Procedure for Determining the Angle of Basic Friction (Static) Using a Tilting Table Test

This procedure is under the jurisdiction of the Materials Engineering and Research Laboratory, code 86-68180, Technical Service Center, Denver, Colorado. The procedure is issued under the fixed designation USBR 6258. The number immediately following the designation indicates the first year of acceptance or the year of last revision. owing the designation indicates the first year of acceptance or the year of last revision.

1. Scope

1.1 *Explanation*.-This designation establishes the guidelines, requirements, and procedure for determining the angle of basic friction (static) using the tilting table test method.

1.2 *Context*.-The procedure is described in the context of obtaining data for designing, constructing, or maintaining Reclamation structures.

1.3 *Application*.-The procedure applies to hard and soft rock test specimens.

1.4 *Validity*.-This test method is valid for testing pairs of rock specimens that contain a common single plane of discontinuity.

1.5 *Units*.-The values stated in SI/metric (inch-pound) units are to be regarded as standard.

1.6 *Caveats*.-This designation does not purport to address all the safety issues associated with its use and may involve use of hazardous materials, equipment, and operations. The user has the responsibility to establish and adopt appropriate safety and health practices. Also, the user must comply with prevalent regulatory codes while using this procedure.

1.7 *Sources*.-This designation reflects the information available from Reclamation and other sources.

2. Applicable Documents

2.1 *USBR Procedures:*

USBR 3000	Using Significant Digits in Calculating and Reporting Laboratory Data
USBR 3910	Standard Terms and Symbols Relating to Rock Mechanics
USBR 5300	Determining Moisture Content of Soil and Rock by the Oven Method

USBR 6010 Handling, Storage, Shipment, Inspection and Photographing of Rock Core

USBR 9300 Procedure for Checking, Rounding, and Reporting of Laboratory Data

2.2 *Other Documents:*

Cawsey, D. C., and Farrar, N. S., "A Simple Sliding Apparatus for the Measurement of Rock Joint Friction," *Geotechnique*, The Institution of Civil Engineers, vol. 26, no. 2, pp. 382-386, June 1976.

Bruce, I. G., Cruden, D. M., Eaton, T. M., "Use of a Tilting Table to Determine the Basic Friction Angle of Hard Rock Samples," *Can. Geotechnical Journal*, vol. 26, pp. 474-479, 1989.

3. Summary of Method

3.1 A carefully prepared rock specimen with an open discontinuity is placed on and attached to a horizontal tabletop designed to tilt.

3.2 The tabletop is slowly tilted until the top portion of the specimen starts to slide over the bottom portion of the specimen. Further tilting of tabletop is stopped and the angle of tilt is measured.

3.3 The measured angle of tilt is equal to the angle of basic friction (static) of the rock specimen.

4. Significance and Use

4.1 The tilting table method is a simple and inexpensive method to determine the angle of basic friction (static) of a rock joint or discontinuity surface. A major advantage of the tilting table is in the large specimen size that can be easily tested with a minimum of complexity and cost.

4.2 Rock joints are features of considerable extent and as such their surfaces may show significant spatial variations. To find a representative value of angle of basic friction (static), it is best to test the largest possible surface area. The tilting table accommodates large sliding surfaces that are consistent with the surface area of the tilting table.

5. Description of Terms Specific to This Designation

5.1 *Angle of Basic Friction (Static)*.-The friction angle (static) between two flat surfaces when one surface slides over the other surface.

5.2 *Angle of Peak Friction*.-The sum of the angle of basic friction (static) and the angle contributed by the asperity.

5.3 *Other Terms*.-See USBR 3910.

6. Apparatus

6.1 *General*.-The apparatus consists of a tilting table, devices to measure angle of tilt, and a device to control the tilting table.

6.2 *The Tilt Table*:

6.2.1 The USBR tilt table, shown on figure 1, consists of a smooth, flat tabletop surface mounted on two upright support metal rods, which serve as pivot points. The tabletop can be tilted. The table includes:

(a) Tilting tabletop.
(b) Lip at the end of the tilting tabletop.
(c) Bottom (base) of tilting table.
(d) "V" notched specimen holding jig. (the items a through d will be identified later on the figure)
(e) Two vertical upright metal rods that support tilting tabletop.
(f) The angle measuring device with vernier.
(g) Scissor jack lifting device with a top platform and a control lever for lowering and raising the tilting tabletop

6.2.2 The bottom plate of the table serves as the base of the tilting table. The tabletop has a "lip" that is normal to the tabletop, which is used to keep test specimens from falling off the tabletop. A "V" notched specimen holding jig (figure 1) may be used to hold and center circular specimen on the tabletop.

6.3 *Tilt Measuring Device*.-Consists of two angle measuring devices (figure 1) mounted on the two metal upright rods that can measure the tilt angles with a precision of 0.2 degrees.

6.4 *Tilt Control Device*.-A scissor jack with a screw feed (figure 1) that is manually controlled to tilt the tabletop. The top platform of this lifting device supports one of the free ends of the tabletop.

6.5 *Specimen Holding Jig*.-A "V" notched specimen holding jig (figure 1) to properly restrain a circular specimen in position during testing.

7. Miscellaneous Items

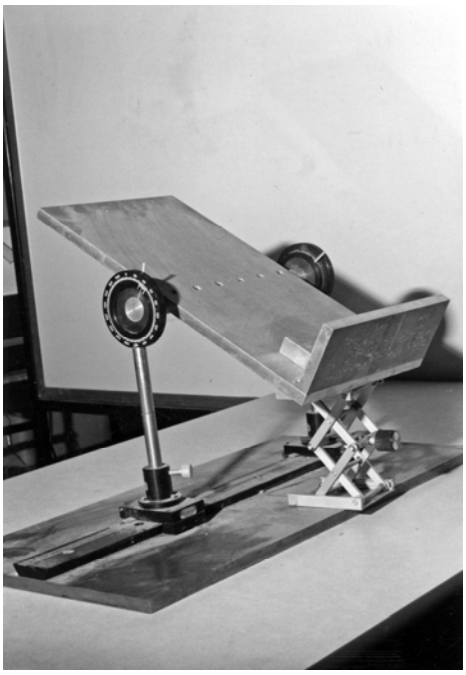
- Molding clay or specimen handling jig
- Two steel false platens (50-mm [2-in] diameter and 31.75-mm [1.25-in] height)
- Spirit level and microlevel
- Hand tools
- Specimen cutting tools
- Grit plates (No. 80 & No. 200)
- Towel
- Water
- Hand calculator

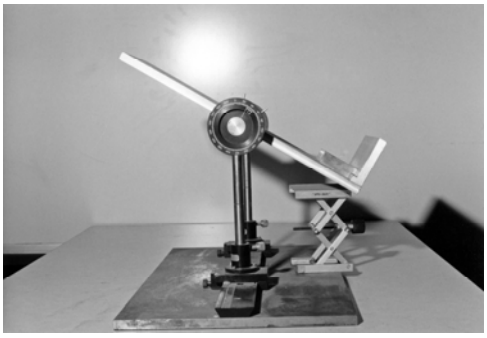
8. Calibration and Standardization

8.1 *Horizontal check*.-Using a spirit level, check if the tilting tabletop is horizontal before the test begins.

8.2 *Angle measurement check*.-Using a microlevel, check if the angle measurement devices are functioning properly.

8.3 *Replicability check*.-Using the pair of steel false platens and the procedure outlined in section 12, perform three sets of tilting table tests. Proper tilting tabletop calibration require that the test values for the angle of friction of one steel platen sliding over the other during the three tests not vary by more than five percent.





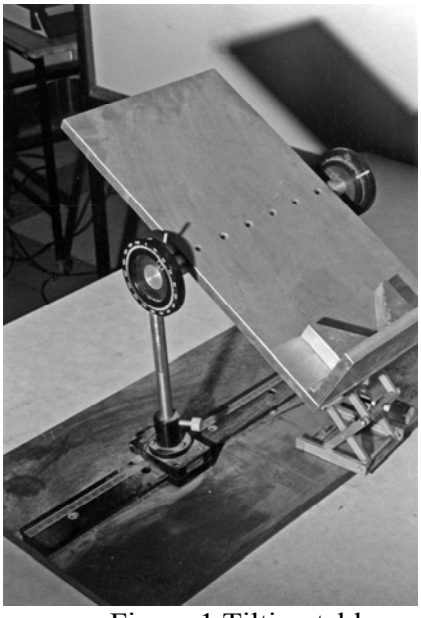


Figure 1 Tilting table

9. Test Specimen

9.1 *Shape*.-The shape of the specimen may be irregular, square, rectangular, or cylindrical.

9.2 *Contact Area*.-The contact area at the interface of the top and bottom specimens shall at least be 1775 mm^2 (2.75 in^2).

9.3 *Surface Roughness*.-The surfaces of the contact planes may be polished with either No. 80 or No. 200 grit plates, or they may retain their natural roughness. However, the sliding surfaces should not contain abrupt irregularities.

10. Conditioning

10.1 *Moisture*.-The moisture condition of the test specimens affects the value of the angle of basic friction. If the rock is to be tested at the natural moisture condition of the host rock, care must be exercised to preserve that moisture condition by storing and transporting the samples in moisture-proof bags (see USBR 6010).

Note 1.-A wet or moist specimen will yield a lower angle of basic friction (static) than a dry specimen because of the lubricating effect of the moisture.

11. Precautions

Do not use a fast rate (above 2.5° per minute) of tilting. Doing so will induce dynamic effects during testing, and the results will not represent the true value of the angle of basic friction (static).

12. Procedure

12.1 *Place bottom specimen*.-With the prepared surface up, place the bottom rock specimen on the horizontally held tabletop. This specimen provides the lower interface of the sliding surface.

12.2 *Secure*.-Secure the bottom specimen to prevent sliding, rotating, or shifting during testing. Molding clay or the specimen handling jig can be used to secure specimen's position.

12.3 *Place top specimen*.-Carefully place the top specimen on the bottom specimen such that the contact surfaces form the interfaces of the sliding surfaces. Visually check that the sliding surfaces are in good contact with each other.

12.4 *Record*.-Read and record the initial angle of the tilting tabletop (it should be close to zero). Read both angle measuring devices. Calculate and record the average angle.

12.5 *Tilt*.-With the aid of the thumb screw of the scissor jack lifting device, slowly lower the top platform of the lifting device. The rate of tilt is not to exceed 2.5E per minute. Lowering the top platform lowers the edge of the tabletop and tilts the tabletop.

12.6 *Record at slide*.-Continue lowering and tilting the tabletop until sliding just starts at the contact interface. Immediately stop further lowering of the lifting device and measure and record the angle of tilt. Read both angle measuring devices and calculate and record the average tilt angle.

12.7 *Record average angle*.-Calculate and record the average angle of basic friction (static) (see section 13).

12.8 *Finish*.-Remove the tested specimens and clean the test area.

13. Calculations

13.1 *Angle of basic friction*.-The sliding mechanism of a specimen resting on a tilting table when the latter is slowly raised is shown on figure 2.

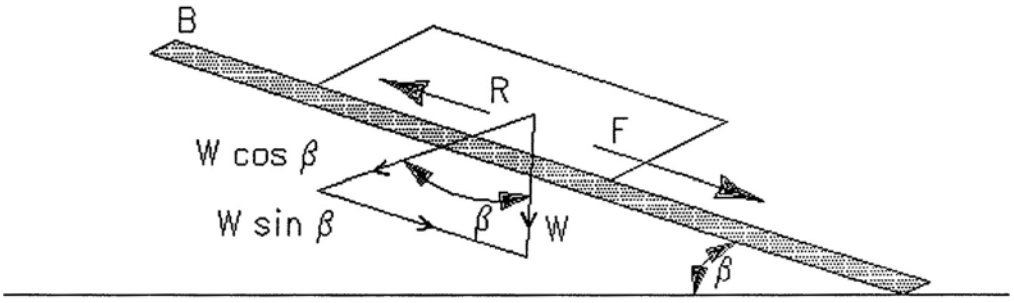


Figure 2. –Mechanics of sliding on a tilting table test.

In the limiting condition, the angle of basic friction (static) is determined by equating the downward force, *F*, to the resisting force, *R*, as shown in equation 1.

$F = R$, but

$$F = W \sin \beta, \quad \text{and} \quad R = W \cos \beta \tan \varphi \qquad (1)$$

Therefore:

$W \sin \beta = W \cos \beta \tan \varphi$

or:
$\tan \beta = \tan \varphi$

or:
$\beta = \varphi$

Thus, the angle of tilt = angle of basic friction.

where:

W = weight of a body resting on a tilting body, kN (lbf)

β = angle of tilt when sliding occurs because of tilting

φ = angle of friction

14. Report

14.1 The report shall include:

14.1.1 *Source*.-Source of sample including: project name, location, date of sampling, and, if known, curatorial history. The location may be specified in terms of borehole number and depth of sample from collar of hole.

14.1.2 *Appearance*.-Physical description of sample including rock type; location and orientation of discontinuities, such as apparent weakness planes, bedding planes, or schistosity; and large inclusions or inhomogeneities, if any.

14.1.4 *Date*.-Date of testing and test personnel involved.

14.1.5 *Angle*.-Measured angle of tilt (when sliding occurs) = angle of basic friction (static).

14.1.6 *Results*.-The calculated average angle of basic friction (static).

Note 2.-The reporting form Reclamation uses is appended as table 1.

Note 3.-The laboratory test results shall be reported in accordance with Reclamation designations USBR 3000 and USBR 9300.

15. Precision and Bias

The precision and bias for this designation have not been determined. Any variations observed in these data are just as likely to be caused by specimen variations as by operator or laboratory testing variations. Because of the variability of rock, this test procedure has no reference value.

Table 1. - Data sheet - tilting table test.

Project: _____
Feature: _____
Borehole No.: _____
Depth of specimen from borehole collar: _____
Date tested: _____

(1) Trail or test No.	(2) Initial Angle of Top of Tilting Table		(3) Final Angle of Top of Tilting Table When Sliding was Initiated		(4) Difference of Angle,(3)-(2) = Static Angle of Basic Friction		(5) Average
	Angular Dial 1	Angular Dial 2	Angular Dial 1	Angular Dial 2	Dial 1	Dial 2	
1.							
2.							
3.							
Average							

Average angle of basic friction (static) = _____
Average angle of tilt = _____