then placed on top of the Norton disc and a total load of 1215 lb. is applied and held for two minutes. The 4-in. by ½-in. perforated steel disc is then placed on top of the Norton disc.

The special depth gauge is fitted with the proper length rod to measure down to the steel ball on top of the perforated steel plate.

The swell test mold assembly containing the prepared specimen is placed in a large shallow pan. The initial reading

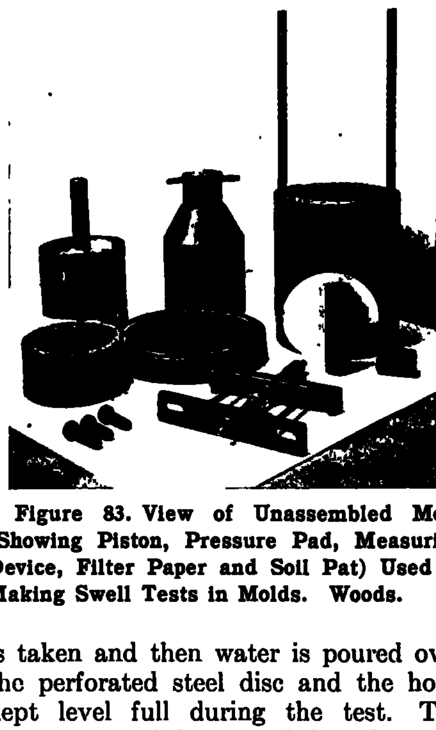

Figure 83. View of Unassembled Mold (Showing Piston, Pressure Pad, Measuring Device, Filter Paper and Soil Pat) Used in Making Swell Tests in Molds. Woods.

is taken and then water is poured over the perforated steel disc and the holes kept level full during the test. The temperature of the water is kept between 65° and 75°F.

Additional readings are taken at 6-hour intervals for the first 48 hours and at 12-hour intervals for the next 96 hours. An 8-in. diameter apparatus is also used.

C. A. Hogentogler: A modification of the Proctor mold which is described under consolidation tests is used for testing swell. The sample may be formed by the standard Proctor compaction method and the top section cut off, or formed by static compaction to the required depth.

W. H. Wood: We are making swell tests on samples of subgrade soil taken from underneath old concrete pavements. The procedure followed is that described for disturbed samples in "The Results of Tests to Determine the Expansive Properties of Soils" by Harold Allen and A. W. Johnson, as published in the Proceedings of the Sixteenth Annual Meeting of the Highway Research Board, 1936 (Vol. 16, p. 220). The equipment used for these tests is illustrated in Figure 83. The mold itself is made of bronze, the compacting cylinder of steel, and the pressure pad of zinc plated steel.

FIELD TESTS AND SAMPLING EQUIPMENT

Field tests are made on the soil in place. Some of the penetration devices described under Penetration and Extrusion tests are also used as field tests.

This section is devoted to additional contributions listed in Table 9.

Fred Burggraf: The apparatus shown in Figure 84 for measuring the resistance of road surfaces to lateral displacement is of the hydraulic type, and the manually operated power is attained through a hand wheel screw type pump mounted in a vertical position. An 8-in. diameter dial hydraulic pressure gauge graduated from 0 to 10,000 lb. is connected to one side of the base of the vertical hydraulic cylinder. A small hydraulic thrust cylinder having a 2-in. range of travel is connected to the opposite side of the vertical cylinder by a 24-in. piece of flexible rubber hose. To the rigid end of this thrust cylinder, parabolic shaped plates of different heights are attached, depending upon the depth of the layer to be tested. The plates used vary in height from 1½ to 6 in.

Figure 85 shows the shape and type of excavation that it is necessary to make in the structure to be tested for receiving the thrust cylinder. This figure also shows a parabolic plate attached to the rigid end of the thrust cylinder and the transversely. The outer face of the parabolic plate is placed approximately ¼ inch from the vertical face of the material to be tested and fine sand passing the No. 20 sieve is tamped into this opening. This sand assures a uniform

TABLE 9

ADDITIONAL FIELD TESTS AND SAMPLING EQUIPMENT

Organization	Subject	Contributor
Calcium Chloride Association, Detroit, Michigan	Surface Shear Test	Fred Burggraf
California Division of Highways	Combination Drilling Rig	O. J. Porter
California Division of Highways	Improved Soil Sampler	T. E. Stanton, Jr.

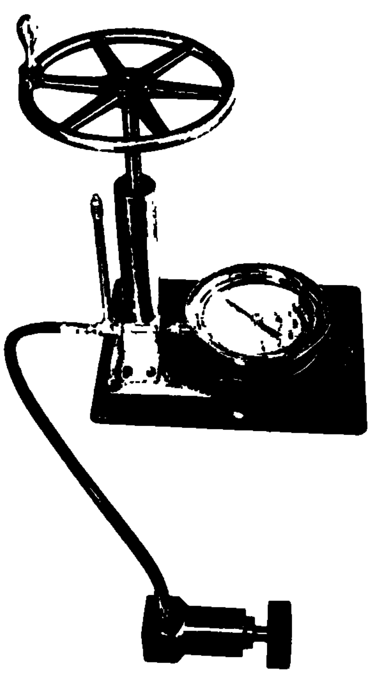

Figure 84. Portable Machine for Making Surface Shear Tests. Burggraf

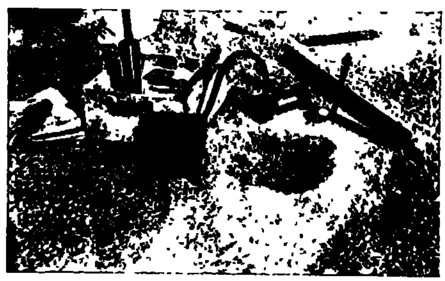

Figure 85. View Showing the Shape and Type of Excavation in the Road Surface Necessary for Receiving the Thrust Cylinder, also the Equipment and Part of Carrying Case. Burggraf.

Figure 86. The Set-up at the Start of the Test. Burggraf

assembly for making the deformation readings.

Figure 86 shows the set-up at the start of the test. By means of a T-level, which is visible under the stem of the micrometer dial, the entire thrust cylinder system is levelled both laterally and bearing area during the test. The opposite end of the thrust cylinder is in contact with a plate having an end area larger than the parabolic plate to assure

that failure takes place ahead of the latter plate. A horizontal angle member placed back of the larger plate and anchored to the road surface by a steel peg is added assurance that the failure will occur ahead of the parabolic plate.

In applying the load the pressure on the hydraulic pressure gauge is recorded for each .01 inch movement on the micrometer dial.

O. J. Porter: Foundation explorations must determine not only the type

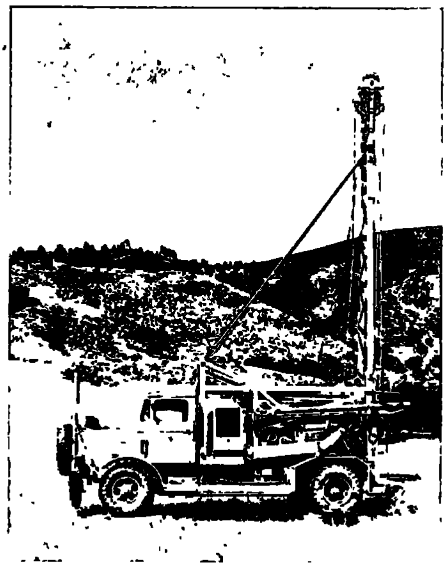

Figure 87. Combination Foundation Drilling Rig. Porter

of material, but also its condition in place. Since commercial machines are usually built for only one type of drilling and the tools designed for opening a hole to water or oil bearing strata, special equipment and tools are required to procure undisturbed cores for determination of moisture content, density, compressibility, and shear strength.

The combination foundation exploration rig described herein (Figs. 87–88–89) was designed for churn drilling, rotary boring, and for operating the improved type soil sampler, described in *California Highways and Public Works*, July, 1936.

The churn drill with a spudding beam actuates a 500 lb. hammer to drive the sampler outfit and also breaks through large boulders and solid rock with regular well drilling tools. A 1500 lb. string of

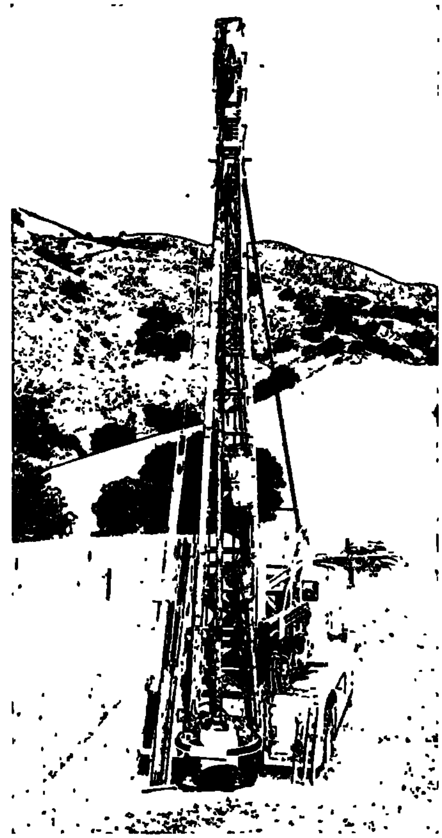

Figure 88. Rig with Tools for Churn Drilling, Rotary Boring and Soil Sampler for Procuring Undisturbed Cores. Porter.

tools with a 6-in. bit is included as regular equipment. With proper bits 8-in. to 12-in. holes can be opened through rock to a depth of 400 ft.

A 30-in. rotary table is mounted on the back of the drill frame for driving a 24-in. auger bucket. Holes up to 48 in. in size may be dug with the same tool by attaching a reamer to the top of the

bucket. Large diameter holes are often desired in earth and soft bedded shale formations to determine ground water conditions and the dip and nature of the strata. Undisturbed samples of large dimensions can also be obtained from any of the ground explored with such borings.

The rotary table is designed to operate at any speed between 5 and 50 R. P. M. and can also be used for driving Calyx type rock coring bits up to 30 in. in size.

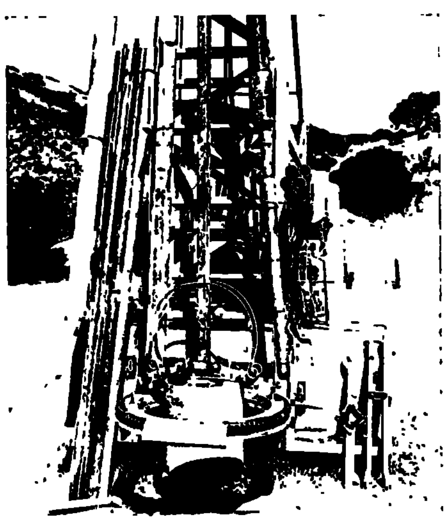

Figure 89. Close-up of Tools. Left to right are sand bailer, extension rod for the soil sampler, churn bit, rotary bucket with Kelly bar and driving yoke and the sampler assembly. Porter.

It is not contemplated that this type of drilling will normally be required and large rock core bits are not, at present, included with the tools for the outfit. The complete rotary mechanism is demountable and, when desired, can be removed from the main rig frame in thirty minutes.

Description of Drill: All drill units are mounted in a welded box-type steel frame constructed from heavy channels. This frame is attached to the truck chassis with six heavy "U" bolt clamps, but the outfit can be quickly detached and moved onto a barge for drilling over water or skidded to difficult boring locations on steep hillsides. The equipment can also be readily rigged for driving light piles in marsh lands or river-beds whenever a temporary trestle or working platform is required to reach such inaccessible locations.

The power unit is independent of the truck and consists of a Ford V-8 motor with a five-speed truck transmission mounted in a K. R. Wilson industrial conversion unit. This provides ample power and flexibility with the gear ratios to meet all operating requirements for the various types of drill tools. A heavy duty 110-volt, 1000-watt generator, providing lights for night operating is also built into the motor assembly.

The main hoisting unit is a 7-ton, double drum with a three-speed transmission. Both of the drums are supplied with $\frac{3}{4}$-in. steel cables for sampling and drilling lines. A small single drum utility hoist with nigger head attachment is mounted near the derrick for operating a sand line.

The derrick was constructed from heavy steel ship channels and designed for a 30-ton pull. A Keystone Spudding sheave assembly is welded to the top of the derrick for the spudding cable and the sand line. Two additional sheaves accommodate a heavy pulling line for sampler operations. The overall height of the derrick is 32 ft. from the ground when erected and 11 ft. 6 in. when folded and ready for the road.

Assembly: Power from the motor and transmission assembly is carried through an extension shaft to the main drive sprocket. Through the medium of a 4-in. chain, power is then transmitted to a main countershaft mounted parallel with the engine. This shaft serves the dual purpose of driving a secondary longitudinal countershaft through mitre

gears and a secondary transverse countershaft which operates the spudding pinion and utility hoist. The longitudinal shaft drives the double drum hoist and the rotary table.

Double and triple tooth sprockets and chains are used throughout for transmitting the power. All shafts are mounted in self-aligning roller bearings.

The entire unit complete with drilling tools is transported on the four-wheel drive truck. This truck, equipped with tractor tread type tires and dual rear wheels, has proved its worth on steep hillside climbs and pulling over soft unstable ground.

A 2-in., two-stage centrifugal pump mounted on a separate skid frame and power with a four-cylinder, 12-hp., air-cooled gasoline engine is used in conjunction with the drill outfit for dewatering holes and jetting casing when required. A 2-in. Ventura tube type hydro-jet is used in conjunction with the pump for dewatering holes and making tests of ground water flow. The latter assembly can be used to dewater a 7-in. hole to a depth of about 120 ft. if the inflow does not exceed 20 gal. per min.

Large Saving Made in Drilling Costs: Since the rig was constructed in February, 1937, it has worked very satisfactorily and proved invaluable for investigating a variety of foundation conditions. Approximately 70 holes, 24 in. in diameter, have been bored to depths varying between 30 and 80 ft. and averaging 45 ft. at costs of \$.25 to \$.75 per foot in clay and shaly clay, and between \$.50 and \$1.00 per foot in soft shales and cemented sand formations. These drilling costs are exclusive of overhead but include all labor charges and a drill rental of \$2.50 per hour. Sinking of shafts in similar ground, under old methods, to depths of 20 or 30 ft. often cost more than \$5:00 or \$10.00 per foot making such exploration too expensive for extensive use. The cost of procuring cores with the new type Porter Soil Sampler has also been reduced through the development of this special drill outfit.

T. E. Stanton, Jr.: The sampler unit shown in Figure 90 consists of a cutting point, sampler sections, couplings, 2-in. brass tube sample retainers, and a plug, screw, and nut assembly. The cutting point is constructed of tool steel and its outer shape conforms in general with that found by Veihmeyer and Beckett to be suitable for securing undisturbed samples of agricultural soils.

The sampler sections, couplings, and the cutting point are bored on the inside to receive the brass tube sample retainers. These brass tube retainers permit ready removal of the cores from the sampler and prevent disturbance of the specimens. This part of the outfit is conventional.

The important element of the new sampler is the plug assembly. First, it plugs the sampler until the depth is reached at which samples are desired; and second, it provides a seal against suction immediately above the top of the sample.

The screw shaft and nut section are provided with a fast pitch, left hand thread, the former being connected to the plug in a manner to permit swivel action.

Extension rods and all sampler sections are provided with suitable size R. H. square threads. In the couplings the ends are butted against a square shoulder in order to prevent excessive thread stress during driving.

Operation: Samples are taken by (1) driving the sampler as a plugged tube to the desired depth; (2) retracting the plug and forcing the open sampler into undisturbed material; (3) retracting the plug further to effect an air tight seal above the sample; (4) withdrawing the entire sampler unit to the surface.

A 3- to 4-ft. length of soil core is normally obtained in one sampling operation. On important work one 3- to 4-ft. sample is usually taken for each 5 ft. of depth. In many cases, however, plete with plug, screw, and nut assembly are usually kept on rush jobs so that drill operations will not be shut down while samples are being removed and prepared for shipment to the laboratory.

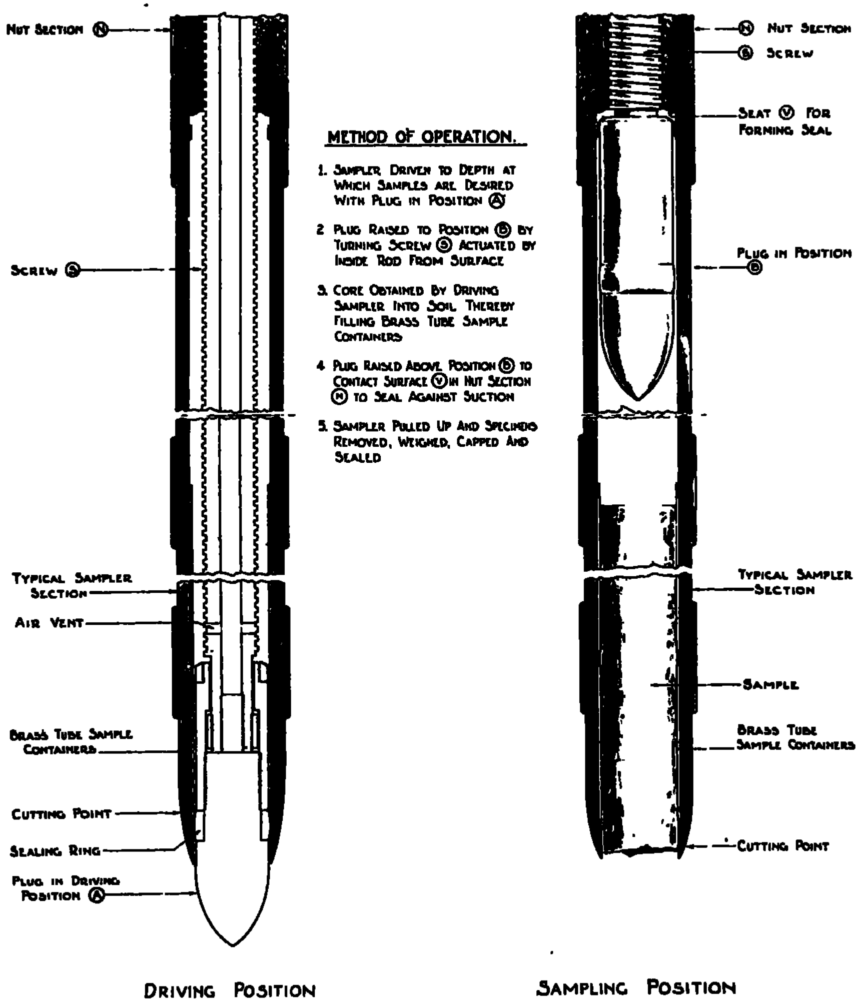

Figure 90. Porter Type Soil Sampler. Stanton

the driving record for the plugged sampler furnishes sufficient information regarding the uniformity of the material. In such cases the drilling operations are expedited by taking samples at less frequent intervals. Two samplers com-

Samples: The string of 2-in. long brass tube retainers, with contained sample, are pushed out of the sampler sections immediately following removal from the hole, cut into sections 2 in. long at the joints between retainers with a fine piano

wire saw, capped and weighed. The weight of the 2-in. cores, together with examination of the cut surface, immediately furnishes an index to the uniformity and character of the material. Specimens retained for shipment to the laboratory are at once taped, marked, and sealed with paraffin in order to prevent any change in the original condition, see Figure 91.

To determine the extent of disturbance, if any, during sampling, a large specimen of Class A-4 soil having a moisture content of approximately 17 per cent was mixed with 10 per cent of flowers of sulphur and consolidated at the laboratory in alternate layers of light and dark material; 5 per cent by weight of precipitated magnetic oxide being used for coloring. Cores were cut with the sampler with the results shown in Figure 92. The specimens were hardened by heating at a low temperature and then cut so as to expose any deformation of the strata. As will be noted, there was no apparent disturbance of the material in the core, whereas there is a very marked disturbance in the portion of the original sample outside of the core and adjacent to the sampling tube. The unit weight and moisture content of the 2 by 2-in. cored specimens checked within one-half of one percent of the unit weight and moisture of the larger prepared specimen from which the core was cut.

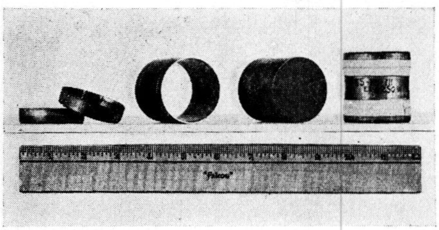

Figure 91. Caps, Empty Sample Container and Typical Soil Specimen after Removal from the Container, and a Typical Two-inch Container and Sample Sealed and Prepared for Shipment to the Laboratory. Stanton.

Class A-4 soil was selected because it is the most plastic soil available which could be used without excessive shrinkage and cracking under the heating required to harden before cutting to expose the condition of the soil strata.

Size of Sampler: Two sizes of this sampler are now being used by the California Materials and Research Department. One size, of light-weight design for hand power and air hammer operation, cuts cores of approximately 1-in. diameter and is used extensively for preliminary borings ranging down to 50 ft. in depth.

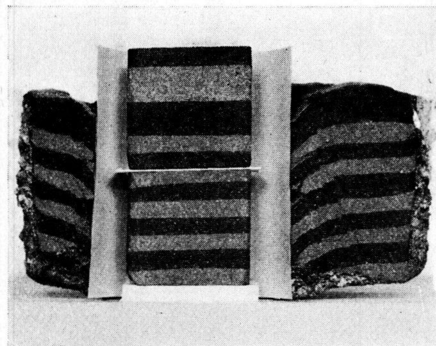

Figure 92. Condition of 2-in. Cores Cut with a California Type Soil Sampler from a Prepared Block of Class A-4 Soil Containing 17 Per Cent Moisture. Stanton. The white space between the core and the main block shows the area through which the sampler passed. No disturbance of the soil particles on the periphery of the cores can be noted, whereas there is a very marked disturbance outside of the sampler. The sampler was driven 12 in. below the bottom of the cores shown; therefore, these cores were forced through 12 to 16 in. of the sectional brass tube lining.

The sampler successfully used on deep borings for the last three years cuts a 2-in. diameter core. The design is suitable, however, for larger diameter samples if desired. The 2-in. samples are

satisfactory for testing and this size sampler is operated with power equipment at a somewhat lower cost than heavier equipment

When the site of the drilling operations is accessible to truck equipment, a churn drill is usually used with the spudder or walking beam actuating the drop hammer Any other standard type of power drilling equipment may be used Borings over the bay and overflow marsh land were made from a barge equipped with a derrick, winch, and jetting facilities In deep borings the lling capacity from the barge was metimes insufficient and jetting was necessary to reduce the skin friction and free the sampler

Little difficulty has been encountered in freeing the sampler unit with a jet, consisting of lengths of the inside drill rod tubing, washed down along the outside of the sampler unit without a guide The ground disturbed in driving the sampler is more easily jetted than the undisturbed material away from the hole, and therefore the jet usually follows down directly adjacent to the sampler In some cases a ring is slipped over the top of the sampler unit and attached near the bottom of the jet to serve as a guide