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CALIBRATION OF LABORATORY SOILS TESTING EQUIPMENT

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ABSTRACT

Soil test results are only as accurate as the procedures and equipment used to produce them. By constant vigilance and regular, careful calibration and inspection of equipment, laboratory personnel can ensure acceptable accuracy of test results. The necessary frequency of calibration depends on the type and use of equipment. A record should be kept containing the actual calibration data: date of calibration, names of persons doing the calibration and information on calibration devices and methods used.

A central forced draft system, where the air is heated or cooled as required, filtered to remove dust, and returned through ducts to the various parts of the laboratory, is generally the most satisfactory means of temperature control. In areas where undisturbed soil samples are stored or test specimens are prepared, a high relative humidity should be maintained. To measure the humidity of such areas, a wet and dry bulb thermometer or a direct indicating dial hygrometer may be used.

Dial hygrometers frequently need checking to ensure a reasonable accuracy; this may be easily done by using a sling psychrometer or a wet and dry bulb thermometer. Erroneous and erratic results may be obtained on some soils under conditions of low relative humidity when liquid and plastic limits tests are being made. Operations that produce dust such as sieving, processing, or pulverizing should be conducted in an area separate from the main laboratory, and an adequate means of removing, the dust from the atmosphere, either by filtration or exhausting to the outside, should be provided. Noisy operations such as sieving, compaction, and maximum density tests should be conducted in rooms separate from the main laboratory because of their adverse effect on other laboratory personnel.

If possible, the laboratory floor should be concrete. Many testing devices are driven bymotors which should be isolated from the soil specimens being tested. Special rubber or cork pads can be used to mount shear and consolidation equipment, isolating them from objectionable vibration. Generally, to be detrimental a vibration must be of such amplitude as to be more than barely perceptible. One simple method to determine the magnitude of vibration is to place a beaker of water on the platform holding the test specimen and observe the water surface. An unrippled water surface usually indicates, for routine testing, a level of vibration not detrimental to the specimen being tested. Tests of long duration, such as consolidation, shear, etc., on sensitive soils, require a much more vibration-free testing environment than insensitive soils or short testing times.

LINEAR MEASUREMENTS

The specific device to be used for making linear measurements depends upon the accuracy required; however, several of the devices listed in Table 1 have about the same degree of accuracy and could be used interchangeably. Linear measurements are made for two basic purposes:
(a) to establish the accuracy of testing equipment
(b) to measure the physical phenomena occurring in a test to determine the properties of the soil sample.

Table 1. Linear Measuring Equipment

Device	Range	Smallest Reading	Application
Flexible metal printed tape	0-10 ft	1/32 in.	Fall of compaction rammer
Engraved metal or hardwood rules	0-30 cm 0-100 cm	1/2 mm 1 mm	Head in permeability tests Size of permeameters
Cathetometers	0-40 cm 0-100 cm	0.1 mm	Size of cylindrical cutters, compaction molds
Calipers			
Vernier	0-13 cm 0-6 in.	0.1 mm 0.001 in.	Size of cylindrical cutters
Micrometer	0-6 in.	0.001 in. 0.0001 in.	Size of molds, shear boxes
Dial gages	0-0.5 in. 0-1 in. 0-12 in.	0.0001 in. 0.001 in. 0.001 in.	Consolidation, change in thickness, and deformation of shear specimens under applied loads
Optical reticles	0-0.5 in.	0.005 in.	Liquid limit grooving tools, standpipe diameters, sieve openings
Linear potentiometers Differential transformers	0-0.5 in. 0-2 in. 0-4 in.	0.001 in. 0.01 in. 0.01 in.	Axial or horizontal deformation of specimens in shear tests
Gage blocks	0-1 in. 0-25 mm		Primary standards for checking measuring equipment

a. Rules and Tapes.
Rigid steel rules that have machine-divided graduations are suitable for measurements to 0.01 in. These rules may be used as primary standards to check flexible printed-scale steel tapes should this ever become desirable.

b. Cathetometers.
Cathetometers are suitable for linear measurements that require a precision between that provided by machine-divided metal rules and vernier or micrometer calipers.
Cathetometers are usually 40 or 100 cm in length and read to 0.1 mm by means of a vernier. Instruments with higher precision but shorter lengths and reading to 0.01 mm are available. Because readings are made by means of a telescope with cross hairs, cathetometers are particularly suited for making measurements where it is impractical or difficult to contact the object being measured, e.g. heights of liquid in manometers or standpipes. Other instruments similar to cathetometers are available; most of these have short ranges (15-cm maximum). Some of these instruments are toolmaker's microscope, measuring microscope, and a low-power (10X) microscope with a cross-hair reticle in the eyepiece and a graduated mechanical stage. Cathetometers and similar instruments may be calibrated with a vernier caliper (reading to 0.001 in.) or a micrometer caliper by setting a known length between the jaws of the caliper; this distance is then measured with the instrument being calibrated. Care should be taken to ensure that the plane of the jaws of the caliper is perpendicular to the line of sight of the telescope on the cathetometer.

c. Optical Reticles.
Optical reticles or micrometer disks are glass disks, 20 to 27 mm in diameter, on which are accurate scales, typically 0-10 mm or 0-0.5 in. Reticles either are used with magnifiers (called measuring magnifiers or pocket comparators) or are inserted into the optical system of a low-power (10X) microscope. Because the object and scale are both magnified, good accuracy is easily secured. Reticles are very convenient for small linear measurements such as the diameter of permeability standpipes, dimensions of liquid limit grooving tools, and sieve openings. To calibrate an optical reticle, it should be assembled in the magnification system in which it will be used: A suitable distance is then set between the jaws of either a vernier or micrometer caliper (reading to 0.001 in.) and the distance as read using the reticle determined. If available, a stage micrometer may also be used to check a reticle. Stage micrometers are glass slides, 25 by 75 mm, with scales ruled directly upon them Either reflected or transmitted light may be used with the stage micrometer.

d. Calipers.
Calipers are made in a variety of styles and degrees of precision. Vernier calipers with dual scales reading to 1/128 in. and to 0.1 mm are available. Vernier calipers are also made reading to 0.001 in. or, if metric measurements are preferred, to 0.02 mm. Micrometer calipers usually read to 0.001 in. or to 0.0001 in. Micrometer calipers are also made reading to 0.01 mm. Micrometer calipers are not as versatile as vernier calipers because a separate tool is required for outside and inside measurements. Usually, for the same range and precision, micrometer calipers are more expensive than vernier calipers. A machinist's 0- to 6-in. vernier caliper reading to 0.001 in. is useful for the measurement of soils testing equipment such as compaction molds, direct shear boxes and cutters, consolidation rings, and height of drop gage for liquid limit tests. Calipers may be checked for accuracy by using

gage blocks of the appropriate size (para g below). Usually checks at three or four settings of the calipers are sufficient to establish their accuracy. Tools of good design are provided with an adjustment of the zero setting when the jaws are closed. This adjustment varies with the tool, and the manufacturer's instructions should be followed in setting the zero reading. Care should be taken not to close the jaws of the calipers too tightly either when making a measurement or the zero adjustment of a reading on a gage block. Some micrometer calipers are provided with a ratchet stop to eliminate this possibility.

e. Dial Gages.

(1) Dial gages are used extensively for linear measurements in soil testing, the most common use being the measurement of specimen dimensions before and during testing. When equipped with special holders or stands, dial gages are useful in calibration of equipment for measuring inside diameters and heights of cylinders, inside dimensions of direct shear boxes, and specimen cutters. In load rings, they are used to measure deflection (loads). Dial gages are available in ranges from 0.625 to 200 mm and graduations of 0.001, 0.0025, 0.005, 0.02, and 0.01 mm in the metric system.

For most soils laboratory testing, jeweled bearings and shockproof movements are unnecessary.

(2) To calibrate dial gages, a suitable holder or stand should be obtained

A precise plane surface .on which the dial gage contact point will rest must also be provided. The dial gage should be carefully mounted so that the axis of the dial stem is perpendicular to the plane surface. Gages with clockwise dials should be set at zero reading and the desired size gage block then inserted under the contact point and the dial reading taken. Gages with counterclockwise dials should be set at zero with the desired size gage block under the contact point. The gage block is then removed, and the contact point allowed to come in contact with the plane surface and the dial then read. This operation should be repeated at several points along the dial gage's travel. Care should be taken not to allow the dial gage hands to spin too rapidly as the measurements are made, as damage to the instrument or erroneous reading's may occur.

f. Electrical Devices.

Electrical devices such as rectilinear potentiometers and differential transformers are used with appropriate indicating or recording equipment to measure deformation of soil specimens during testing., They are particularly useful where it is desirable to record test data in the absence of the operator (for example, in tests of long duration, such as direct shear tests that extend into off-duty hours). Electrical devices are calibrated using gage blocks or feeler (thickness) gages, using a procedure similar to that used for dial gages.

g. Gage Blocks.

Gage blocks are metal blocks with two parallel faces machined to a very accurate dimension. They are used as primary standards for the calibration or checking of practically all the linear measuring devices previously discussed, micrometer calipers, dial gages, and electrical devices. Gage blocks should be kept clean and dry, and should be stored in boxes provided for them when not in use. They should be handled preferably with gloves or with clean, dry hands and wiped with a clean, dry cloth before storing after use. When stacked in use, care should be taken that no dust particles are between the contact faces.

VOLUMETRIC MEASUREMENTS.

a. Cylinders and Molds.
The volume of trimming cylinders and compaction or maximum-minimum molds should be determined either by linear measurements or by the water-filling method as described below:

(1) Volume by Linear Measurement. Using either a vernier or micrometer caliper and a metal rule, determine the inside diameter and height of the container. Determine the average of four equally spaced height measurements and the average of four equally spaced measurements of the inside diameter. Have a second technician verify all measurements and compute the volume of the container.

(2) Volume by Water-Filling Method. The bottom of a cylinder open at both ends should be placed on or clamped to a section of plate glass or metal and sealed against water leakage at the contact edges using wax, stopcock grease, or similar sealant. Fill the cylinder slightly above its rim with distilled, deaired water and place a section of plate glass over the surface to eliminate the meniscus. Take care to entrap no air bubbles. Determine the weight of water required to fill the container, taking into account the temperature of the liquid in determining its density. At least three determinations of volume should be made.

b. Volumetric Flasks.

(1)Preliminary to the calibration, the flask should be cleaned using a synthetic detergent, followed by several rinses with distilled water. It is important that the neck of the flask where the calibration mark is located be thoroughly clean and uniformly wetted so that a good meniscus is developed by the water.

(2) In view of the calibration expense, flasks of borosilicate glass (Pyrex, Kimax) should be used as they are much more resistant to breakage.

c. Graduated Cylinders.
Graduated cylinders when used as sedimentation jars in hydrometer analysis are of sufficient accuracy to be used without calibration.

Nominal capacity, ml 10 25 50 100 200 250 500 1000 2000

Maximum allowable tolerance, ml ±0.1 0.3 0.4 0.6 1.4 1.4 2.6 5.0 10.0

Calibration can be made by the following procedure:

Weigh the cylinder filled to the capacity mark with distilled water.

Subtract the weight of the clean, dry cylinder.

Determine the temperature of the water.

Determine the volume at 20 C (standard temperature for volumetric glassware calibration) from the following tabulation.

Test Temp C	Apparent Wt of 1 liter of Water, g	Test Temp C	Apparent Wt of 1 liter of Water, g
15	997.93	21	996.99
16	997.80	22	996.81
17	997.66	23	996.61
18	997.51	24	996.39
19	997.36	25	996.16
20	997.18		

The tabulation above takes into account the buoyancy of air when weighing with brass weights, and the coefficient of cubical expansion of glass.
Because of their large diameter relative to height, graduated cylinders are not suitable for measurements when accuracy better than 1 percent is required.

d. Burettes, Pipettes, and Standpipes.
Burettes are available in capacities from 10 to 1000 ml, but only rarely are sizes larger than 50 ml used. Pipettes are available in capacities of 0.1 to 25 ml. If a burette or pipette is selected having a capacity slightly in excess of the volume to be measured, it will not be necessary to calibrate it before use in routine and most research soils testing. Should calibration be desired, it is done by weighing the water metered from the apparatus.
The piece should be cleaned before calibration so that the inside is uniformly wetted. A rinse with alcohol and then distilled water is usually sufficient. The piece should be mounted vertically and filled with distilled water at 20 C so that the bottom of the meniscus coincides with the zero mark. The water in appropriate amounts is then allowed to flow into a glass weighing bottle or an Erlenmeyer flask (of known weight) and weighed. The term standpipe as used herein refers to small-bore (maximum 10 mm) transparent tubes of glass or rigid plastic, having no graduation markings to indicate volume.

PRESSURE MEASUREMENTS

a. Primary Standards for Pressure Measurements. Several types of equipment are available that can be used as primary standards for the calibration of pressure measuring devices. Three types are described below:

(1) Dead Load Tester.
The most frequently used primary standard is the dead-load tester. This is a hydraulic system in which an accurate pressure is obtained by balancing calibrated weights on a vertical piston of accurately known area. Accuracy is usually 0.1 percent of full range. These instruments are made in a wide span of pressure ranges from low to very high.

(2) Precision Laboratory Test Gages.
These are Bourdon-tubetype gages, usually 12 in. or more in diameter, with an accuracy of 0.1. percent or better of full-scale range.

(3) Quartz Tube Pressure Gage.
This device, consists of a capsule containing a quartz spiral Bourdon tube that has its free end attached to a pointer or the free end has a mirror attached. The rotation of the mirror is measured by means of photoelectric cells that convert the rotation into a digital reading. The digital reading is multiplied by a calibration factor to give the pressure in pounds per square inch. Interchangeable capsules are available for any desired pressure range. Accuracy for some of these devices is in the order of 0.015 percent full-scale reading.

b. Bourdon Tube Pressure Gages.
The most widely used instrument for the measurement of fluid or gas pressures is the Bourdon tube gage. Gages for the measurement of vacuum and low pressure (maximum 15 psi) often use a diaphragm or bellows, as this construction more readily develops the force necessary to actuate the mechanism. Both types of gages require a volume change to indicate pressure; this precludes their use where volume change cannot be tolerated (direct measurement of pore water pressure).

PROCEDURE FOR CALIBRATION OF PRESSURE GAGES

All pressure gages should be calibrated before being first used. Gages that have been accidentally subjected to excess pressure or have been dropped should be checked before using.
The gage to be calibrated should be connected to a primary standard for the measurement of pressure. The gage must be mounted in the position in which it is designed to be used (usually vertical). With no pressure applied, the pointer should be set on zero if necessary.

(1) Slowly increase the pressure on the gage and observe the movement of the pointer to full range of pressure.

(2) Slowly release the pressure and observe the zero position of the pointer; reset if necessary.

(3) Select approximately ten equally spaced intervals of pressure covering the range of the gage. This number may be increased or decreased, depending upon the construction of the gage. Generally, it is more convenient to use the major divisions of a gage as check points in the calibration.

(4) Apply pressure to the gage in the desired increments, reading the primary standard and the corresponding reading of the gage being calibrated.

(5) If the gage reading does not correspond to the primary standard, a table of true pressures versus gage readings should be made and used to obtain the correct test pressures.
measurement of pore water pressure).