Theories and Hypotheses of General Character, Soil Properties, Classification, Engineering Geology

Théories et hypothèses de caractère général, propriétés des sols, classification, géologie technique

General Report

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(1) Comments on Organization of Sections

This reporter considers it his duty to review certain shortcomings in the distribution of topics that should be considered as belonging in each Section, and also the procedure of determining the classification of each paper. In pointing out the present difficulties there is no intent to criticize those who have devoted so much effort and time in organizing the Second and this Third Conference. It is inevitable that various schemes must first be tried and experience gained before one can arrive at a satisfactory organization of Sections. I believe that sufficient experience is now available and that it would be timely for a Committee to study this problem and to make specific recommendations to the organizers of future Conferences.

The writer believes that the following are the principal difficulties which require correction:

(*a*) The Reporter on Section I of the Second Conference (Vol. VI, p. 51 of the Second Conference Proceedings) made the following statement: "Thus the section I comprises the whole extensive branch of soil mechanics, from natural-historical considerations in the borderland of geology, through the physical-chemical investigations of soil properties and the descriptive and analytical treatment of definite soil mechanics phenomenon, up to the solution of concrete problems of engineering science." It must be fairly obvious to anyone reading that report that at least one half of the papers which are reviewed in that report should have been included in other sections. This confusion has spread to the Annual Reports of the National Committees. While some committees are strictly adhering to the principle that only general theories belong in Section I, others classify all theoretical papers in the first section, irrespective whether they deal with settlement analysis, stress distribution, stability of slopes, earth pressure against retaining walls, or bearing capacity of footings. For these reasons I did not accept the invitation to serve as reporter for Session 1 until I received the assurance that only those theoretical papers would be included which were truly general in character and did not deal with specific soil mechanics problems. Even though this assurance was given, numerous papers on such topics were assigned this reporter because the authors had classified their papers as belonging in Session 1, and on the other hand, a number of papers which might have better been assigned to this Session are included in other Sessions. Attempts of this reporter to rectify the situation by sending a number of papers to other reporters resulted only in additional difficulties since these reporters had not been informed of the condition under which this reporter had accepted his assignment.

(*b*) Although the authors should recommend the classification of their papers, the final classification should be made by a review board of the organizing committee, to assure that papers which should be grouped together, are not distributed among different Sessions in a manner which defeats the purpose of the General Reports.

(*c*) Since it is evidently the purpose of the General Reports to present to the profession a well-considered review of given topics, it is essential that the scope assigned to each reporter be not greater than what he can cover conveniently in the available period, and with due allowance for the fact that the professional activities of the reporters leave them little spare time. The scope for several reporters is obviously excessive, and the available time from the date when the papers were received to the date when the reports were due, far too short.

(*d*) In a new classification of sections, every effort should be made not to separate the testing for specific engineering properties from the application of these properties. For example, shear strength of soils (both theory and all testing), and all practical applications which are governed chiefly by the shear strength of the soils, should be treated in one section. In this respect soil mechanics differs radically from structural design and the testing of the common structural materials. The structural designer need not be concerned about the details of testing the materials, and he may in general accept with confidence the results of testing laboratories, and devote all his energy and skill to the design problems. However, the engineer who applies soil mechanics must understand soil testing at least as well as the man who carries out the tests; and in many instances it is the designer who must specify exactly how the tests must be performed to assure that the results will be applicable to his design problem. Probably most of the abuse of soil mechanics in engineering design is due to the fact that the designer has learned theoretical soil mechanics from a book, but has never made a single soil test with his hands and has never learned to identify soils in the field.

(2) Soil Classification and Identification

Under this heading a number of papers are combined which have in common the study of soil properties in which the engineer is not directly interested but which are or may be of assistance in the classification of soils with respect to one or several engineering properties.

A. W. Skempton (1/14)[1]) presents a study of a new soil constant which he terms the "activity" of the soil, and which he defines as the ratio of the plasticity index to the clay fraction (< 0.002 mm). The author shows that activity is related to the mineralogy and geological history of clays, and to the proportion of their shear strength contributed by cohesion. The author classifies clays according to activity as follows: (*a*) inactive clays–activity < 0.75; (*b*) normal clays–activity 0.75 to 1.25; and active clays–activity > 1.25. Finally, evidence is presented which shows that the difficulty of taking undisturbed samples of clays from great depth is dependent not only on the sensitivity but also on the activity; and that neither sensitivity nor activity alone is a sufficient criterion.

R. Selmer-Olsen (1/12), makes a somewhat similar attempt to that of *Skempton*, correlating the liquid limit, plastic limit, and the plasticity index with the percentage of minus 2 micron. He arrives also at the conclusion that the plot of plasticity index versus percentage of minus 2 micron is most revealing regarding the content and character of the clay minerals. A distinct difference in this relationship is noticed between the inorganic clays of Norway which are chiefly Illite clays, and the organic clays.

Another attempt at correlating the liquid limit, plasticity index and the grain size distribution is made by *M. P. P. dos Santos* (1/11), who introduces a new soil constant which is derived from the grain size distribution curve. In the development of this approach the author had in mind chiefly applications to mechanical soil stabilization. As a basis for comparison and evaluation of results he uses the modified Public Roads soil classification.

The identification of clay minerals by means of a simple adsorption test is investigated by *E. Pichler* (1/10). The author carried out adsorption tests in a modified *Enslin-Schmidt* adsorption apparatus. He investigated systematically various mixtures of Quartz sand and Kaolinite, Illite, Haloysite, Ca- and Na-Bentonite, as well as several natural soils. The curve obtained when plotting the amount of adsorption vs. the logarithm of the time is shown to have a characteristic shape for each of the types of clay minerals tested. The author does not recommend the adsorption test as a substitute for other methods of identification of clay minerals, but he considers the information obtained with this test helpful for the ordinary requirements of soil mechanics.

G. D. Aitchison (1/1) described the use of pedological soil classification as a basis for the design of shallow foundations. All examples given demonstrate that many foundation difficulties in Australia are the result of seasonal moisture variations due to the pronounced cycle of wetting and drying which is the dominant seasonal effect on soils in Australia. Since, in addition, the cities where this approach has been developed, possess only a relatively small number of basic soil types, this method was proved to be practical. The paper also contains some data on the depth to which foundations, usually 12-in. diameter bored piles, must be carried in order to reduce the effects of seasonal vertical movements to a tolerable amount.

(3) Regional Soil Studies and Geology

Comprehensive and competent investigations of regional subsoil conditions are of major importance, not only as an invaluable basis for the rational design of foundations and earthworks, but as an important source for new information and new ideas for the further development of soil mechanics, as well as geology.

Perhaps the most interesting recent example of regional soil studies are the thorough investigations of the volcanic clay deposits of the valley of Mexico which have been in progress for several years; see e.g. the recent publications by Ingenieros Civiles Asociados (Artes No. 142, Mexico D.F.) entitled Arcillas del Valle de Mexico.

In view of the location of the meeting place of this Third Conference special attention is called to the publications by Dr. *A. von Moos*, the General Secretary of the Organization Committee. Those foreign members of this Conference who desire to inform themselves about the main features of the foundation conditions in the portions of Switzerland which they may visit during the excursions, are referred specifically to his papers entitled "Der Baugrund der Stadt Zürich" and "Der Baugrund des schweizerischen Mittellandes" contained in No. 18 and No. 23 of the series of publications from the "Versuchsanstalt für Wasserbau und Erdbau" of the Swiss Federal Institute of Technology in Zurich.

An interesting regional soil study concerning residual clays of Southern Brazil is presented by *Milton Vargas* (1/16). The author gives examples of similar profiles of residual soils which have developed to surprising depths on different types of rocks, in particular gneiss, basalt and sandstone. It is shown that the soil profile can be divided into three principal layers: (*a*) a surface layer of mature residual clay which has a high void ratio and a relatively low degree of saturation; (*b*) a young residual clay, with a somewhat higher degree of saturation, much less compressible than the surface layer, and in which the original structure of the parent rock can still be recognized; and (*c*) a disintegrated stratum of bedrock that requires explosives for removal. The paper contains a number of representative profiles including results of classification tests. On the plasticity chart the position of these residual soils is generally below the A-line, because the principal clay mineral formed by the weathering process is kaolin. There are substantial differences in the areas on the plasticity chart for residual clays derived from different types of rocks; the highest position is for clays derived from gneiss and sandstone, and the lowest one is for those clays derived from granite. The author defines as "virtual preconsolidation load" the stress at which the semi-log plot of the void ratio-pressure curve from a consolidation test shows the characteristic sharp curvature which usually indicates preconsolidation. In one location which was thor-

[1]) Session 1, Paper 14, Vol. I of the Proceedings of the Third Int. Conf. on Soil Mechanics and Foundation Engineering

oughly investigated, a plot of results shows for depths greater than about 20 ft. good agreement between overburden stress and preconsolidation stress derived from consolidation tests. However, for the surface zone the preconsolidation pressures from the tests are much greater and scatter over a wide range.

C. K. Smith and *J. F. Redlinger* (1/15) present a summary of the comprehensive geological and soil mechanics investigations on the Ft. Union clay-shale that constitutes the principal foundation material at the site of the Garrison Dam in North Dakota. This is one of several types of clay-shales which cover large areas of Montana, North and South Dakota and adjacent prairie provinces of Canada. Other types have also been investigated thoroughly in connection with various earth dam projects. In addition to geological description and classification tests, this paper summarizes the results of consolidation, swell and strength tests on undisturbed samples, as well as data on stability of slopes and swelling characteristics derived from field observations. With equipment especially designed for this purpose, consolidation tests were carried to 500 tons/sq.ft. (kg/cm^2) and showed preconsolidation pressures of 80 to 100 tons/sq.ft. (kg/cm^2). This checks with the order of magnitude of 1500 ft. maximum overburden which was estimated from geological evidence. Comparison of the results of consolidation and swell tests with evidence from field observations shows that the magnitude of the rebound which actually developed is much greater than indicated by laboratory tests. This difference has also been observed in the study of other clay shales and is probably due to long-time secondary swelling effects.

W. Dienemann (1/4) describes the efforts made by various communities in Germany to prepare subsoil maps with special attention to the needs of city planners and foundation engineers. Depending on local conditions there are great differences in contents and manner of presentation of these maps. It is the expressed purpose of this paper to encourage critical review in the hope that this would lead to the development o certain standards for the preparation of subsoil maps. Most of the maps which are described in this paper have not yet been published. The paper concludes with a list of guiding principles which should be considered in the preparation of such maps. The author recognizes that it would not be possible to establish standards which would be applicable in every instance.

The increasing importance of geology in soil mechanics is so well realized by soils engineers that this reporter need not waste the time of his colleagues in trying to sell them geology. However, the importance of soil mechanics to geologists is being recognized at a slower pace. Professor *Stephen Taber*, a geologist who is well known for his classic research work on frost action, emphasized the importance of the training of geologists in soil mechanics in the 27 June 1952, issue of "Science", in an article entitled "Geology, Soil Mechanics and Botany", from which the following statements are quoted:

"The youthful science of soil mechanics properly belongs with the other earth sciences in the geology family, for it deals with the physical properties of the surficial mantle of the earth and the explanation of geological phenomena, but we geologists have neglected our infant, and it has been kidnapped by the engineers." Then Professor *Taber* proceeds to describe a number of examples how geologists and other scientists engaged in research on frost action including permafrost, have been handicapped by lack of knowledge of soil mechanics; and he concludes his article as follows: "If geology students planning to study problems involving frost action could take a well-designed laboratory course in soil mechanics, we would have fewer papers in which geological phenomena are attributed to horizontal thrusting or expansion in volume; and also, they might better appreciate the value of experimental, as well as observational, evidence in the solution of geological problems."

Without entering into a discussion on the question whether engineers or geologists have fathered soil mechanics, it is agreed that soil mechanics may well be classified as one of the *earth sciences*, in addition to its position as one of the basic civil engineering subjects. In this respect a logical attitude is that taken by those European colleagues who use the terms Geotechnical Sciences, or Géotechnique, in order to group together all those engineering and geological sciences, supplemented by certain topics in physical chemistry, which are of service to the engineer in the solution of earthwork and foundation problems. This whole area obviously overlaps with several disciplines which in the past were not considered related.

(4) Consolidation

Icahary da Silveira (1/13) presents the mathematical solution of consolidation of a cylindrical test specimen subjected to radial drainage through the cylindrical surface. The solution is also presented by a semi-log plot of time factor vs. % consolidation. The author suggests that tests performed in this manner have certain advantages, but no test results are included in the paper.

The consolidation of fine-grained deposits during the process of sedimentation is treated by *R. Gran Olsson* (1/9) with greater thoroughness than has been done in preceding mathematical analyses of this problem. The author has also prepared numerical solutions for the time curves as function of dimensionless quantities which will facilitate the practical application of his solutions. The analysis uses the same basic assumptions on which *Terzaghi*'s theory of consolidation is based.

(5) Shear Strength of Clays

B. Jakobson (1/8) presents the results of systematic vane tests on clay deposits which are covered by a few feet of water and which are believed to have never been exposed to a drying cycle. These tests show that at the surface where it presumably has never been exposed to prestress, the clay has a shear strength between 0.06 and 0.08 kg/cm^2. In addition to the results of vane tests, grain size curves are included, and also profiles showing the variation of natural water content, liquid and plastic limits with depth. A representative combination of these tests is e.g.: Natural water content 85%, liquid limit 75, and plastic limit 25.

Milton Vargas (1/17) discusses the relationship between the angle of internal friction and the shear strength of clays. Based on preceding work by others, he derives a formula which gives the relationship between the true angle of internal friction, the apparent friction angle from consolidated-quick tests, and the ratio of the expansion and compression indices as obtained from an ordinary consolidation test. This formula is found to check with the results of tests on several types of residual clays.

P. Habib (1/6) reports the results of unconfined compression tests on a highly plastic clay which gave rupture planes sloping 45 degrees with the axis. Various other tests are performed in order to develop a hypothesis that may explain this result.

(6) Soil Moisture Variations

For certain soil and climatic conditions, the variations of soil moisture below pavements and building foundations are of great importance.

In many parts of the world it has been observed that highly plastic clays which are preconsolidated by drying, will swell under buildings where the normal process of surface evaporation is eliminated, causing serious unequal heaving of the buildings. Beneath pavements, the swelling of clays results in substantial loss of bearing capacity. Damage to structures founded on such clays can also result during long periods of drought when the desiccation of the clay may extend below the exterior footings, particularly below the corners of buildings. In such soils local reduction in moisture content and shrinkage will also cause irregular building settlements when trees are planted too close to buildings with shallow foundations.

L. A. DuBose (1/2) reports on moisture and temperature observations which were made inside and outside of a half-century old building in Texas which had cracked badly. It had been assumed that moisture changes below the building might have been responsible. However, only a negligible moisture differential was found between soil profiles inside and outside the building area. Since the summer during which the measurements were made, was unusually hot and dry, with large differences in ground temperature between outside and inside the building and extending to a depth of about 20 ft., a maximum moisture differential between inside and outside the building area should have been shown if the thermo-osmotic hypothesis was applicable. The author points out that additional investigations on this question are currently in progress.

Earl J. Felt (1/5) reports measurements on variations in moisture content due to different rates of transpiration by different types of vegetation, and he discusses also differential swelling due to local wetting, or due to prevention of evaporation.

D. Croney and *J. D. Coleman* (1/3) analyse the moisture conditions on the basis of pore pressure measurements in the ground and of measurements of soil suction on samples taken from the ground. Pore pressure observations to a depth of 7 ft. for the same soil under a grass cover and under a concrete slab are reported for a two-year period. The reader of this paper will have to refer to some of the previous publications by the authors for details on methods for measuring soil suction to which they have made important contributions.

(7) Stresses Induced in Compressible Soils by Electro-Osmosis

The possibility of important practical applications as well as the fascinating unsolved scientific aspects of the effects of the application of electricity to fine-grained soils continues to attract attention of investigators.

W. S. Wang and *E. Vey* (1/18) present equations of combined hydraulic and electro-osmotic flow which are based on the conventional assumptions. In addition, they report test results on a sandy silt which were performed in a lucite cylinder on specimens with a diameter of 7.6 cm and a length of 48 cm. Special attention was paid to observing variations in the distribution of pore pressures and of the electric resistivity.

A review of this paper by *Wang* and *Vey*, as well as of other recent publications on this subject, particularly the paper on "Principles of Electro-Osmotic Flow through Capillaries" by *L. Casagrande* in the January 1952 issue of the Journal of the Boston Society of Civil Engineers, convey the impression that all tests so far conducted are clouded by the effects of a number of variables which have not been properly evaluated and some of which are hardly understood. At this stage there is a real need for more fundamental research on the effects of electro-osmosis on highly compressible, colloidal materials.

Summary

This report reviews the following subjects:

(*a*) Difficulties which have arisen from the lack of a clear definition of the topics belonging in each section. Suggestions are offered for correcting these difficulties.

(*b*) Four contributions on soil classification and identification show definite progress. *Skempton* defines a new soil constant correlating the clay fraction with the plasticity index.

(*c*) Regional soil studies and engineering geology are represented by three interesting papers. However, the number is not representative for the intensive activity in recent years in various border areas between soil mechanics and geology.

(*d*) New solutions of consolidation problems are given in two papers.

(*e*) The shear strength of clays is discussed in three papers, each one presenting a different facet of this topic.

(*f*) Soil moisture variations and their implications are examined by three authors representing work done on three continents.

(*g*) Stresses in soil specimens which are subjected to electro-osmotic flow, is the subject of one paper.

Proposals for Discussion

Based on consideration of the importance of the topics and as well as the merits of the contributions contained in the papers in Session 1, it is recommended to confine the discussions principally to

1° shear strength of clays,

and also to devote some time to

2° soil classification and identification.

Since the topic of shear strength is also covered in other Sessions, particularly in Session 2, it is suggested that the shear strength of clays be covered in a special discussion period, rather than have this subject discussed in the separate discussion periods of the corresponding sessions.

The results of the rapidly increasing number of detailed investigations on the strength characteristics of widely different fine-grained soils strongly indicates that we cannot expect a single working hypothesis to explain all observed phenomena. This reporter believes that in order to facilitate discussion of this difficult and important subject, it would be better not to try to review the detailed working hypotheses which have been suggested at various times, but to concentrate on establishing clearly defined "models" by means of certain basic concepts or elements. Most important among these basic elements will be a clear and simple definition of shear strength due to *cohesion* and shear strength due to *internal friction*; also the concept of *residual strength* due to preloading, cementation, or other phenomena which becomes effective only over an extremely small contact area and which is destroyed by small strains. Although residual strength will usually have the characteristics of cohesion, one should also consider models in which the residual strength can further increase with the applied normal stress in accordance with the definition of internal friction. The concept of residual strength will lead to the definition of double failure, namely the failure of residual strength under low strains, and then the failure due to that strength which is independent of the location of contact area and which generally permits the development of larger failure strains.

If during the discussion agreement should be reached on a number of such models, it would serve as a common working platform for the examination of the published test results.

There are certain specific questions on which clarification is urgently needed and which may be helped by a detailed discussion. In particular, the question of what portion of the total measured shear strength deserves to be referred to as "cohesion".

If during virgin loading the shear strength increases in direct proportion to the stress, with the strength envelope a straight line through the origin, then such strength would appear to fulfill the definition of internal friction, even though some of this strength may, upon unloading remain as a residual strength and which then should correctly be termed cohesion.

When test specimens of isotropic materials develop well-defined shear planes, and when the tests are stopped promptly after appearance of such planes to prevent distortion of the slope angle, this angle may also be used as additional evidence in establishing the true angle of internal friction. Unfortunately, even a slight inherent or induced anistotropy has an important effect upon this angle, so that this approach requires rather comprehensive and precise testing before one may dare to use the results as positive evidence. In this connection this reporter calls attention to observations that an extremely rapid rate of loading (e.g. 0.01 second) not only gives much greater strength than the strength obtained when loading the clay specimens gradually over a period of a number of minutes, but that it may also change the slope of the shear planes from about 60 degrees to about 45 degrees. A few observations of this type were made seven years ago at Harvard, but were then considered the result of accidental causes. More recently similar tests at Massachusetts Institute of Technology, have developed beyond doubt that in such rapid loading clay behaves like a perfectly cohesive material. If the sample has been preconsolidated under a pressure equal in all directions, the transient strength under very rapid loading appears to be entirely independent of the additional effective and neutral stresses developed during loading. On the other hand, 45° shear planes obtained by some investigators during static loading are for this reporter difficult to reconcile with the slopes of 10° to 15° of the envelopes of consolidated-quick triaxial tests on the same materials.

The question as to whether results obtained on remolded clay samples bear any relationship to the strength characteristics of the same clay in the undisturbed state would also be a worthwhile topic for discussion.

Sommaire

Ce rapport passe en revue les sujets suivants:

a) Difficultés soulevées par l'absence d'une définition claire des sujets appartenant à chaque section.

b) Progrès réel apporté à la classification et à l'identification des sols: quatre mémoires. *Skempton* définit une nouvelle constante du sol établissant un rapport entre la fraction «argile» et l'indice de plasticité.

c) Etudes régionales du sol et géologie du génie civil: trois mémoires intéressants. Cependant, ce nombre n'est pas représentatif de l'intense activité déployée ces dernières années dans plusieurs domaines formant la transition entre la mécanique des sols et la géologie.

d) Nouvelles solutions aux problèmes de consolidation: deux mémoires.

e) Résistance des argiles au cisaillement: trois mémoires traitant chacun un aspect différent du sujet.

f) Variations de la teneur en eau des sols et leurs conséquences traitées par trois auteurs représentant le travail accompli dans trois continents.

g) Tensions dans des échantillons de sol soumis à un flux électro-osmotique: un mémoire.

Sujets de discussion

Vu l'importance des sujets et l'intérêts des contributions apportées par les mémoires de la session 1, il est souhaitable de limiter les discussions principalement

1º à la résistance au cisaillement des argiles

et de consacrer aussi du temps

2º à la classification et l'identification des sols.

Comme la résistance au cisaillement des argiles est traitée aussi dans d'autres sessions, principalement la session 2, nous suggérons de consacrer une séance spéciale aux échanges de vues relatifs à ce sujet, plutôt que de le voir aborder au cours des réunions séparées des sessions correspondantes.

Les résultats de minutieuses observations, dont le nombre croît rapidement, ayant trait aux caractéristiques de résistance de sols à grains fins, très différents les uns des autres, indiquent nettement que l'on ne peut pas s'attendre à ce qu'une seule hypothèse de base explique tous les phénomènes observés. Nous pensons que pour faciliter la discussion de ce sujet difficile et important il vaudrait mieux ne pas essayer de passer en revue le détail des hypothèses de base qui ont été avancées à diverses reprises, mais de concentrer les efforts à l'établissement de modèles théoriques (model) clairement définis au moyen de certains éléments ou concepts de base. Et parmi ceux-ci, il serait de la plus haute importance d'établir une définition claire et simple de la résistance au cisaillement due à la *cohésion* d'une part et au *frottement interne* d'autre part. Il en va de même pour le concept de *résistance résiduelle* due à une surcharge préalable ou à la cimentation et autres phénomènes qui ne se manifestent que sur de très petites surfaces de contact et qui sont détruits par de faibles déformations.

Bien que la résistance résiduelle présente généralement les caractéristiques extérieures de la cohésion, il y aurait lieu de considérer aussi des modèles théoriques pour lesquels la résistance résiduelle augmente par l'application de tensions normales comme ce serait le cas pour une résistance due au frottement interne. Le concept de résistance résiduelle doit mener à la définition d'une double rupture (en deux étapes), c'est-à-dire l'épuisement de la résistance résiduelle sous de faibles déformations et ensuite l'épuisement de la résistance qui est indépendante de la localisation des surfaces de contact et qui, d'une façon générale permet le développement de déformations de rupture plus importantes.

Si au cours de la discussion un accord pouvait être établi au sujet de tels modèles théoriques, ceux-ci pourraient servir comme base de travail commune pour l'examen des résultats d'essais qui sont publiés.

Il y a quelques questions bien précises qui devraient être tirées au clair immédiatement et un échange de vues détaillé pourrait contribuer à atteindre ce résultat. C'est le cas notamment pour la partie de la résistance totale au cisaillement, qui peut être appelée «cohésion».

Si, durant une première mise en charge, la résistance au cisaillement augmente en proportion directe de la tension normale, présentant une enveloppe ayant la forme d'une droite issue de l'origine, une telle résistance semblerait satisfaire la définition du frottement interne même si, lors du déchargement, une fraction de cette résistance subsiste sous forme de résistance résiduelle qui devrait alors être appelée «cohésion».

Lorsque des éprouvettes de matériaux isotropes présentent des plans de rupture bien définis, et quand les essais ont été arrêtés assez tôt, après l'apparition de tels plans, pour éviter la distortion de l'angle de pente, celui-ci peut servir de preuve supplémentaire pour établir le véritable angle de frottement interne. Malheureusement, la moindre anisotropie (inhérente à l'échantillon ou provoquée) affecte cet angle, si bien que cet aspect de l'étude exige une technique d'essai assez précise et bien comprise pour permettre l'usage des résultats à titre de preuve concluante.

A ce sujet nous désirons attirer l'attention sur les résultats observés lors de mise en charge très rapides (p. ex. 0,01 seconde). De telles mises en charge, n'ont pas pour seul effet de donner à l'argile des résistances de beaucoup supérieures à celles que l'on obtient pour un chargement progressif des échantillons s'étendant sur une période de plusieurs minutes, mais en outre elles peuvent changer la pente des plans de rupture de 60 à 45 degrés environ. Quelques observations de ce genre furent faites à Harvard il y a sept ans, mais furent considérées alors comme le résultat de causes accidentelles.

Plus récemment des essais semblables, conduits au Massachusetts Institute of Technology ont démontré indubitablement que sous l'action de chargements aussi rapides l'argile se comporte comme un matériau parfaitement cohésif. Si l'échantillon a été préalablement consolidé sous une pression égale en toutes directions, la résistance transitoire sous un chargement très rapide semble être entièrement indépendante des tensions supplémentaires, tant effectives que neutres (tensions dans l'eau interstitielle), développées durant la mise en charge. D'autre part, une inclinaison à 45 degrés des plans de rupture obtenus par certains expérimentateurs par des mises en charge statiques est, à notre avis, bien difficile à concilier avec l'inclinaison de 10° à 15° des enveloppes fournies par des essais triaxiaux rapides effectués sur les mêmes matériaux après consolidation (Qc Test).

Il vaudrait également la peine de discuter si les résultats obtenus sur des échantillons d'argile remaniée sont reliés en quelque façon aux caractéristiques de résistance de la même argile dans l'état non remanié.