Atterberg Limits Testing

Atterberg Limits testing is widely used in the design stage of construction to ensure that the soils being used exhibit the proper consistency to support structures even as their moisture levels change. Soils for engineering use are often classified based on properties relative to foundation support or how they might perform under pavements and in earthworks. In the early 1900s, the Swedish chemist Albert Atterberg developed a classification system and method with which these states of consistency could be determined. His methods were later defined by Arthur Casagrande. The method is based on the determination of the water content at distinct transitions between different states of soil consistency. These transitions are defined as shrinkage limit, plastic limit, and liquid limit, and collectively are referred to as Atterberg limits. The liquid limit and plastic limit tests are the most commonly used of the Atterberg limits tests. The values for these limits are dependent on various soil parameters (e.g., particle size, specific surface area of the particles that are able to attract water molecules).

Geotechnical classification systems are designed to make it easy to equate field observations to estimates of engineering properties. As moisture content of a fine-grained, clay-like soil increases, it goes through four distinct states of consistency: solid, semi-solid, plastic, and liquid. Each stage is defined by significant changes in strength, consistency and behavior. As a hard, rigid solid in the dry state, fine grained soil becomes a crumbly (friable) semisolid when certain moisture content, or shrinkage limit, is reached. This soil will also begin to swell as shrinkage limit is exceeded. Increasing the water content beyond the soil's plastic limit will transform it into a plastic mass, which causes additional swelling. The soil will remain in this plastic state until its liquid limit is exceeded, which causes it to transform into a viscous liquid that flows when jarred. These limits can be determined with the three tests that make up the Atterberg limits tests. They are Shrinkage limit, Plastic limit and Liquid limit.

Knowledge of these values helps in foundation design of structures and to predict behavior of soils in fills and embankments. The values derived from Atterberg limit tests can contribute to estimates of shear strength, permeability, settlement and the identification of potentially expansive soils.

The Atterberg limits for different types of fine-grained soils can vary greatly. For example, Illite exhibits a shrinkage limit of 15% to 17% depending on particle sizes, while its plastic limit is typically 24% to 52%, and its liquid limit is typically 30% to 110%. Kaolinite exhibits a shrinkage limit of 25% to 29% depending on particle sizes, while its plastic limit is typically 30% to 40%, and its liquid limit is typically 35% to 72%.

A common way to describe expansive soils is through plasticity index values. The plasticity index refers to the range of plastic properties a soil exhibits at varying levels of water content. The plasticity index is essentially the difference between liquid limit and plastic limit values. Clay loam has a plasticity index of 10-20% and is referred to as a medium plastic soil. Silty clay has a plasticity index of 20-35% and is considered a highly plastic soil. Very high plasticity soils have a plasticity index of over 35% and contain a predominance of clay.

Liquid Limit

The liquid limit (ASTM D4318) is defined as the water content at which the behavior of a clayey soil changes from plastic to liquid. However, the transition from plastic to liquid behavior is gradual over a range of water contents, and the shear strength of the soil is not actually zero at the liquid limit. The precise definition of the liquid limit is based on standard test procedures described below.

The original liquid limit test developed by Atterberg involved mixing a pat of clay in a round-bottomed porcelain bowl of 10–12cm diameter. A groove was cut through the pat of clay with a spatula, and the bowl was then struck many times against the palm of one hand. Casagrande subsequently standardized the apparatus and the procedure to make the measurement more repeatable.

Soil is placed into the metal cup portion of a liquid limit device and a groove is cut down its center with a standardized tool of 2mm (0.079") width. The cup is repeatedly dropped 10mm onto a hard rubber base at a rate of 120 blows per minute, during which the groove closes up gradually as a result of the impact. The number of blows for the groove to close is recorded.

The moisture content at which it takes 25 drops of the cup to cause the groove to close over a distance of 12.7mm (0.50") is defined as the liquid limit. The test is normally run at several moisture contents, and the moisture content which requires 25 blows to close the groove is interpolated from the test results. The test method also allows running the test at one moisture content where 20 to 30 blows are required to close the groove; then a correction factor is applied to obtain the liquid limit from the moisture content.

Another method for measuring the liquid limit is the fall cone test, also called the cone penetrometer test. It is based on the measurement of penetration into the soil of a standardized cone of specific mass. Although the Casagrande test is widely used across North America, the fall cone test is much more prevalent in Europe.

Plastic Limit

Water content at the change from a plastic to a semisolid state is known as the plastic limit. The plastic limit test (ASTM D4318) is done by rolling out a small thread of soil on a flat, non-porous surface. If the soil is at a moisture content where its behavior is plastic, the thread will retain its shape down to a very narrow diameter. As the moisture content falls due to evaporation, the thread will begin to break apart at larger diameters. The sample can then be re-molded and the test repeated. The plastic limit is defined as the moisture content where the thread breaks apart at a diameter of 3.2mm (about 0.125"). A soil is considered non-plastic if a thread cannot be rolled out down to 3.2 mm at any moisture possible.

Shrinkage Limit

The shrinkage limit (ASTM D4943) is defined as the point where the water content of the soil will not result in any more volume reduction. This test is much less commonly used than the liquid and plastic limit tests. Humboldt offers the H-4254 Shrinkage Limit Set for performing this test.

ASTM D4318

Related Standards: C702, D75, D420, D653, D1241, D2216, D2487, D3282, D3740, D4542, D4753, D6026, E11, E177, E691, AASHTO T89, T90

Liquid Limit, Plastic Limit, and Plasticity Index of Soils

Qty.	Model	Description
1	Choose one: H-4234 H-4235	ASTM liquid limit test set, includes: H-4230, manual, liquid limit machine w/o counter, mixing dish, spatula, graduated cylinder and moisture cans ASTM liquid limit test set, H-4228, manual, liquid limit machine with counter, mixing dish, spatula, graduated cylinder, and moisture cans

or

Qty.	Model	Description
1	Choose one: H-4230 H-4228 H-4226 H-4226.5F	ASTM liquid limit machine ASTM liquid limit machine with counter ASTM liquid limit machine, motorized, 120V 60Hz ASTM liquid limit machine, motorized, 220V 50/60Hz
1	H-4253	ASTM plastic limit set, plastic limit plate, mixing dish, spatula, graduated cylinder and moisture cans
1	H-4233	Resiliency tester, for testing base every 90 days
1	H-4222D	Durometer, for testing hardness of base

Accessories/*Options*

Qty.	Model	Description
1	H-4229	ASTM grooving tool, Metal
1	H-4229P	ASTM grooving tool, Plastic
1	H-4232	AASHTO liquid limit metal grooving tool
1	H-4262	Plastic limit roller and 50 sheets of paper for surface
1	Choose one: HB-5315A HB-5315A.4F	Ohaus adventurer balance, 1520g x 0.01g, 120V 60Hz Ohaus adventurer balance, 1520g x 0.01g, 220V 50/60Hz
1	H-4926	Aluminum moisture boxes 2" (51mm) dia. x 7/8" (22mm) Height
1	Choose one: H-30145 H-30145.4F	Laboratory bench oven, 7.0 cu. ft. (198 L) cap., 115V 60Hz Laboratory bench oven, 7.0 cu. ft. (198 L) cap., 230V 50/60Hz


H-4234


H-4226
H-4230
H-4228


H-4253

H-4229P


H-4229


H-4232


H-4262


HB-5315A


H-30145