No. B-9

OPENING DISCUSSION

Henry A. Mohr, Boston, Massachusetts

The papers presented, indicate a concerted effort to improve present methods of obtaining soil samples. In general the methods employed in one country are essentially the same as those employed in other countries.

Eliminating materials requiring core drills, two distinct classes of soils are to be considered.

1. Granular soils.
2. Plastic soils.

Considering granular soils. Spoons with side openings, bailers with flap or dart valves, augers of any type, driven pipes or any other known devices will not produce what might be considered as undisturbed samples.

The method described in one paper, that of impregnating the stratum with quickly coagulating asphalt emulsion, to obtain such samples, is interesting. This method has possibilities in rather coarse grained soils. But its successful use in fine grain sands is doubtful. Certainly, in cases where the soil must be prepared for the impregnation process, the resulting sample is not of the soil in its natural condition. A discussion of the method should develop something of interest.

In addition, it should be of interest to discuss the necessity for undisturbed samples of granular soils.

Considering Plastic Soils. By the use of specially built sampling spoons, so-called undisturbed samples are obtainable today. The development and perfection of these spoons seem to follow along the same lines the world over. The factors are:

1. An inside clearance on the cutting edge to eliminate friction as the sample enters the spoon.
2. Some method for disconnecting the sample at the bottom of the spoon.
3. The necessity of a vacuum created by check valves, or mechanically, at the top of the spoon, to retain the sample. This becomes increasingly necessary as the diameter of the spoon is increased.

The samples are cared for by taking and leaving them in glass liners, solid or split brass liners, or by removing them from the spoon and sealing them in independent split containers. Something might be said for and against each method but the differences are immaterial.

Future development and refinement in these special spoons would seem to rest with discoveries in the soil testing laboratories. In other words, is the structure of the clay, in the samples as now taken, disturbed to such an extent as to produce noticeable error in the laboratory test results?

Two papers refer to sounding methods with a cone-shaped apparatus. The method evidently was developed for a particular condition and purpose and is not applicable in general.

No. B-10

DISCUSSION

Daniel E. Moran, Vice President of the Conference

A phase of Soil Mechanics is the determination of the volumetric and shape changes which may be anticipated when a mass of alluvial material in its natural condition and position is subjected to changes in stress condition, as when a bridge pier increases the unit load on a layer of clay or silt previously loaded by a natural surcharge of other alluvial matter and water. For the purpose of making various tests, it is desirable to obtain samples of the material as nearly as possible in its natural or "undisturbed" condition. At San Francisco, the 38th Street Tunnel under the Hudson River, and the Flushing Meadow Park Site, samples were obtained by forcing a cylindrical shell into the material through a previously sunk casing pipe. The details of the apparatus used were successively improved upon. The last form, as used in the soil survey of the Flushing Meadow Park Site, is shown in Mr. George L. Freeman's Paper No. C-2, Vol I, page 27, Fig. 4. We are now intending to add Dr. Casagrande's wire cut-off device and in addition a device marking the length of the sample. The subsequent volume change can then be determined by remeasurement of the distance between the marks made on the sample in its original position.

How nearly may we expect to secure, with present methods, the desired result of a truly unchanged sample?

Using the present tools, (1) the top of the sample is exposed to contact with water, both before sampling and during the trip to the surface, (2) the cutting or shearing of the sample by the cutting edge deforms the outer portion of the sample to a depth of possibly 1/4", (3) the breaking off the sample at its base affects the lower portion of the sample, (4) the lower face of the sample is exposed to contact with water during the trip to the surface, and (5) it is inevitable that the external pressure on the sample is reduced from an original intensity, due to atmospheric, water and soil load, to atmospheric load alone.

Prior to the San Francisco borings (Fall 1931) the writer believed that the material in the center of the sample, a reasonable distance from the ends and sides, could be considered a true sample, unchanged from its original state, as to its volume, structure and water content. This belief was disturbed when at San Francisco it was noticed that the sample, when brought to the surface, was swelling and that it continued to swell in the container, sometimes breaking the top or bottom seal, and weeks later swelling slightly when the caps were removed in the laboratory. Evidently the voids had increased by an unknown gas filled volume. The only reasonable explanation of the swelling that the writer could supply was that the water in the sample, in its natural position under high pressure, contained marsh or other gas in solution, which on the reduction of pressure was freed from solution and as free gas occupied space causing the increase in volume of the sample.

With the Hudson River borings, taken by the Port of New York Authority, the swelling was more pronounced. Unfortunately, no careful measurements were taken in either case of the amount of swelling which took place between the time the sample arrived at the surface and the completion of the capping operation. From verbal reports it is estimated that samples 16" long, from depths of over 100', would swell as much as 1/4" in 10 minutes after arriving at the surface. After capping the swelling continued, breaking the sealing. After several weeks additional swelling, bringing the total up to possibly 1/2" in an 16" sample, was noted. The total swelling after the arrival of the sample at the surface from depths of over 100' was probably not less than 3% of the total volume.

There was no way to measure the amount of swelling which occurred during the time required to lift the sample from its original level to the surface, and for the removal of the sample tube from its position in the apparatus.

At the Flushing Meadow Park Development site, 3" samples were taken using the sampling device described by Mr. Freeman. The ends of the sample, in the brass container were struck off and tightly fitted brass caps were placed on the ends, taped to hold them in position, and finally waterproofed with 4 or 5 coatings of paraffin. Notwithstanding these precautions, water broke through the seal and a considerable amount escaped. Here, there was no swelling of the sample but water was expelled under pressure and replaced by gas.

The Flushing Meadow silt is more permeable than that sampled at San Francisco or the Hudson River.

In our laboratory small volumes of gas were collected from the Hudson River silt and found to be inflamable. In the tunnel the gas collected in bubbles on the wet upper surface of recently excavated material and was ignited in sport by the workmen. There was no smell of sulphur and it seems highly probable that the gas was principally CH_4, commonly known as marsh gas.

The expansion of the sample as a result of the formation, throughout its mass, of innumerable small bubbles of gas, will cause an error in any result based on the assumption that the volume of the sample when ready for test is the same as its volume in its natural condition and position.

In the consolidation test a load equal to that to which the sample was subjected in its natural state, may expel part of the entrapped air, and cause a complete or partial reabsorption of the methane gas bubbles. The reabsorption is a slow process and may not be completed in the time allotted to this stage of the loading, so that it is by no means safe to assume that the sample has been restored to its true volume. If during the preliminary loading some water is expelled, we cannot be sure whether the volume of the sample, under its original load, is greater or less than its original in place volume.

The fact that in all three cases the swelling continued for a long time after the reduction of pressure seems to the writer to demonstrate that in its natural position the gas is in solution. Otherwise, the expansion should be complete on the arrival of the sample at the surface. This is contrary to the observed facts.

These considerations have led the writer to the belief that a measurement of the volume of water expelled gives a more accurate index of the volume change to be expected in the natural foundation bed than the usual method using extensometers to measure the volume change in a sample. This can be done by weighing or measuring the volume of the expressed water, or by weighing the sample in its retaining ring at intervals and noting the loss in weight. The writer has used both methods.

With slight modification of the usual consolidation apparatus a test on a sample of Hudson River silt was run and simultaneous observations made, first on the reduction in volume of the sample, using a pair of extensometers, and second on the volume of the expressed water. For loads above the initial load the results were practically identical.

If, as the writer believes, the real object of the consolidation test is to determine what part of the water contained in the material in its natural condition will be expelled by an increase in load and in what time, and if there is no free gas in the material in situ, then we no longer need consider the puffing of the sample by gas or air bubbles and may confine our test to the water loss due to increased load. We can be sure that the sum of the volume of the compacted sample, plus the volume of the expressed water, is the original volume of the sample before being brought to the surface. It would, however, still be essential to obtain a sample which had neither gained nor lost water.

To the writer it seems a relatively simple matter to investigate and prove or disprove the points brought up in this discussion.

No. B-11

DISCUSSION

Earl F. Bennett, Junior Engineer, Maine Highway Department

In the preliminary exploration of soil conditions for highway and bridge design three methods are used in the state of Maine; namely, soil auger boring, rod sounding, and wash-boring.

Since the state is practically covered with shallow glacial drift a boring over one hundred feet deep to ledge is exceptional while an average depth of boring to ledge would be well under fifty feet. Up to the present time only preliminary explorations (disturbed sampling) have been made for highway and bridge design with the exception of undisturbed sampling for the settlement analysis of muck swamps. Hence the simpler methods of sounding are used extensively.

The soil auger which is best suited for fine grained soils is used whenever possible in exploring either highway or bridge foundations. It is used also on the foundation exploration of buildings where the ledge is relatively close to the surface. Borings with a three-inch auger have been made to depths of 68 feet.

The rod soundings are made with one-inch round steel rods in four-foot sections connected by couplings four inches long. The rods are driven with a sixty-pound hammer made up of a sleeve of two-inch pipe twenty inches long, connected to a two and a half-inch pipe eighteen inches long filled with lead. The stroke of the hammer is approximately eighteen inches. The rods are pulled either by jacks or a lever arrangement.

These rod soundings are very useful for ledge location in highway cuts, where the material encountered above the ledge is too coarse to be penetrated with the soil auger. This type of exploration has been used in sand and gravel cuts to depths of twenty-five feet.

Rod soundings in conjunction with the soil auger are especially useful for estimating the length of piles required for a bridge structure before it is possible to drive test piles. The soil auger is used to locate the soil layers and then the sounding rods are driven to observe the rate of penetration. The piles in general can be driven to the point at which the penetration becomes less than one-quarter inch per blow. Care must be taken in using rod soundings without soil auger borings, as boulders, coarse till soil, clay, or sand will alter the results materially.

As wash boring is the most expensive method of preliminary exploration at moderate depth, it is used only when the soil auger and sounding rods are not practical, due to the rugged character of the soil.

Undisturbed samples of muck are obtained by boring to the desired depth for the sample with the soil auger. A steel tube is then lowered to the bottom of the auger hole and driven into the muck. A comparison of the disturbance in the material caused by the soil auger and the steel tube is shown in the following. In a swamp of very woody, undeteriorated muck three samples were taken with the soil auger at a depth of twenty feet below the surface. The average water content of the three samples was 415% of the dry weight of the material, while an undisturbed sample at the same depth had a water content of 800% based on its dry weight. Approximately one-half of the water in the muck had been squeezed out by sampling with the soil auger.

No. B-12

DISCUSSION

A METHOD FOR DETERMINING THE REPRESENTATIVE CHARACTER OF UNDISTURBED SAMPLES AND SOMETHING OF THE DISTURBANCE CAUSED BY THE SAMPLING OPERATION

Donald M. Burmister, Instructor in Civil Engineering, Columbia University, New York City

The physical analysis of foundation conditions and of the settlement of structures is based upon two premises:

1. That undisturbed samples can be obtained which are representative of the soil in its undisturbed, natural state in the underground.

2. That the essential engineering properties of the soil can be determined accurately in the soil mechanics laboratory.

The first is the basic factor in soil analysis. Disturbance due to the sampling operation cannot be measured because the true natural condition of the soil cannot be known at present. The effect of frictional drag can, however, be shown by partially drying a section of a sample as in Fig. 1.

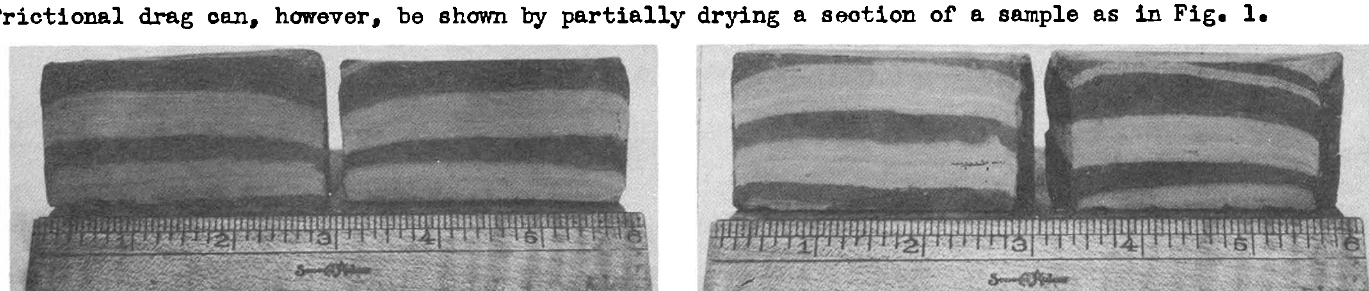
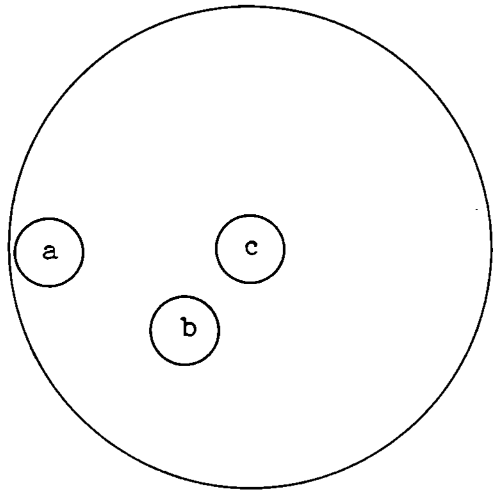


Fig. 1 Distortion of Sample as a Result of Frictional Drag within the Sampling Tube

In order that the information on the condition or the character of the soil may be of real practical value, it must yield numerical results, which can be used for comparison and rating of samples as to whether they are representative. Consistency tests, described by the writer in Paper No. A-13 of Vol. II of the Proceedings, are used for this purpose as shown in Fig. 2.



Undisturbed   Relative Consistency, dia. in cm.

a. Edge

b. quarter point

c. center

Remolded

Slice of a three-inch undisturbed sample.

Fig. 2
Tests to Determine Degree of Disturbance across a Section of Sample

Any serious disturbance should be reflected in the results obtained because disturbance always causes a decrease in shear strength. A decrease in shear strength due to any cause is represented by an increase in the diameter of the squeezed soil specimen in the consistency test. The following examples illustrate this point:

T A B L E I

Sample	6-u9	11-u4	11-u4
Location of Cut	Top of Tube	Top of Tube	Bottom of Tube
Condition			
Undisturbed			
a. edge	1.40 cm.	2.0 cm.	1.9 cm.
b. quarter point	1.32	1.85	1.85
c. center	1.30	1.85	1.80
Remolded	1.85	2.6	2.60
Moisture Content	32.8%		63.8%

The results show that the edges have been disturbed as illustrated in Fig. 1. The zone of greatest disturbance extends inward about 1/4 to 3/8 inches from the edge. Hence, the consolidation test sample should be of such size as to permit this more or less disturbed material to be trimmed off.

In order to get some idea as to the variation in character of the material from top to bottom of the sample tube and whether the sample as a whole is relatively undisturbed the following series of consistency tests are suggested as the basis of rating of samples. This series has become a regular part of the routine soil testing at the Soil Mechanics Laboratory, Columbia University, and are the first tests made upon each sample, in the order illustrated in Fig. 3.

Consistency tests are made at the center of each of cuts 1, 2, and 3 and from the center of the end trimmings of sufficient thickness for 4 and 5 whenever these latter tests are made. The following

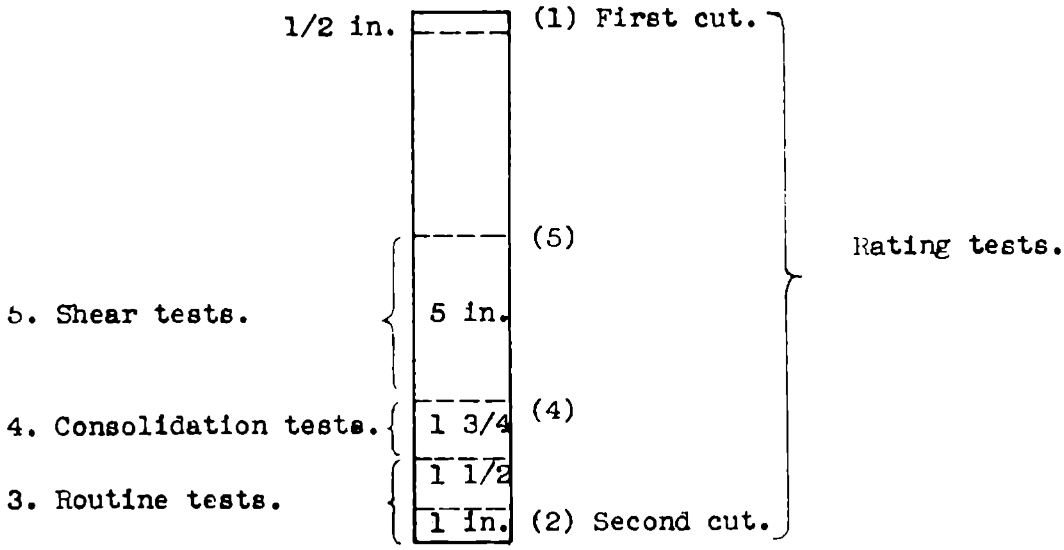


Fig. 3
Tests for Rating Samples as to their Character and Condition of Disturbance

table illustrates this method.

Sample 6-u4 shows that the character and the condition of the sample was practically constant from top to bottom. This still leaves as an unknown factor the condition of the sample with respect to its true natural undisturbed state. But it is more likely that, in this case, the sample has suffered very little disturbance. Sample 5-u6, on the other hand, which swelled sufficiently to force the cap off at the top more than 1/4 inch, has suffered great disturbance at the top. In this case the top of the sample has been practically completely remolded, probably by the expansion of gas. Comparison of the remolded tests at the top and bottom shows that the moisture content was unchanged and practically constant in the length of the tube, hence variation in consistency is due to disturbance. The tests show also that the bottom half of the sample is the least disturbed and may furnish fairly reliable consolidation test data.

TABLE II

Sample		5-u6	6-u4
1. Top	Undisturbed	3.0	2.4
	Remolded	3.2	3.4
2. Bottom	U	2.7	2.3
	R	3.2	3.4
3.	L.L.	3.3	3.2
	P.L.	1.3	1.3
	Moisture	90.1	89.0
Remarks		Top of sample swelled 3/8 inch and forced off cap.	No swelling evident.
4. Consolidation	U	2.7	2.3
	R	3.2	3.3
	Moisture	95.6	91.8
5. Shear	U	2.8	2.4
	R	3.2	2.3
	Moisture	95.7	111.0

There seems to be real need of a field consistency test to be used during boring operations, which would serve as a control and check test to disclose changes in consistency from any cause between the boring operations and the time the laboratory tests are made and even subsequently, if the samples are stored. Furthermore the test would be particularly useful for obtaining more definite information on all ordinary dry or bottle samples immediately. These tests would bring into the picture some specific information from all of the samples taken from an area and hence make possible a more complete interpretation of underground soil conditions.

No. B-13 DISCUSSION

Harold E. Russell, Associate of R. G. Osborne, Foundation Investigations, Los Angeles, California

It would seem inevitable that a great deal of research work will be stimulated by this Conference, and I think that one of the first things that every one must do is to secure accurate and complete samples of any type of terrain that they are investigating.

During the work for the San Francisco-Oakland Bay bridge the Division of Highways developed a sampler from its preliminary stage into what is now considered a very good and excellent tool. (A complete description of this apparatus is given in Paper No. B-6, Vol I). It is believed that this sampler is extremely efficient. To my knowledge samples have been taken from pier E4 on the East Bay of the bridge to a depth of two hundred and seventy feet, in a sample of very coarse sand. I personally have handled it and while I cannot judge the condition of it compared to what it is in the bay, it seemed to be absolutely undisturbed and not altered in any way. In some samples pieces of gravel about the size of the end of your finger were contained, and they seemed to have absolutely no effect on the structure. When broken open these pieces remained in there, surrounded by the very fine particles of sand, and absolutely undisturbed.

It seems that there are several possibilities of this sampler: (1) In sampling for consolidation, for permeability, and for shear; (2) For correlating the resistance in driving and the variation in bearing value--a valuable work on that has been done on that in Michigan, with which I am sure you are all familiar;(3) The determination of the length of piling required from the resistance to driving. It is rather interesting to know that work has been done on that in Maine. I am sure that you are familiar with the publication from the University of Ohio, which states that they have also carried out work of that nature. To my knowledge this has not been done with the California type of sampler, but it is obviously possible to do so. And I believe that most of you will find, if you are going to enter a period of sampling and experimentation, that this sampler is certainly entitled to your very serious consideration.

No. B-14 DISCUSSION

Spencer J. Buchanan, Chief of Soil Mechanics Laboratory
U. S. Waterways Experiment Station, Vicksburg, Mississippi

The difficulty, which was encountered by the gentleman from the TVA (Mr. Vaughn) in the disturbance of material when using a small sampling tube, is one that we, too, encountered with a tube such as the one described in the Progress Report of the American Society of Civil Engineers Committee on Earth and Foundations. To overcome that difficulty we changed our cutting edge of the tube, so that a small shoulder on the inside of the cutting edge eliminated the interior friction as the sample is driven into the tube. There is also a small shoulder on the outside of the tube which eliminates the friction described by Dr. Terzaghi. We have taken a great many samples with this equipment, all over the country, and found that all of our samples check up pretty well in length with the depth to which the tube had been driven. Of course, if the material beneath it is soft, it is natural that you will get some compression, as Dr. Terzaghi has described.

Likewise we have had considerable experience with sampling equipment such as that shown here by the gentleman from California (Mr. Russell). We have found that driving equipment of this sort into the material disturbs the formation before you can sample it, so that the samples are not very good indicators of what actually exists in place.

No. B-15 DISCUSSION

E. W. Vaughan, Asst. Hydraulic Engineer, Tennessee Valley Authority, Norris, Tennessee

I have just a few rather rambling remarks which I want to make and which have to do with things we have observed in making our tests, some of which do not always come up to expectations.

One of the first things that we have noted had to do with our sampling operations and the probable amount of distortion that we got by driving a sampling tube into the ground. At the Chickamauga Dam site we had some material composed of very fine laminations of micacious sand in a rather stiff clay, so that these layers varied in thickness from about a quarter of an inch to a sixteenth of an inch. The sampling tube used was a two-inch outside diameter brass tube, contained in a driving shell. That was driven into the ground with the ordinary well driving outfit. We found that where the laminations of the material had originally been horizontal, after we took the sample out of the brass tube these laminations were definitely curved. This showed that the material in that small sized tube had probably been disturbed for the entire cross-section, which would indicate that it would be far better in anything outside of a preliminary test to get a sample as large as any practical device could be devised for getting it.

Another thing that we discovered on our compaction tests was that, contrary to the common belief, the maximum density of material does not correspond to the maximum shearing resistance of that same material.

In applying Dr. Terzaghi's theory of consolidation to any clay layer that is loaded, it is definitely advisable to reconsider his initial assumptions and also the method by which the test is made. In an earth dam, for instance, on an earth foundation, where the thickness of the compressible layer is rather small in comparison with the base width of the dam, the condition is very similar to the one we have in the ordinary consolidation cylinder, for the probable motion of the water that is squeezed from this compressible layer to the drainage boundaries is more or less in a vertical direction. If this compressible layer is very deep with respect to the width of the loaded area, it seems that the water squeezed from this compressible layer would probably take a more or less curved path. This would indicate that the length of the path would be somewhat longer than the length of path that we would get if we used simply the vertical depth of that layer.

No. B-16

COMMENTS ON VARIOUS PAPERS

(Editorial notes abstracted from oral and written communications.)

Paper B-3: During the alternate driving down of the casing and jacking down of the rod and cone it is inevitable that soil will come in contact with the rod and even be wedged into the space between the rod and the casing, introducing considerable friction which will ordinarily increase with depth. How has this factor been taken into account?

Paper B-6: Samples of several feet in length and of relatively small diameters are, according to the statements of a number of engineers and soil specialists, disturbed to such a degree that they exclude the possibility of testing the "undisturbed" material. It is stated that even samples 5 in. in diameter and one foot long, taken with thin steel cylinders and cutting edge, show some deformation. The amount of deformation depends on the character of the soil and is most intense in silts and clays, while in soils of a character as represented by the tests in Fig. 4 it is least. The question is raised whether the author considers the effect of disturbance on a sample 2 in. long, Fig. 4, the same as for a sample two or three feet in length.

Paper B-7: How is the faultless contact between the bottom of the drill hole and the pressure plate insured? If the bottom is uneven the test results are unreliable!