 2) To implement with additional information the state-of-the-art paper. Discussions on questions formulated must be submitted in written by the participants, as soon as feasible. The publication of the final report must be very soon after the meeting, to comply with the principal objectives of a Specialty Session, namely: to inform and promote the knowledge on the selected subject.

References

Hill, R., "The Mathematical Theory of Plasticity, Oxford University Press, 1960, pag.

SPECIALTY SESSION 13

Marsal, R. J., "Plane Strain Testing of Rockfill Materials", Proceedings, Third Conference on Soil Mechanics, Caracas, 1966.

Marsal, R. J., "Large Scale Testing of Rockfill Materials", Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol. 93, No. SM2, Proc. Paper 5128, March, 1967.