Normal loads are applied in three ways:

C. Compressed fluid

J. Jack (screw)

W. Weights and simple levers

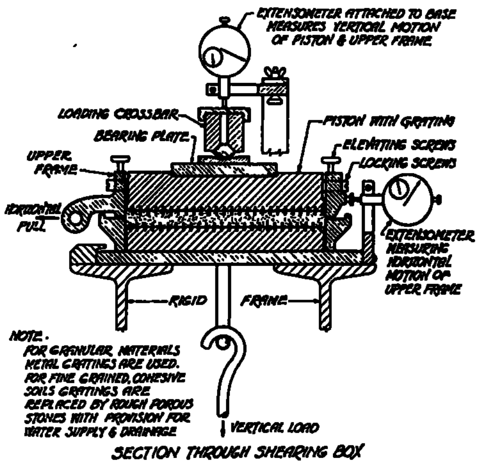

Figure 12. Box Type Shearing Apparatus

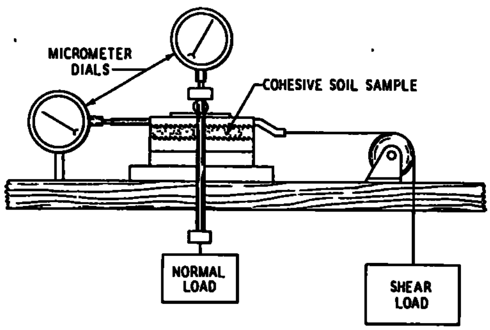

Figure 13. Essential Features of Plate Shear Test

Shearing loads are applied in five ways:

C, J and W as above

B. Bell crank and weights

P. Pulley and weights

Table 2 summarizes the equipment reported by the various laboratories. The symbol for type in column three is explained by an example. Thus, 3C J means the shearing device is of type 3, double, the normal load is applied by a compressed fluid and the shearing load is applied by a screw jack.

DIRECT SHEAR DEVICES—BOX

Prof. D. M. Burmister: The shear apparatus illustrated in Figure 16, is of the Harvard-shear box type, 2½ by 3½ in. equipped with either gratings or porous stones. The horizontal shearing deformation and the vertical expansion or compression of the specimen during shearing are measured by Ames dials. Vertical normal loads are applied by counterbalanced lever systems and dead weights. The shearing load is applied by a motor operated gear reduction device through a loading bar which permits either one of two shear tests to be made independently of the other. The load is measured by means of a calibrated loading ring fitted with an Ames dial. The shear loading device is of the "constant strain type," the rate being controlled by means of a rheostat to 0.1 or 0.05 in. per min. for most soils. This rate requires about 5 to 10 min. to complete the test.

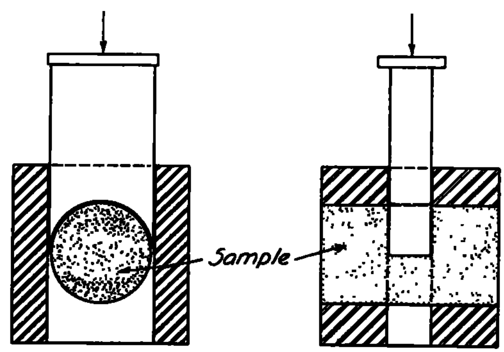

Figure 14. Double Shear

Sample Preparation: A sample of the undisturbed soil is fitted into a sample box by means of a fitting knife as for the consolidation test. The natural moisture content of the soil is determined for each test. The sample box is lined up with the upper frame of the shear box and held in place by means of pins. One-half of the sample, about ¾ in. thick, is pushed into the upper frame and sliced off between the sample box and upper frame by means of a wire saw. The face of the sample is then screeded off smooth. The upper frame is then placed

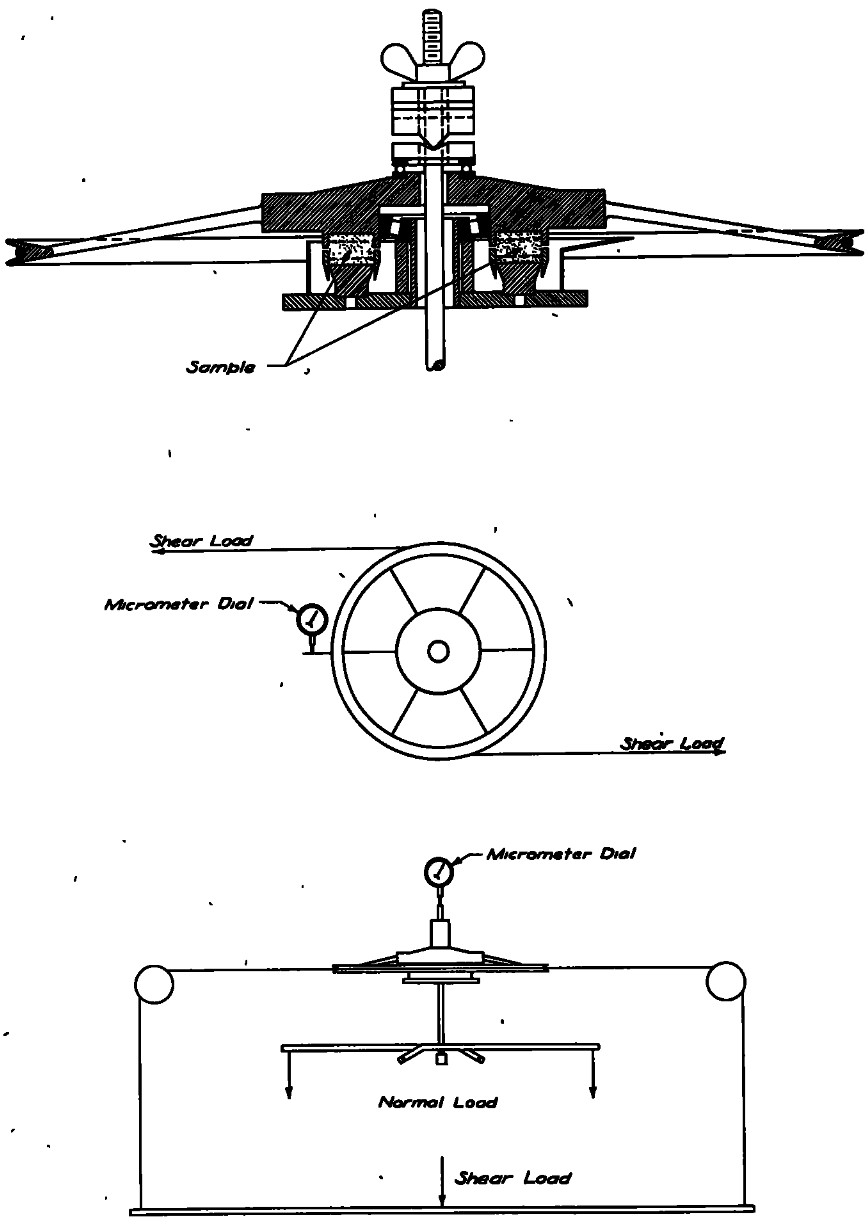

Figure 15. Torsion Test

in position on the lower frame. In the quick shear tests solid impervious gratings are used, while in the delayed shear test coarse-grained porous stones are used. After the sample has been pushed into position in contact with the lower grating or stone, the thickness of the sample is determined by means of the straddle gauge and Ames dial shown in Figure 16.

The Shear Test: The upper frame is raised by the elevating screws and clamped to the piston by means of set screws. The elevating screws are then backed off and the guide pins are pulled. The load dial, horizontal dial, vertical dial readings, and the time are recorded at such intervals as are necessary to define the stress-strain curves. The motor is operated at a constant shearing strain of 0.1 in. per min., and the test is continued until a slight falling off of the shearing load occurs.

Dr. D. P. Krynine: A shear apparatus for sand consists of two sliding boxes

TABLE 2
DIRECT SHEAR TESTING DEVICES

State or Country	Organization	Type	Dimensions of Samples: Cross-section or Diameter, Inches	Dimensions of Samples: Thickness, Inches	Contributor
Arizona	Arizona Highway Department	3CJ	3	...	W. G. O'Harra
N. Y.	Brooklyn Polytechnic Inst.	-W-	Circular	....	Prof. L. F. Rader
N. Y.	Columbia University	1WJ	2.5 x 3.5	.	Prof. D. M. Burmister
Conn.	Connecticut Highway Department and Yale University	1WJ	2 x 2	.	Dr. D. P. Krynine
Pa.	Engineer Office, U. S., Pittsburgh	1JJ	4 x 4	0.56	R. R. Philippe
D. C.	George Washington University	1WP	2.52	1	C. A. Hogentogler, Jr.
Mass.	Harvard University	1WP	6 x 6	....	Dr. A. Casagrande
		1WB	12 x 20	.	
Idaho	Idaho, University of	1WB	...	....	Prof. A. S. Janssen
Ill.	Illinois Division of Highways	1—	...	....	V. L. Glover
Kansas	Kansas State College	1WB	. .	. . .	Prof. C. H. Scholer
La.	Louisiana Highway Department	1WB	3½ x 3½	.	H. L. Lehmann
Maine	Maine, U. of & Highway Dept.	1WP	...	...	E. F. Bennett
Mich.	Michigan Highway Department	3CW	4.5	....	Prof. W. S. Housel
		3WW	1.38	.	
Ohio	Ohio Department of Highways	1JJ	4 x 4	0.75	K. B. Woods
D. C.	Park Service, National	1WP	2.5	..	E. F. Preece
N. J.	Princeton University	1WP	2.4 x 2.4	. .	Prof. G. P. Tschebotareff
D. C.	Public Roads, U. S. Bureau of	1WP	3.5 x 3.5	0.34, 0.75	C. A. Hogentogler
		2WP	3.5 x 3.5	0.34	
		3-J	1.13	2	
D. C.	Reclamation, U. S. Bureau of	1CC	12 x 12	4	J. C. Page
Utah	Utah Road Commission	2WP	....	. .	Levi Muir
Wash.	Washington, University of	1WB		.	Prof. R. G. Hennes
W. Va.	West Virginia Road Commission	1WP	. . .	.	A. M. Miller
D. C.	Yards and Docks, U. S. Bureau of	1WP	2.5 x 2.5	. . .	C. H. Bramhall
		1WP	2	.	
Canada	University of Toronto	1JJ	. .	.	Prof. C. R. Young
Denmark	Danish Geological Survey	1W-	.	....	Mrs. E. L. Mertz
France	Laboratory for the Study of Soils and Foundations	1WP	. . .	.	Dr. A. Mayer
		4 (Hvorslev)	.	...	
		4 (Langer)	...	.	
Germany	Prussian Research Station	1WB	. . .	.	Prof. R. Seifert
		4WP	.	.	
Netherlands	Laboratory for Soil Mech. Delft	2WP	. .	...	Dr. T. K. Huizinga
Switzerland	Testing Institute of Dr. Bendel at Luzerne	1WP	....		
		3WP	5, 7, 8 6, 10	.	Dr. L. Bendel
		4WP	...	. .	

(horiz. area 240 sq. cm.) from which the upper may move horizontally due to the action of a wheel and screw which are fixed to the base which in its turn is fixed with clamps to a heavy metallic table. A dynamometer between the screw and the upper box measures the load.

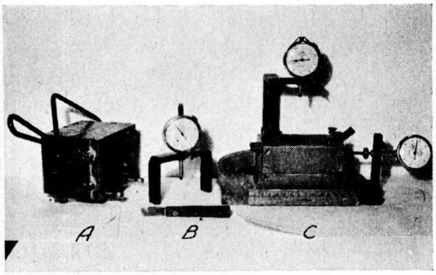

Figure 16. Box Shear Test Device. Burmister. A. Inserting sample into upper frame and cutting off half the sample for test. B. Straddle gauge for measuring the initial and final thicknesses. C. Harvard type shear box, 2.5 in. x 3.5 in.

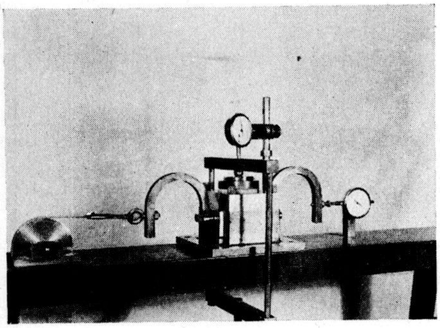

Figure 17. Box Shear Test Device. Hogentogler, Jr.

Another apparatus for the study of shear in clays, subject to consolidation, is similar to the one reported by Professor Tschebotareff.

C. A. Hogentogler, Jr.: In the box shear device of Figure 17, a round sample between porous stones is sheared by pulling out the lower box which rides on three ball bearings and has a running fit in relation to the upper box. To facilitate the transfer of consolidated samples, the shear test samples have the same diameter as the samples for the consolidation test. Figure 18 shows the use of levers to apply the normal and shear loads.

Dr. A. Casagrande: The equipment for direct shear tests consists of a large shearing beam which forms part of the Universal soil testing machine, and of a

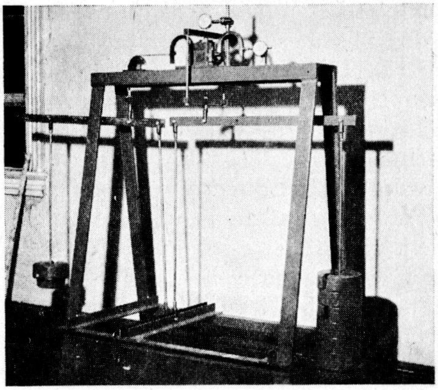

Figure 18. Lever for Applying Normal and Shear Loads. Hogentogler, Jr.

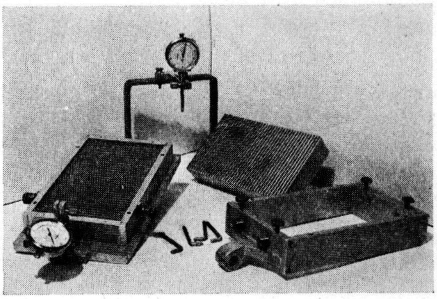

Figure 19. Shearing Test Frame. Casagrande

small precision machine for very light loads. The types of shearing frames used in both machines are essentially the same and are based on a design which the author developed in 1930, while working for the U. S. Bureau of Public Roads. A cross section through such a frame is shown in Figure 12, and a photograph in Figure 19. The essential innovations introduced by the author are the provision for the measurement of the volume change of the sample during the test by means of a vertically mounted extensometer and the use of elevating screws for separating the upper and lower frames just prior to testing, to prevent an unknown portion of the vertical load from being transmitted by direct contact of the frames. The gratings may be made of metal, or of porous stones, either rough or dentated, for the testing of cohesive soils.

H. L. Lehmann: The shear machine is so constructed that both horizontal and vertical stress may be applied to the specimen in the shear box. The vertical stress is applied directly to the specimen by a swing attachment and weight. The horizontal stress is applied by a bell crank lever and weights.

The shear box is made of bronze in two parts, the upper part movable in a horizontal direction and the bottom one stationary. The opening for the specimen and its accessories is 3½ in. square and extends through the upper part and into the lower part. Porous stones are placed above and below the test specimen to allow free drainage of the water for the delayed test and impervious bronze plates are used for the quick test. The bronze plates have saw-tooth grooves in the faces adjacent to the specimen in order that the full shearing resistance of the soil may be developed. A thick bronze piston is placed above the porous stone and pressure applied directly to it.

K. B. Woods: The apparatus shown in Figure 20 was modeled after the design of R. R. Philippe and Glennon Gilboy. It consists essentially of a shear box for testing the undisturbed sample mounted on a frame rack provided with a jack with bellows attached to a mercury gauge for applying a vertical load, and a motor with gears to pull the base of the shear box laterally. The top of the shear box is fastened to a bellows attached to a mercury gauge which measures the resistance of the sample in shear to the horizontal pull.

A square specimen of undisturbed soil 4 by 4 by ¾ in., is carved in a moist room from the sample to be tested and carefully placed in the shear box. The sample box and sample are fastened on the shear machine frame and the upper portion of the shear box raised ⅛ in. and fastened to the sample box block to insure a frictionless plane except for the resistance of the soil sample itself. A given vertical load is applied by means of the jack and kept constant throughout the test. Shear of the sample is then begun

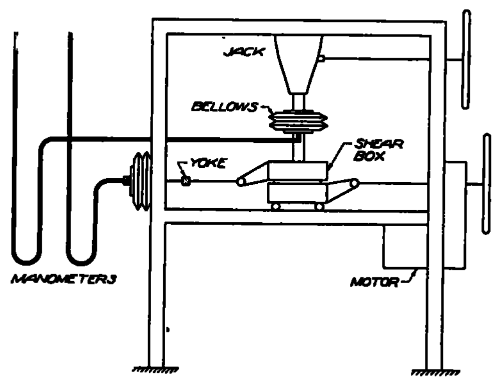

Figure 20. Sketch of Ohio Shear Test Apparatus, Modeled after the design of R. R. Philippe and Glennon Gilboy. Woods

by starting the motor to pull the lower portion of the shear box at the rate of 2 in. per hr. As the shearing stress increases the mercury gauge rises until the ultimate strength of the undisturbed soil is reached, after which it recedes. Any convenient series of vertical loads may be chosen, with the common series for this size shear box being 50, 150, 250, and 350 lb.

E. F. Preece: In our test the sample is kept saturated between porous stones. A water tank load pulls out lower section of box.

Prof. G. P. Tschebotareff: A special type of shearing device has been de-

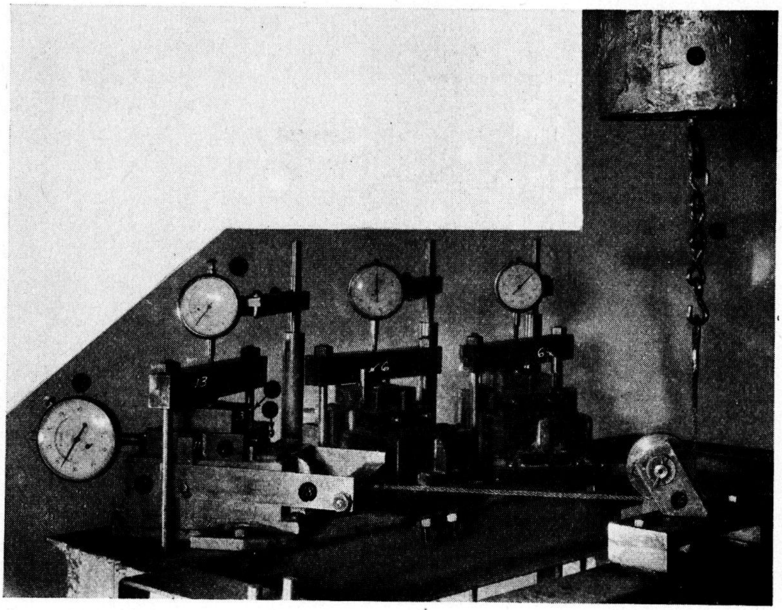

Figure 21. Princeton Shear Test Apparatus. Tschebotareff

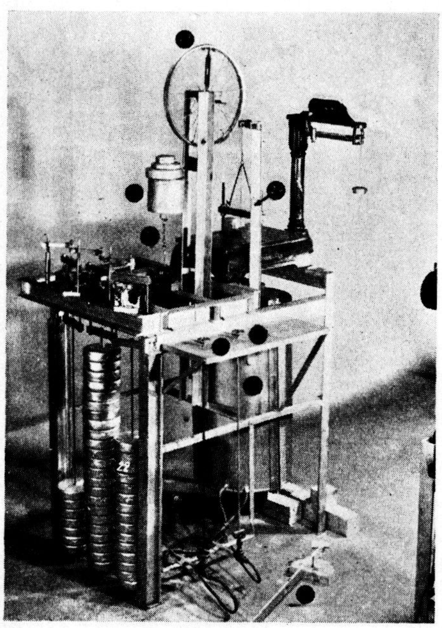

Figure 22. Loading Arrangement, Princeton Shear Test Apparatus. Tschebotareff

veloped by us as shown in Figures 21 and 22. It has three shear boxes, each of 60 by 60 mm. area. The normal force is applied by weights suspended on a directly acting yoke without levers. A novel feature is that the horizontal shearing force is applied to two lugs located in the plane of the application of the vertical normal force. Thereby, the possibility of tilting of the movable part of the box is eliminated during the test. This possibility is always present in the usual type of box, if the direction of application of the shearing force does not exactly coincide with the shearing plane between the two boxes of the shear box. The shearing force can be applied at any desired rate by means of a water loading tank connected to the water main and provided with a float and graduated scale indicator.

C. A. Hogentogler: The box shear test apparatus used by the Bureau of Public Roads is illustrated in Figure 23. Porous stones to provide the open system of test may be used as shown in the figure or they may be replaced by metal fillers

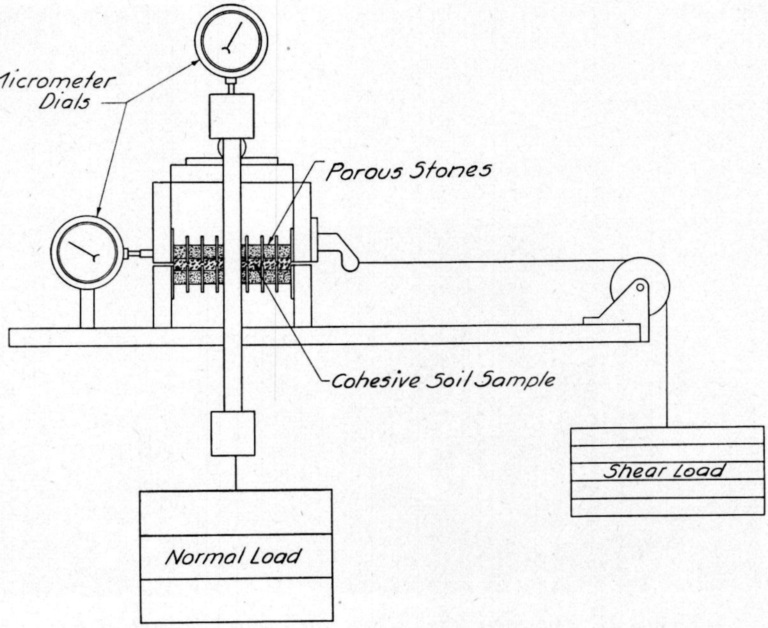

Figure 23. Bureau of Public Road Box Shear Test Apparatus. Hogentogler

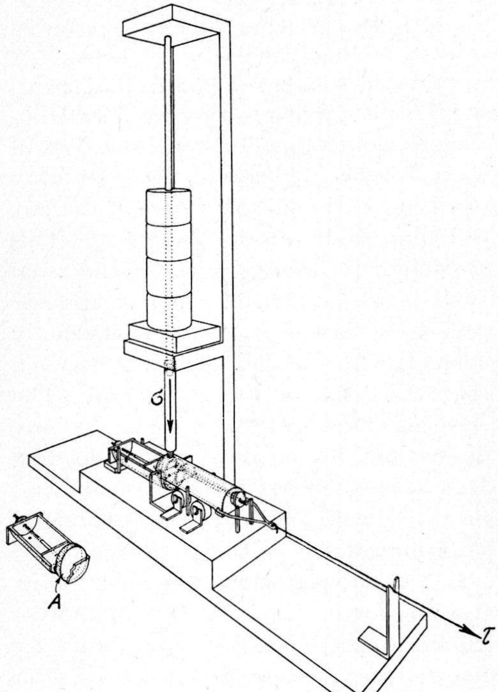

Figure 24. Disk Shape Sample Sheared Perpendicular to its Plane Faces. Mertz

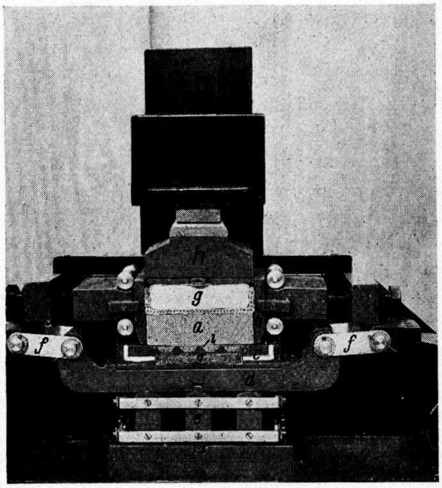

Figure 25. Cross Section of Krey's Shear Apparatus. Seifert. a—Sample. b—Frame Around Sample. c—Bottom of Sample Fastened to d. d—Movable Carriage. e—Roller Bearing. f—Shear Load Coupling. g—Filter for Removing Water. h—Bearing Plate. i—Shear Load Distributor.

in order that the closed system of test may be used.

Prof. R. G. Hennes: Horizontal load is applied by a beam carrying a constant weight, the position of which is varied by a rack and gear arrangement.

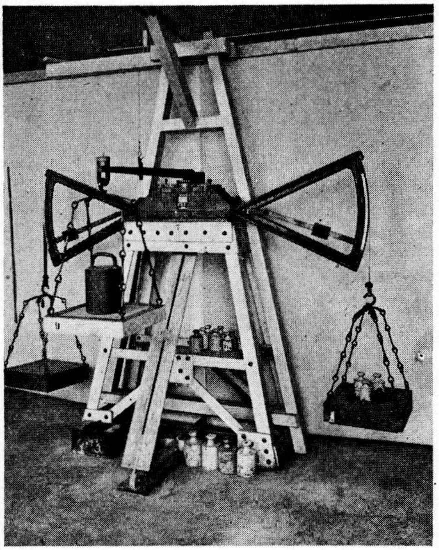

Figure 26. Krey's Shear Apparatus. Seifert

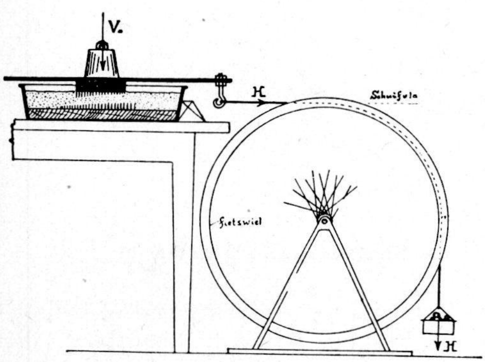

Figure 27. Plate Shear Device. Huizinga

Mrs. E. L. Mertz: A disk shaped sample, A, is sheared perpendicular to its plane faces as shown in Figure 24.

Prof. R. Seifert: Shear resistance is measured in our laboratory by Krey's apparatus, shown in Figures 25 and 26.

PLATE DEVICE FOR DIRECT SHEAR

C. A. Hogentogler: Data obtained from early tests with the box shear apparatus in the laboratory of the Bureau of Public Roads indicated an experimental error due presumably to the bunching of cohesive soil. The plate device shown in Figure 13, in which all effects of the box are removed, was constructed in order to learn more about this error and the means to compensate for it. The upper plate placed on a box of material similar to the Delft method shown later in Figure 27 is suitable also

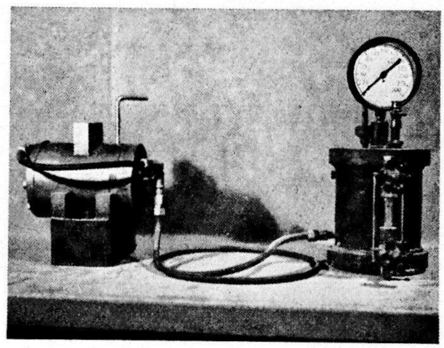

Figure 28. Arizona Double Shear Device. O'Harra

for testing sands and similar grained material for internal friction.

Dr. T. K. Huizinga: The apparatus sketched in Figure 27 is essentially the same as those in use in other countries. We only use it in some special cases such as determination of shearing strain-stress diagram.

DOUBLE DIRECT SHEAR DEVICES

W. G. O'Harra: The apparatus shown in Figures 28 and 29 is essentially the same as that used by Berry, but it has been altered to allow the use of compressed air in applying the pressure normal to the shearing force. The shearing force is applied by means of a