

5.16.10 PLASTICITY TESTS (Kansas Test Method KT-10)

a. SCOPE

This method of test covers the procedures for determining the liquid limit, plastic limit and plastic index of soils and the minus 425 μm (No. 40) portions of aggregates. For aggregates, use the wet preparation method described in section **h** of this procedure. **KT-10** reflects testing procedures found in AASHTO T 87, T 89, T 90.

b. REFERENCED DOCUMENTS

- b.1.** KT-11; Moisture Test
- b.2.** AASHTO M 92; Wire-Cloth Sieves for Testing Purposes
- b.3.** AASHTO M 231; Balances Used in the Testing of Materials
- b.4.** AASHTO T 87; Dry Preparation of Disturbed Soil Aggregate Samples for Test
- b.5.** AASHTO T 89; Determining the Liquid Limit of Soils
- b.6.** AASHTO T 90; Determining the Plastic Limit and Plasticity Index of Soils

c. APPARATUS

- c.1.** The balance shall conform to the requirements of AASHTO M 231 Class G1.
- c.2.** A suitable device capable of drying samples at a temperature not exceeding 60°C (140°F), for the preparation of the samples.
- c.3.** Oven thermostatically controlled capable of maintaining a uniform temperature of 110 \pm 5°C (230 \pm 9°F), for the drying of moisture samples.
- c.4.** A porcelain-evaporating dish, preferably unglazed about 115 mm (4.5 in) in diameter.
- c.5.** Spatula having a blade about 20 mm (0.75 in) wide and 75 mm (3 in) long.
- c.6.** A mechanically operated liquid limit device consisting of a brass cup and carriage meeting the requirements of AASHTO T 89, figure 1 and Sections **d.3.a.** and **d.3.b.**
- c.7.** A manually operated device constructed in accordance with AASHTO T 89 Section 2.3.1.
- c.8.** Grooving tool meeting the requirements of AASHTO T 89, figure 1.

c.9. A gage whether attached to the grooving tool or separate, conforming to the critical dimension "d" shown in figure 1 of AASHTO T 89 and may be, if separate, a metal bar 10.0 ± 0.2 mm (0.394 ± 0.008 in) thick and approximately 50 mm (2 in) long.

NOTE: All liquid limit devices and grooving tools should be examined for conformance with the requirements of AASHTO T 89 before they are used.

c.10. Suitable containers made of material resistant to corrosion and not subject to change in mass or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination. One container is needed for each moisture content determination.

c.11. Pulverizing apparatus: Either a mortar and rubber-covered pestle or a mechanical device consisting of a power driven rubber-covered muller suitable for breaking up the aggregations of soil particulars without reducing the size of the individual grains.^a

NOTE a: Other types of apparatus, such as a revolving drum into which the soil sample and rubber-covered rollers are placed and tumbled until soil aggregations are pulverized, are satisfactory if the aggregations of soil particles are broken up without reducing the size of the individual grains.

c.12. Series of sieves including 4.75 mm (No. 4), 2.00 mm (No. 10), and 425 μ m (No. 40) conforming to AASHTO M 92.

c.13. Standard KDOT 400 by 250 by 140 mm (16 by 10 by 5.5 in) wash pan equipped with 425 μ m (No. 40) screen (optional).

c.14. Ground glass plate. The finish on the ground glass plate is obtained using a medium to fine grade of abrasive dust. An emery dust essentially passing the 250 μ m (No. 60) sieve and retained on the 150 μ m (No. 100) sieve has been found to be satisfactory.

A small amount of water is sprinkled on a glass plate along with the abrasive dust. Another plate is laid on top and the plates are rubbed together until a uniform frosty finish is obtained.

c.15. Plastic Limit device such as a Gilson SA-18. (see figure 2)

d. LIQUID LIMIT TEST¹

d.1. Definition: The liquid limit of a material is the water content, when determined in accordance with this test method, at which the material passes from a plastic to a liquid state. This corresponds to the moisture content at which the material will flow in such a manner as to produce a 13 mm (0.5 in) closure of a groove when jarred by 25 drops of the cup on the liquid limit device.

¹ AASHTO T 89 and ASTM D 4318 allow for both method "A" and method "B". **KT-10** allows for method "A" only.

d.2. Preparation of Sample: Dry the material at a temperature not exceeding 60°C (140°F). (See section **h** for aggregate material preparation).

d.2.a. The dried sample shall be separated into two fractions using a 2.00 mm (No. 10) sieve. The fraction retained on the sieve shall be ground with the pulverizing apparatus until the aggregations of soil particles are broken into separate grains. The ground soil shall then be separated into two fractions using the 2.00 mm (No. 10) sieve. Discarding the material retained on the sieve.

d.2.b. Dry-screen the material over a 425 µm (No. 40) sieve to remove as much of the portion passing the 425 µm (No. 40) sieve as possible.

d.2.c. The fraction retained on the 425 µm (No.40) sieve shall be ground with the pulverizing apparatus in such a manner as to break up the aggregations without fracturing the individual grains. If the sample contains brittle particles, such as flakes of mica, fragments of sea shells, etc., the pulverizing operation shall be done carefully and with just enough pressure to free the finer material that adheres to the coarser particles. The ground soil shall then be separated into two fractions by means of the 425 µm (No. 40) sieve and the material shall be reground as before. When the repeated grinding produces only a small quantity of soil passing the 425 µm sieve, the material retained on the 425 µm sieve shall be discarded. The several fractions passing the 425 µm sieve obtained from the grinding and sieving operations just described shall be thoroughly mixed together and set aside for use in performing the physical tests.

d.3. Test Procedure

d.3.a. Adjust the height of drop of the brass cup on the liquid limit device by means of the adjustment plate. The height to which the cup is lifted by the cam is adjusted so that the point on the cup which comes in contact with the base is 10.0 ± 0.2 mm (0.394 ± 0.008 in) above the base. Secure the adjustment plate by tightening the appropriate screws.

The adjustment is checked with the gage in place by revolving the crank several times. If the adjustment is correct, a slight ringing sound will be heard when the cam strikes the cam follower. If the cup is raised off the gage or no sound is heard, further adjustment is made.

d.3.b. Inspect the liquid limit device to be sure that it is in good working order and that there are no worn or "out of alignment" parts that will affect the test results.

d.3.c. Take a sample weighing approximately 100 g and place in the mixing dish. The sample shall be thoroughly mixed with 15 to 20 mL of distilled or demineralized water^b by alternately and repeatedly stirring, kneading, and chopping with a spatula. Further additions of water shall be made in 1 to 3 mL increments. Each increment of water shall be thoroughly mixed with the soil, as previously described, before another increment of water is added. Once testing has begun, no additional dry soil should be added to the moistened soil. The cup of the Liquid Limit Device shall not be used for mixing soil and water. If too much moisture has been added to the sample, the sample shall either be discarded, or mixed and kneaded until the natural evaporation lowers the closure point into acceptable range.

NOTE b: Some soils are slow to absorb water, therefore, it is possible to add increments of water so fast that a false liquid limit value is obtained. This can be avoided if more mixing and/or time is allowed. Tap water may be used for routine testing if comparative test indicate no differences in results between using tap water and distilled or demineralized water. However, referee, or disputed tests shall be performed using distilled or demineralized.

d.3.d. When sufficient water has been thoroughly mixed with the soil to form a uniform mass of stiff consistency, a sufficient quantity of this mixture shall be placed in the cup above the spot where the cup rests on the base and shall be squeezed and spread with the spatula to level and at the same time trimmed to a depth of 10 mm at the point of maximum thickness. As few strokes of the spatula as possible shall be used, care being taken to prevent the entrapment of air bubbles within the mass. The excess soil shall be returned to the mixing dish. The soil in the cup of the device shall be divided by a firm stroke of the grooving tool along the diameter through the centerline of the cam follower so that a clean sharp groove of the proper dimensions will be formed. To avoid tearing the sides of the groove or slipping of the soil cake on the cup, up to six strokes from front to back or from back to front counting as one stroke shall be permitted. The depth of the groove should be increased with each stroke and only the last stroke should scrape the bottom of the cup.

d.3.e. ^c The cup containing the sample prepared as described in section **d.3.d.** shall be lifted and dropped by turning the crank at the rate of approximately two revolutions per second until the two sides of the sample come in contact at the bottom of the groove along a distance of about 13 mm (0.5 in). The number of shocks required to close the groove this distance shall be recorded. The base of the machine shall not be held with the free hand while the crank is turned.

NOTE c: Some soils tend to slide on the surface of the cup instead of flowing. If this occurs, more water should be added to the sample and remixed, then the soil-water mixture placed in the cup, a groove cut with the grooving tool and section **d.3.e.** repeated. If the soil continues to slide on the cup at a lesser number of blows than 25, the test is not applicable and a note should be made that the liquid limit could not be determined.

d.3.f. A slice of soil approximately the width of the spatula, extending from edge to edge of the soil cake at right angles to the groove and including that portion of the groove in which the soil flowed together, shall be removed and placed in a suitable container. Record the sample mass to the nearest 0.01 g. The soil in the container shall be dried in accordance with **KT-11** to determine the moisture content, and record the results.

d.3.g. The soil remaining in the cup shall be transferred to the mixing dish. The cup and grooving tool shall be washed and dried in preparation for the next trial.

d.3.h. The foregoing operations shall be repeated for at least two additional portions of the sample to which sufficient water has been added to bring the soil to a more fluid condition. The object of this procedure is to obtain samples of such consistency that at least one determination will be made in each of the following ranges of shocks: 25-35, 20-30, 15-25, so the range in the three determinations is at least 10 shocks.

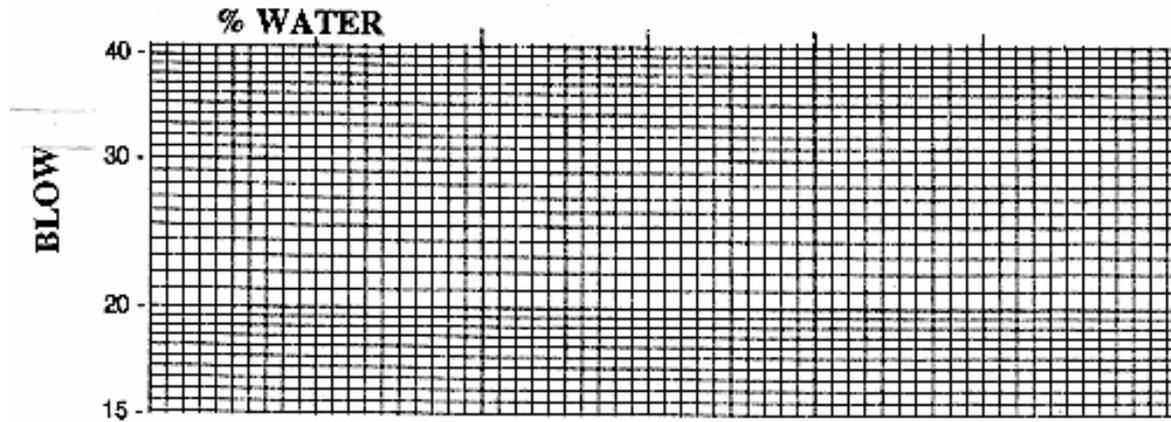
d.4. Calculations: Calculate the moisture content of the sample as follows:

$$\text{Moisture Content} = \frac{100([A-B] - [C-B])}{(C - B)}$$

Where: A = Mass of wet soil and container, g
B = Mass of container, g
C = Mass of dry soil and container, g

d.5. Calculate the percentage of moisture to the nearest whole percent.

d.6. A "Flow Curve" representing relation between moisture content and corresponding number of shocks shall be plotted on a semi-logarithmic graph with the moisture contents as abscissae on the arithmetical scale, and the number of shocks as ordinates on the logarithmic scale. The flow curve shall be a straight line drawn as nearly as possible through the three plotted points. (Figure 1)



Flow Curve Chart
(KDOT Form No. 664)
Figure 1

d.7. The moisture content corresponding to the intersection of the flow curve with the 25 shock ordinate shall be taken as the liquid limit of the soil. Report this value to the nearest whole number.

e. PLASTIC LIMIT TEST

e.1. Definition: The plastic limit of a material is the lowest water content, when determined in accordance with this test method, at which the material remains plastic.

e.2. Preparation of Sample: The test is conducted using material finer than the 425 μm (No. 40) sieve. The minus 425 μm (No. 40) material is prepared as outlined in **d.2.** of this test method.

e.3. Procedure

e.3.a. Thoroughly mix the minus 425 μm (No. 40) material and place approximately 20 g in an evaporating dish.

e.3.b. Thoroughly mix with distilled or demineralized^d water until the mass becomes plastic enough to be easily shaped into a ball. Take a portion of this ball with a mass of about 8 g for the test sample.

e.3.c. If both the liquid and plastic limits are required, take a test sample with a mass of about 8 g from the thoroughly wet and mixed portion of the soil prepared in accordance with section **d.3.c.** Take the sample at any stage of the mixing process at which the mass becomes plastic enough to be easily shaped into a ball without sticking to the fingers excessively when squeezed. If the sample is taken before completion of the liquid limit test, set it aside and allow it to season in air until the liquid limit test has been

completed. If the sample taken during the liquid limit test is too dry to permit rolling to a 3.2 mm (1/8 in) thread, add more water and remix.

NOTE d: Tap water may be used for routine testing if comparative tests indicate no differences between using tap water and distilled or demineralized water. However, referee or disputed tests shall be performed using distilled or demineralized water.

e.3.d. Select 1.5 to 2.0 g of soil taken in section **e.3.c.** Form into an ellipsoidal mass.

e.3.e. Roll this mass between the fingers and the palm of the hand and a ground glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. The rate of rolling shall be between 80 and 90 strokes per minute, counting a stroke as one complete motion of the hand forward and back to the starting position again. Reduce the diameter of the thread to 3.0 mm (1/8 in), taking no more than 2 min. Quickly squeeze and reform the thread into an ellipsoidal shaped mass and re-roll. Continue this alternate reforming and re-rolling to a thread 3.0 mm (1/8 in) in diameter, gathering together, kneading and re-rolling, until the thread crumbles under the pressure required for rolling and the material can no longer be rolled into a thread. The crumbling may occur when the thread is greater than 3.0 mm (1/8 in) in diameter. This shall be considered a satisfactory end point, provided the material has been rolled to a thread of 3.0 mm (1/8 in) during the previous rolling. The crumbling will manifest itself differently with various types of material. Some materials fall apart in numerous small aggregations of particles; others may form an outside tubular layer that starts splitting at both ends. Splitting progresses toward the middle, and finally, the thread falls apart in many small platy particles. It is not practical to define crumbling to an exact degree since, as stated above, crumbling will manifest itself differently for different materials. At no time shall the operator attempt to produce failure at exactly 3.0 mm (1/8 in) diameter by allowing the thread to reach 3.0 mm (1/8 in), then reducing the rate of rolling or the hand pressure or both, and continuing the rolling without further deformation until the thread falls apart. It is permissible, however, to reduce the total amount of deformation for feebly plastic soils by making the initial diameter of the ellipsoidal shaped mass nearer to the required 3.0 mm (1/8 in) final diameter.

e.3.f. Place the crumbled thread in a watch glass or other suitable container of known mass and close to prevent evaporation loss.

e.3.g. Gather the portions of the crumbled soil together and place in a suitable tared container. Record the sample mass to the nearest 0.01 g. The soil in the container shall be dried in accordance with **KT-11** sections **c** through **e**, to determine the moisture content, and record the results.

e.4. Alternate procedure using the Plastic Limit Device.

e.4.a. Attach smooth unglazed paper to both the bottom fixed plate and the top plate of the plastic limit device.

e.4.b. Split the 8 g test sample taken in section **e.3.c.** and **e.3.d.** into four or five masses of 1.5 to 2.0 g each. Squeeze into an ellipsoidal-shape and place two to three masses on the bottom plate. Place the top plate in contact with the soil masses. Simultaneously with a slight downward force, apply a back-and-forth rolling motion with the top plate until the top plate comes into contact with the 3.2 mm side rails, within two minutes. Do not allow the soil thread to come into contact with the side rails.

e.4.c. Continue the test as outlined in sections **e.3.e.**, **e.3.f.**, and **e.3.g.**

f. Calculations

f.1. Calculate the moisture content of the sample at its plastic limit as follows:

$$\text{Plastic Limit} = \frac{100([A-B] - [C-B])}{(C-B)}$$

Where: A = Mass of wet soil and container, g
 B = Mass of container, g
 C = Mass of dry soil and container, g

f.2. Recording: Record the plastic limit to the nearest whole percent.

g. PLASTIC INDEX

g.1. Definition: The plastic index of a material is the numerical difference between the liquid limit and the plastic limit.

g.2. Calculations: Calculate the plastic index as follows, or calculate on form 663.

Plastic Index = Liquid Limit (as recorded) - Plastic Limit (as recorded).

g.3. Reporting: Report the plastic index and liquid limit (when required) to the nearest whole number.

NOTE e: When testing extremely sandy samples, it is permissible to conduct the plastic limit test first. If the plastic limit cannot be determined, report the plastic index as NP (i.e. nonplastic). If the plastic limit is equal to or greater than the liquid limit, report the plastic index as NP.

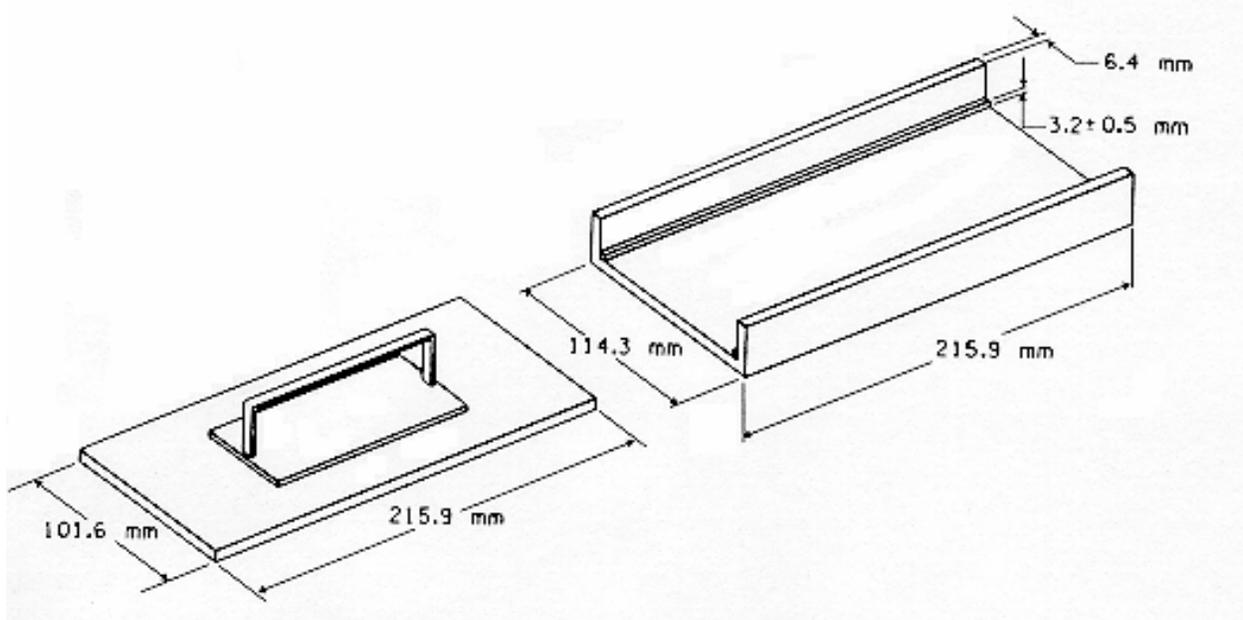
h. WET PREPARATION (FOR AGGREGATE MATERIAL ONLY)

h.1. The following "wash" method of preparation shall be used for all types of aggregates, binder soil and mineral fillers. However, in the case of a mineral filler which all passes a 425 µm (No. 40) sieve, the washing process may be waived and the sample prepared for testing by reducing it to particle size using the pulverizing apparatus.

h.1.a. Dry the material to a moisture condition at which it can be pulverized and dry-screened without sticking or clogging the screens.

h.1.b. Dry-screen the material over a 425 µm (No. 40) sieve to remove as much of the portion passing the 425 µm (No. 40) sieve as possible before washing. Several larger sieves may be used in this process to keep part of the load off the 425 µm (No. 40) sieve. This initial dry-screening is very important as it helps to reduce the time and water required for the washing process which follows. Set aside the minus 425 µm (No. 40) material obtained in this manner for recombination with material obtained by later steps.

- h.1.c.** Place the material retained on the 425 μm (No. 40) sieve in a pan, cover with water and soak for a minimum of 30 minutes.
- h.1.d.** Following the soaking period, wash the material, using not less than four applications of wash water, including the soaking water. Each application of water must cover the entire sample. The washing for each application is accomplished by a "sloshing" action of the pan. Should an appreciable amount of plastic material remain with the sample after the four applications of water, use additional applications accompanied by more vigorous agitation of the material. Decant each application of the wash water through a 425 μm (No. 40) sieve, saving all of the wash water and material.
- h.1.e.** Evaporate the water from the washed plus 425 μm (No. 40) material and from the material washed through the 425 μm (No. 40) sieve using an oven with temperature settings not to exceed 60°C (140°F). In most cases, after a short period of heating, the particles in suspension will settle out so that the clear water at the top of the pan may be siphoned off to reduce the drying time.
- h.1.f.** If the material in the retained wash water becomes caked during the drying process, break it down to pass the 425 μm (No.40) sieve with the pulverizing apparatus. This pulverizing shall be done, insofar as possible, in a manner which will not change the characteristics of the material.
- h.1.g.** Dry-screen the dried material, retained on the 425 μm (No. 40) sieve during the washing process, over a 425 μm (No. 40) sieve after which the material retained on the sieve may be discarded.
- h.1.h.** Recombine and thoroughly mix the minus 425 μm (No. 40) material obtained by the initial dry-screening, that obtained by washing and that obtained by re-screening the coarse material after washing. The sample thus prepared is ready for testing.



Plastic Limit Device
Figure 2