REPORT OF COMMITTEE ON METHODS OF EXPLORING, SURVEYING AND SAMPLING SOILS FOR HIGHWAY PURPOSES

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SYNOPSIS

Methods of obtaining undisturbed soil samples are described in detail for eight States California, Iowa, Kansas, Louisiana, Michigan, New York, Ohio and Wisconsin Allowing for altering circumstances in various parts of the country, there is still widely differing opinion as to what constitutes satisfactory sampling The two principles of sampling always applicable are that the explored prism should be adequately covered, and that samples should be as nearly as possible undisturbed Because there is no truly satisfactory equipment yet available, it is hoped that highway departments will include a study of the problem in their programs of research

The methods of exploring, surveying and sampling soil for highway purposes may be divided into two general classes The first includes the determination of the physical characteristics of the soil as related to its performance in a reworked or compacted condition The second division includes principally the determination of the bearing capacity and permeability of the undisturbed foundation material

The first division has received a great deal of attention from research workers in the highway departments, and methods of surveying and sampling have been developed to a very satisfactory state The need for extensive work in the second division has not yet been so important in most States, but the development of high speed highways, with their deep cuts, high fills and larger bridges, is making the question of stability of foundations one of ever increasing importance to the highway engineer

Stability determinations are based on tests of undisturbed soil, and consist mainly of the determination of shear and compression strengths, density, and permeability These are laboratory tests, and are usually not performed on the material in place It is necessary, therefore, either to obtain undisturbed samples for use in the tests, or to devise new methods of getting equivalent values for the material in place Although the latter procedure has great possibilities of ultimate success, the former is farther developed at this time, and is giving results which are at least approximately accurate

The work of the committee this year has been directed toward extension of the general knowledge in this latter field By means of a questionnaire, a survey of the existing equipment now in use by the highway departments of the various States was made, particular emphasis being placed on critical analysis of equipment for determining undisturbed samples

The generous response from the State highway departments indicates much interest in the subject, but reveals that few have found it possible to extend personnel and equipment to include such investigations Of those reporting, California, Iowa, Kansas, Louisiana, Michigan, New Mexico, Ohio, and Wisconsin attempt to obtain undisturbed samples The methods used by these States will be described in detail

TEST PITS

For shallow depths the practice of digging pits and carving out a sample is followed in several States The practice in Ohio, as reported by Mr Litehiser, is as follows

"In obtaining undisturbed samples, a test pit of dimensions approximately 6 ft by 6 ft is excavated and samples taken at the desired depths When a sample is to be taken, a mound of undisturbed soil is left in the center of the pit and the remaining portion excavated to a depth of 11 in below the top of the mound This mound is then carefully trimmed until a cylinder of undisturbed soil 11 in high and 5½ in in diameter is left standing in the bottom of the pit A cardboard cylinder mold 12 in high and 6 in in diameter is placed over the cylinder of soil, and the space between the soil and the cardboard filled with hot paraffin When the paraffin has cooled, the cylinder of soil is cut loose from the base, inverted, and the other end sealed with paraffin

"When the test pit reaches a depth of greater than 6 ft, cribbing is used It is sometimes necessary to use pumps to keep the water out of the test pit

"Undisturbed samples are stored and carved for testing in the moist room at the laboratory

"Taking samples by this method insures getting as true undisturbed samples as possible Disadvantages are that this method of obtaining undisturbed samples is quite slow and expensive

"It is impractical to obtain samples from depths greater than 20 or 25 ft by this method "

Mr Kushing of the Michigan State Highway Department reports that·

"Where undisturbed samples are required, it has been the Department's practice to obtain these from a test pit rather than from a boring In the case of clays a large sample (½ to 1 cu ft) is carved from the body of soil, trimmed, and coated with paraffin The sample is packed carefully to avoid breaking the paraffin seal and taken to the laboratory The sample is weighed in the field before and after coating with paraffin and these weights checked when the laboratory tests are run

"In the case of granular materials undisturbed samples have been successfully obtained by carefully forcing a seamless tin sample can into the sand or gravel until it is completely filled The can is raised on a square pointed shovel or trowel, inverted, and the top struck off with a straightedge The sample is weighed and sealed and taken to the laboratory for testing This method of obtaining undisturbed samples of granular materials has been used successfully even in gravel deposits, but is particularly suited for sand

"The methods used for obtaining undisturbed samples require the digging of a test pit for deep foundations, but in the case of subgrade investigation where samples can be taken at or near the surface, the expense is very small It is then possible to take a much larger number of samples and obtain a more comprehensive picture of the soil conditions "

It is recognized by all that this method of sampling, while satisfactory for occasional samples near the surface, is slow and expensive where many samples are required and deep pits are necessary Pipe samplers of many forms have been used extensively for deep sampling The present stage of the development and practical use of such devices is disclosed by the results of the Committee's survey

DRIVEN TUBE SAMPLERS

Mr Roettiger reports that in Wisconsin:

"Attempts have been made to obtain undisturbed samples by driving sharpened sections of pipe with the idea of cutting a core from the soil This has not been satisfactory because it compresses the soil at the circumference of the sample It also squeezes out some of the moisture and the sample is not representative of the natural condition of the soil "

"The regular practice of the Michigan State Highway Department has been described in some detail in a paper entitled "A Penetration Method of Measuring Soil Resistance" in the Proceedings of the A.S T M for 1935, Part II Samples are taken in a 1¼-in steel core barrel driven by a falling weight The core barrel has a removable cutting edge of hardened steel The primary purpose of obtaining samples in this way is to measure the resistance to penetration However, the samples obtained are sealed in the core barrel with paraffin and taken to the laboratory for testing The core is punched out of the core barrel and a transverse shear test, also described in the above article, is run The comparison of the laboratory shear test and the field penetration indicates that for plastic soils the sample obtained is relatively undisturbed In the case of more porous soils, it is believed that the core is compressed somewhat and the two shear tests do not compare favorably "

Louisiana obtains its deep samples by hiring a drilling contractor with a rotary drilling rig having a core barrel of 4 in inside diameter and approximately 36 in long Mr Lehmann reports that this method is very satisfactory

Mr Allen reports that Kansas uses two types of drive tube samplers

"One of the samplers has a tube which is split in halves and hinged at the top The two halves are held together by means of a special collar This tube has been used for taking samples of moderate depths (20 to 30 ft) and has been successful except where the soil has been in a very soft saturated condition (saturated silt) having little cohesion and a comparatively low density

"A second type of sampler consisting of a tube which is open only on the cutting end (except for a small air vent) has also been used

"The only advantage gained by the use of the split tube is ease of removing the sample with the minimum disturbance The advantage of a tube with a cutting edge properly tapered and a thin side wall is greater ease in driving, less disturbance to the layer as well as to the soil density The disadvantage is, of course, reduced strength

"The disadvantage of the split tube is in withdrawing the sample, especially in soils which are low in cohesion, or which are very wet and soft

"It is felt that in order to remove very wet samples we must resort to the use of a suction pump in order to obtain a partial vacuum on the top of the sample Obviously this cannot be done with a split tube The use of a tube which has a slightly elliptical bore would aid in shearing off the sample by turning the tube with the initial lift The tube should have a minimum wall and cutting edge thickness to prevent disturbance It should also have a minimum inside diameter of four and one-half (4½) in and preferably six (6) in The greater the diameter of the core the more nearly is it possible to obtain a minimum disturbance in the four and one-quarter (4¼) in diameter sample for the consolidation test Also, the depth of the sample should be at least three (3) times that required for the sample for consolidation"

Iowa uses a drive sampler consisting of a 4 in diameter tube 8 in long, made of 14 gage material The tube is beveled inward $\frac{1}{16}$ in on the cutting end, and slips over a driving head at the top It is secured to the driving head by four $\frac{5}{16}$ in by $\frac{1}{2}$ in cap screws A bead, $\frac{1}{8}$ in by $\frac{1}{8}$ in in section and extending the full length of the tube, projects from the outside of the sampler The driving head is provided with a ball valve for the release of air, and is tapped to receive the $1\frac{3}{8}$ in diameter driving rod This device is used in auger drill holes to depths of 25 ft

The advantages of this sampler are listed by Mr Myers as (a) core bit cannot be pulled off, (b) bit is easily removed from head, (c) cores are easily removed from bit, (d) air is given access to bottom of core as the core is being pulled, (e) bits can be replaced at small cost, (f) air valve permits the escape of air above the core as the sampling device is driven The valve closes when the core is pulled

The chief disadvantages of the device are (a) the fact that it will not bring up very plastic soils, and (b) too much time is required in the field to assemble the extension rod Mr Myers suggests that the connection threads should be inside of the rod, so that the workman can see when the rods are butted against each other

California has the most elaborate equipment for drive tube sampling and apparently is doing more of that type of work than other States The "California Sampler," developed under the direction of Mr T E Stanton, Jr and Mr O J Porter, has been described in detail in the Engineering News Record of June 4, 1936, in the Proceedings of the International Conference on Soil Mechanics and Foundation Engineering, June 1936, vol 1, and in other periodicals The details will not be repeated here, since they are well known to all interested in the subject Essentially it consists of a soil sampling tube into which a plug can be inserted at the lower end permitting it to be driven through difficult soil without filling the tube The plug may then be withdrawn and the sampler driven further into the soil The whole equipment is then pulled out of the soil and the sampling tube removed Three sizes of soil samplers are separated, 1-in for hand work up to depths of 50 ft, 2-in for practically all other types of sampling up to depths of 250 ft , and a 5-in sampler is occasionally used where there is considerable coarse sand and gravelly material

Mr O J Porter, Associate Physical Testing Engineer for the State of California Division of Highways, in direct charge of the sampling, states that the equipment is in almost constant use and is proving very satisfactory

The advantages of this equipment may be listed as follows

1 No casing is necessary except when the skin friction is too high and it is impossible to withdraw the sampler This may occur in the case of deep loose sand It has been found necessary in some cases to put the casing down through such material, but below that depth driving may be continued without the casing

2 The sampler is adaptable to all types of penetrable soils, including some not usually sampled by this type of equipment It has been used at the bottoms of churn drill holes, in shales, sandstone and other soft and broken bedrock formations and is considered by Mr Porter superior to core drilling in such material

3 Even in cases where churn drilling or other methods are first used to sink a hole, it is not necessary to clean the hole carefully before lowering the sampler The plugged end can be driven a short distance through the broken soil at the bottom of the hole and the sampler then extended This is a distinct advantage over many other types of samplers where disturbed soil at the bottom of a hole will enter the sampling tube

4 The samples go to the laboratory in the containers in which they were extracted The job of trimming the ends of the cylinders, capping, taping, and covering with paraffin requires a minimum of time and handling and the samples therefore usually reach the laboratory in satisfactory condition

5 The positive air seal above the sample obtained by backing off the plug makes it possible to withdraw nearly any type of plastic soil satisfactorily

6 The cost of operation is relatively low, so that undisturbed samples may be obtained by this method at about the same price as is usually paid for disturbed samples

7 By keeping a driving record, it is possible to determine the variation of resistance to penetration, thus making it necessary to take samples only at points where the resistance changes

Disadvantages

1 Possibly the greatest objection to this sampler has been the size of samples which it obtains From long experience with the equipment Mr Porter thinks the samples are plenty large enough He points out that if larger samples are desired, the 5-in sampler can be used at the bottom of drilled holes, as is ordinarily done with other samplers In general the highway department feels that many feet of small sized samples are more valuable to them than a few feet of larger diameter cores

2 The equipment will not satisfactorily sample clean sand or gravel These materials tend to run out of the bottom on withdrawal and are generally loosened and not in the original form

DISCUSSION

From the examples of practice described, it is evident that there is considerable difference in opinion as to what constitutes satisfactory sampling Circumstances naturally alter cases, and equipment which may be satisfactory in one part of the country may be inadequate in another However, there are two principles of sampling for bearing capacity which should always be kept in mind The first of these is that the prism being explored should be adequately covered, and the second is that the samples should be as nearly as possible in the original undisturbed condition Unfortunately it is impossible to obtain the ideal of complete coverage and perfect samples The question of cost is vital, and increases with the number, depth, and size of samples, as well as with the care with which they are taken and prepared for the laboratory

The decision as to what represents adequate coverage must, of necessity, be left to the engineer, for each job is a problem in itself Thorough exploration is essential Wide variations in density are the rule rather than the exception, even in relatively small areas where the soil is of the same general character as far as mechanical analysis is concerned A single sample, even though very carefully taken, may not be at all representative of conditions throughout the prism In order to meet the requirement of thorough coverage without involving prohibitive costs, Michigan and California have developed the equipment previously mentioned, in which the sampler may be used for measuring resistance to penetration Samples need then be taken only where change in resistance indicates a variation in character or density of the soil Another simple method of logging the subsurface above ground water is to drill 28-in holes with a well drilling rig and send a man down the hole to take penetration readings with a Proctor needle This is of no value in gravelly soil, but is very effective in fine-grained material

The second principle of sampling, that of obtaining good samples, is beset with many difficulties According to those most experienced in this work, it is impossible to transfer the soil from its position in the ground to the testing machine without some disturbance taking place which alters the test results The question of how much disturbance can be permitted and still obtain test results of practical value, is one upon which there is a wide variation of opinion For research work, perfection is desired, and any amount of pains in sampling is justifiable For settlement analysis of large structures on beds of saturated clay, where differential settlement of one part relative to another is critical, it is necessary to have truly representative samples in order to get accurate results For the ordinary highway bridge abutments, much less accuracy is required For highway fills, approximate bearing values for the foundation material are frequently satisfactory Excellent examples of sampling equipment which may be adapted to the problem at hand have been presented by the highway departments of Michigan and California

For accurate sampling no truly satisfactory equipment is yet available Clay samples cannot be cut from beds at considerable depths and transferred to the laboratory testing machines without disturbance Loosely consolidated granular materials are almost certainly compacted by the jarring which occurs in the present methods of driving samplers Clean sand can seldom be brought to the surface in anything like its original form There is need for study and development work on this problem, and it is to be hoped that some of the highway departments will find it of sufficient importance to include it in their research programs

Whatever the type of equipment used, there is one important item which should never be omitted In the words of Mr L C Campbell of the New Mexico State Highway Department, "Equip the sampling devices with men to whom sampling is an important function, rather than with men to whom sampling is merely a lot of work" With such equipment the sampling devices now available are capable of producing samples which are adequate for most present-day highway problems Without such men, dependable samples cannot be produced no matter how fine the equipment