

**METHODS OF SAMPLING AND TESTING**  
**MT 213-04**  
**METHOD OF TEST FOR PLASTIC FINES IN GRADED AGGREGATES**  
**AND SOILS BY USE OF THE SAND EQUIVALENT TEST**  
*(Modified AASHTO T 176)*

**1 Scope:**

- 1.1** This test is intended to serve as a rapid field test to show the relative proportions of fine dust or claylike material in soils or graded aggregates.
- 1.2** The following applies to all specified limits in this standard: For the purpose of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value.

**2 Referenced Documents:**

- 2.1 AASHTO:**  
T 176 Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

**3 Apparatus:**

- 3.1** A graduated plastic cylinder, rubber stopper, irrigator tube, weighted foot assembly, and siphon assembly, all conforming to their respective specifications and dimensions shown in Figure 1. Fit the siphon assembly to a 1 gal. (4 liter) bottle of working calcium chloride solution (see 2.8) placed on a shelf  $36 \pm 1$  in. ( $915 \pm 25$  mm) above the work surface. In lieu of the specified 1 gal. (4 liter) bottle, a glass or plastic vat having a larger capacity may be used providing the liquid level of the working solution is maintained between 36 and 46 inches (915 to 1,170 mm) above the work surface.

*Note 1 - An older model of weighted foot assembly has a guide cap that fits over the upper end of the graduated cylinder and centers the rod in the cylinder, and the foot of the assembly has a conical upper surface and three centering screws to center it loosely in the cylinder. The older model does not have the sand reading indicator affixed to the rod (Figure 1), but a slot in the centering screws of the weighted foot is used to indicate the sand reading. Apparatus with the sand reading indicator (Figure 1) is preferred for testing clayey materials.*

- 3.2** A 3 oz. (85 ml) tinned box approximately  $2\frac{1}{4}$  in. (57 mm) in diameter, with Gill style cover and having a capacity of  $85 \pm 5$  ml.
- 3.3** A wide-mouthed funnel approximately 4 in. (100 mm) in diameter at the mouth.
- 3.4** A clock or watch reading in minutes and seconds.
- 3.5** A mechanical shaker as shown in Figure 3, having a throw of  $8 \pm 0.04$  in. ( $203.2 \pm 1.02$  mm), and operating at  $175 \pm 2$  cycles per minute ( $2.92 \pm 0.03$  Hz) (Note 2). Prior to use, fasten the mechanical sand equivalent shaker securely to a firm and level mount.
- 3.6** A manually operated shaker as shown in Figure 4, capable of producing an oscillating motion at the rate of 100 complete cycles in  $45 \pm 5$  s, with a hand-assisted half stroke length of  $5.0 \pm 0.2$  in. ( $127.00 \pm 5.08$  mm). The shaker shall be fastened securely to a firm and level mount by bolts or clamps if a large number of determinations are to be made.

*Note 2 - The mechanical shaker shall be used when performing referee sand equivalent determinations. Either the mechanical or manually operated shaker should be used in lieu of the hand method whenever possible.*

**3 Apparatus:** (continued)

**3.7** Stock calcium chloride solution: Prepare the stock calcium chloride solution with the following:

454 g (1 lb.) technical grade anhydrous calcium chloride  
2.050 g (1.640 ml.) USP glycerine  
47 g (45 ml) formaldehyde (40 percent by volume solution)

**3.7.1** Dissolve the calcium chloride in ½ gal. (1.89 liters) of distilled or demineralized water. Cool the solution, then filter it through Whatman No. 12 or equivalent filter paper. Add the glycerine and formaldehyde to the filtered solution, mix well, and dilute to 1 gal. (3.79 liters) with distilled or demineralized water.

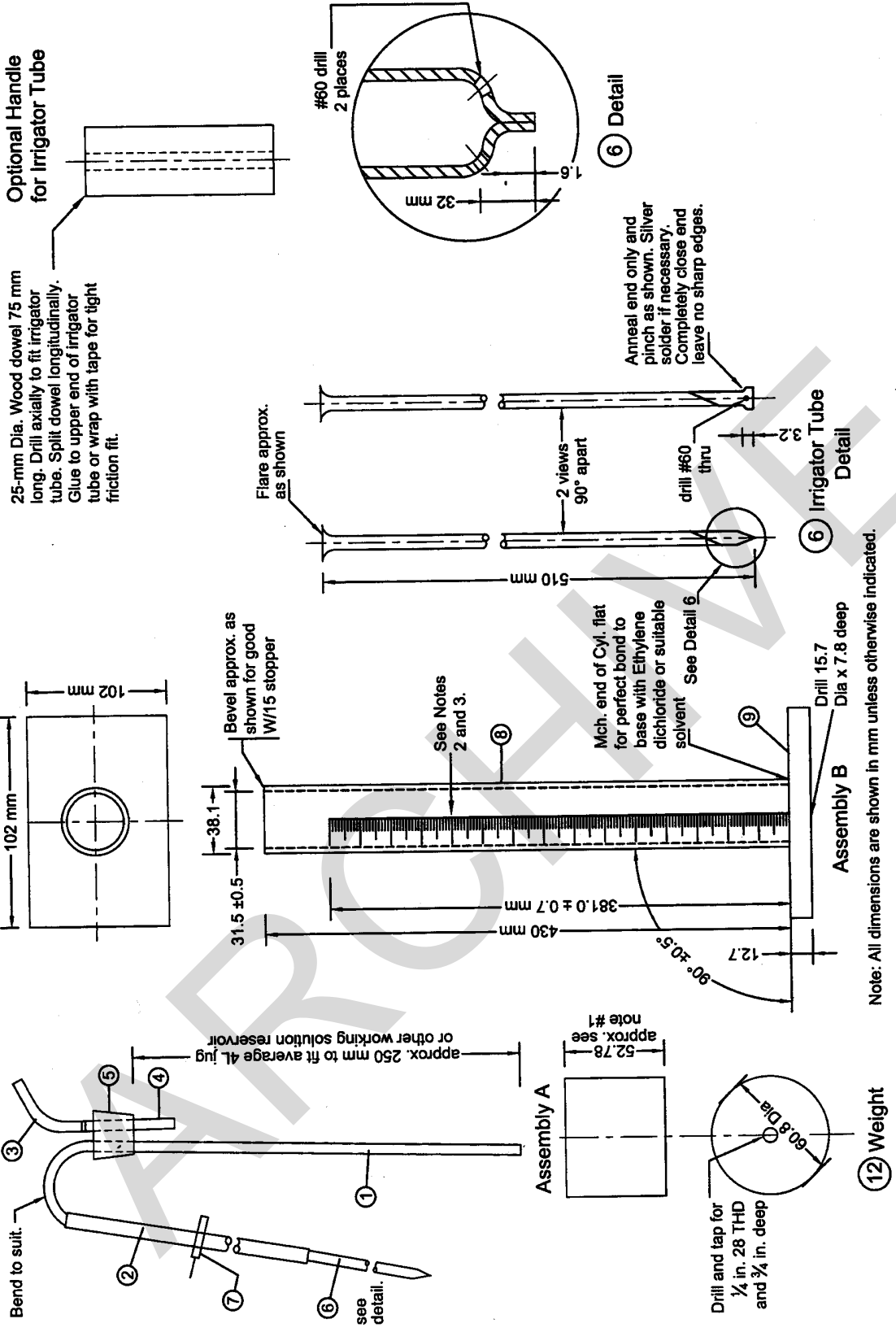
**3.8** Working calcium chloride solution: Prepare the working calcium chloride by diluting one measuring tin fill ( $85 \pm 5$  ml.) of the stock calcium chloride solution to 1 gal. (3.79 liters) with water. Use distilled or demineralized water for the normal preparation of the working solution. However, if it is determined that the local tap water is of such purity that it does not affect the test results, it is permissible to use in lieu of distilled or demineralized water except in the event of dispute.

**3.9** A straightedge or spatula, suitable for striking off the excess soil from the tin measure.

**3.10** A thermostatically controlled drying oven capable of maintaining a temperature of  $110 \pm 5^\circ \text{C}$  ( $230 \pm 9^\circ \text{F}$ ).

**4 Control:**

**4.1** The temperature of the working solution should be maintained at  $22 \pm 3^\circ \text{C}$  ( $72 \pm 5^\circ \text{F}$ ) during the performance of this test. If field conditions preclude the maintenance of the temperature range, frequent referee samples should be submitted to a laboratory where proper temperature control is possible. It is also possible to establish temperature correction curves for each material being tested where proper temperature control is not possible. However, no general correction curve should be utilized for several materials even within a narrow range of sand equivalent values. Samples that meet the minimums and equivalent requirement at a working solution temperature below the recommended range need not be subject to referee testing.



**Figure 1—Sand Equivalent Apparatus**

**FIGURE 1 Sand Equivalent Test Apparatus**

**5 Sample Preparation:**

- 5.1** The sand equivalent test shall be performed on soils or graded aggregate materials passing the 4.75 mm (No. 4) sieve. All aggregations of fine-grained soil material shall be pulverized to pass the 4.75 mm sieve, and all fines shall be cleaned from the particles retained on the 4.75 mm sieve and included with the material passing the 4.75 mm sieve.
- 5.2** Split or quarter enough of the original sample to yield slightly more than four 3-oz. (85 ml.) tin measures of material passing the 4.75 mm sieve. Use extreme care to obtain a truly representative portion of the original sample (Note 3).

*Note 3 - Experiments show that as the amount of material being reduced by splitting or quartering is decreased, the accuracy of providing representative portions is reduced. It is imperative that the sample be split or quartered carefully. When it appears necessary, dampen the material before splitting or quartering, to avoid segregation or loss of fines.*

- 5.3** Prepare the desired number of test samples by one of the following methods:

**5.3.1** *Alternate Method No. 1 - Air Dry.*

- 5.3.1.1** Split or quarter enough material from the passing 4.75 portion to fill the 3 oz. (85 ml) tin measure so it is slightly rounded above the brim. While filling the measure, tap the bottom edge of the tin on the work table or other hard surface to cause consolidation of the material and allow the maximum amount to be placed in the tin. Strike off the tin measure level full with a spatula or straightedge.

**5.3.2** *Alternate Method No. 2 - Pre-Wet.*

- 5.3.2.1** The sample must be in the proper moisture condition to achieve reliable results. This condition is determined by tightly squeezing a small portion of the thoroughly mixed sample in the palm of the hand. If the cast that is formed permits careful handling without breaking, the correct moisture range has been obtained. If the material is too dry, the cast will crumble and it will be necessary to add water and remix and retest until the material forms a cast. If the material shows any free water, it is too wet to test and must be drained and air dried, mixing it frequently to insure uniformity. This overly wet material will form a good cast when checked initially, so the drying process should continue until a squeeze check on the drying material gives a cast which is more fragile and delicate to handle than the original. If the moisture content of the original sample prepared in 5.2 is within the limits described above, the test sample may be obtained immediately. If the moisture content is altered to meet these limits, the altered sample should be placed in a pan, covered with a lid or with a damp cloth which does not touch the material, and allowed to stand for a minimum of 15 minutes.
- 5.3.2.2** After the minimum 15-minute tempering period, place the sample on the splitting cloth and mix by alternately lifting each corner of the cloth and pulling it over the sample toward the diagonally opposite corner, causing the material to be rolled. When the material appears homogeneous, finish the mixing with the sample in a pile near the center of the cloth.
- 5.3.2.3** Fill the 3 oz. (85 ml) tin measure by pushing it through the base of the pile while exerting pressure with the hand against the pile on the side opposite the measure. As the tin is moved through the pile, hold enough pressure with the hand to cause the material to fill the tin to overflowing. Press firmly with the palm of the hand, compacting the material and allowing the maximum amount to be placed in the tin. Strike off the tin measure level full with a spatula or straightedge.

## 5 Sample Preparation: (continued)

*Note 4 - Moist test specimens produce lower sand equivalent values than the corresponding over-dry specimens with almost no exceptions, therefore, if a dual specification encompassing both the wet and dry methods of sample preparation is utilized, it will be necessary to determine the appropriate correction for each material since a standard correction does not appear possible. Either method can be employed with equal confidence, however.*

**5.3.3** Referee Method (Mechanical Shaker) - Obtain the 3 oz. (85 ml) tin measure of material by one of the alternate methods, 5.3.1 or 5.3.2, above, then dry the test sample to constant mass at  $110 \pm 5^\circ \text{C}$  ( $230 \pm 9^\circ \text{F}$ ), and cool to room temperature before testing.

## 6 Procedure:

**6.1** Siphon  $4 \pm 0.1$  in. ( $101.6 \pm 2.5$  ml) of working calcium chloride solution into the plastic cylinder. Pour the prepared test sample from the measuring tin into the plastic cylinder using the funnel to avoid spillage. Tap the bottom of the cylinder sharply on the heel of the hand several times to release air bubbles and to promote thorough wetting of the sample.

**6.2** Allow the wetting sample to stand undisturbed for  $10 \pm 1$  minutes. At the end of the 10-minute soaking period, stopper the cylinder, then loosen the material from the bottom by partially inverting the cylinder and shaking it simultaneously.

**6.3** After loosening the material from the bottom of the cylinder, shake the cylinder and contents by any one of the following methods:

**6.3.1** *Mechanical Shaker Method (Referee Method)* - Place the stoppered cylinder in the mechanical sand equivalent shaker, set the timer, and allow the machine to shake the cylinder and contents for  $45 \pm$  seconds.

**6.3.2** *Manual Shaker Method* - Secure the stoppered cylinder in the three spring clamps on the carriage of the hand operated sand equivalent shaker and reset the stroke counter to zero. Stand directly in front of the shaker and force the pointer to the stroke limit marker painted on the backboard by applying an abrupt horizontal thrust to the upper portion of the right hand spring steel strap. Then remove the hand from the strap and allow the spring action of the straps to move the carriage and cylinder in the opposite direction without assistance or hindrance. Apply enough force to the right hand spring steel strap during the thrust portion of each stroke to move the pointer to the stroke limit marker by pushing against the strap with the ends of the fingers to maintain a smooth oscillating motion. The center of the stroke limit marker is positioned to provide the proper stroke length and its width provides the maximum allowable limits of variation. The proper shaking action is accomplished only when the tip of the pointer reverses direction within the marker limits. Proper shaking action can best be maintained by using only the forearm and wrist action to propel the shaker. Continue the shaking action for 100 strokes.

**6.3.3** *Hand Method* - Hold the cylinder in a horizontal position as illustrated in Figure 7 and shake it vigorously in a horizontal linear motion from end to end. Shake the cylinder 90 cycles in approximately 30 seconds using a throw of  $9 \pm 1$  in. ( $229 \pm 25$  mm). A cycle is defined as a complete back and forth motion. To properly shake the cylinder at this speed, it will be necessary for the operator to shake with the forearms only, relaxing the body and shoulders.

**6.4** Following the shaking operation, set the cylinder upright on the work table and remove the stopper.

**6.5** *Irrigation Procedure* - Insert the irrigator tube in the cylinder and rinse material from the cylinder walls as the irrigator is lowered. Force the irrigator through the material to the bottom of the cylinder by applying a gentle stabbing and twisting action

**6 Procedure:** (continued)

while the working solution flows from the irrigator tip. This flushes the fine material into suspension above the coarser sand particles. Continue to apply the stabbing and twisting action while flushing the fines upward until the cylinder is filled to the 15 in. (381 mm) mark. Then raise the irrigator slowly without shutting off the flow so that the liquid level is maintained at about 15 in. (381 mm) while the irrigator is being withdrawn. Regulate the flow just before the irrigator is entirely withdrawn and adjust the final level to 15 in. (381 mm).

- 6.6** Allow the cylinder and contents to stand undisturbed to 20 minutes  $\pm$  15 seconds. Start the timing immediately after withdrawing the irrigator tube.
- 6.7** At the end of the 20-minute sedimentation period, read and record the level of the top of the clay suspension. This is referred to as the "clay reading." If no clear line of demarcation has formed at the end of the specified 20-minute sedimentation period, allow the sample to stand undisturbed until a clay reading can be obtained, then immediately read and record the level of the top of the clay suspension and the total sedimentation time. If the total sedimentation time exceeds 30 minutes, rerun the test using three individual samples of the same material. Read and record the clay column height of that sample requiring the shortest sedimentation period only.
- 6.8** After the clay reading has been taken, the "sand reading" shall be obtained by one of the following methods:
- 6.8.1** When using the weighted foot assembly having the sand indicator on the rod of the assembly place the assembly over the cylinder and gently lower the assembly toward the sand. Do not allow the indicator to hit the mouth of the cylinder as the assembly is being lowered. As the weighted foot comes to rest on the sand, tip the assembly toward the graduations on the cylinder until the indicator touches the inside of the cylinder. Subtract 10 inches (254 mm) from the level indicated by the extreme top edge of the indicator and record this value as the "sand reading."
- 6.8.2** If an older model weighted foot assembly having centering screws is used, keep one of the centering screws in contact with the cylinder wall near the graduations so that it can be seen at all times while the assembly is being lowered. When the weighted foot has come to rest on the sand, read the level of the centering screw and record this value as the "sand reading."
- 6.9** If clay or sand readings fall between 0.1 in. (2.5 mm) graduations, record the level of the higher graduation as the reading. For example, a clay reading of 7.95 would be recorded as 8.0 and a sand reading of 3.22 would be recorded as 3.3.

*Note 5 - Samples obtained from aggregate proposed for use in hot asphalt paving mixtures shall be prepared by oven-drying if acceptance of the material is based on tests on material that has passed through a hot plant drier.*

**7 Calculations:**

- 7.1** Calculate the sand equivalent (SE) to the nearest 0.1 using the following formula:

$$SE = \frac{\text{Sand Reading}}{\text{Clay Reading}} \times 100$$

**7 Calculations:** (continued)

- 7.2** If the calculated sand equivalent is not a whole number, report it as the next higher whole number, as in the following example:

$$SE = \frac{3.3}{8} \times 100 = 41.25,$$

which is reported as 42.

- 7.3** If it is desired to average a series of sand equivalent values, average the whole number values determined as described above. If the average of these values is not a whole number, raise it to the next higher whole number, as in the following example:

Calculated SE values: 41.2, 43.8, 40.9

After raising each to the next higher whole number, they become: 42, 44, 41

The average of these values is then determined:

$$AVG \frac{42 + 44 + 41}{3} = 42.3$$

- 7.3.1** Since the average value is not a whole number, it is raised to the next higher whole number and the reported averages and equivalent value is reported as "43."

**8 Precautions:**

- 8.1** Perform the test in a location free of vibrations; vibrations may cause the suspended material to settle at a rate greater than normal.
- 8.2** Do not expose the plastic cylinders to direct sunlight any more than is necessary.
- 8.3** Removal of Organic Growth: Occasionally it may be necessary to remove an organic growth from the working calcium chloride solution container and from the inside of the flexible tubing and irrigator tube. This organic material can easily be seen as a slimy substance in the solution. To remove this growth, prepare a cleaning solvent by diluting sodium hypochlorite with an equal quantity of water (see Note 6). Fill the solution container with the prepared cleaning solvent, allow about a liter of the cleaning solvent to flow through the siphon assembly and irrigator tube, then place the pinch clamp on the end of the tubing to cut off the flow of solvent and to hold the solvent in the tube.

*Note 6 - Chlorox or its equivalent has been found satisfactory for this purpose.*

Refill the container and allow to stand overnight. After soaking, allow the cleaning solvent to flow out through the siphon assembly and irrigator tube. Remove the siphon assembly from the solution container and rinse both with clear water. The irrigator tube and siphon assembly can be rinsed easily by attaching a hose between the tip of the irrigator tube and water faucet and backwashing fresh water through the tube.

- 8.4** Occasionally the holes in the tip of the irrigator tube may become clogged by a particle of sand. If the obstruction cannot be freed by any other method, use a pin or other sharp object to force it out, using extreme care not to enlarge the size of the opening.

**9 Operator Qualifications:**

- 9.1** Before an operator is allowed to perform the sand equivalent test by either the manual method or the hand method, he must meet certain qualification requirements for that method. Although the qualification requirements are identical for both methods, an operator shall be permitted to use only that method for which he has qualified.
- 9.1.1** The operator must be capable of obtaining consistent sand equivalent test results on representative samples of any given material when the test is performed in accordance with the prescribed procedure for that particular method. An operator's test results are considered to be consistent if the individual results of three tests performed by him on representative samples of any given material do not vary by more than  $\pm 4$  points from the average of these tests.
- 8.1.2** The average of three tests by an operator on any given material must correspond within  $\pm 4$  points with the average of three tests on the same material when tested using the mechanical shaker method (Referee Method).
- 9.2** If an operator is not capable of obtaining consistent results with the manual shaker method, or if his results do not agree with results obtained by the mechanical shaker method, he is not to perform the sand equivalent test using the manual shaker until he has perfected his technique sufficiently to bring his test results into the specified limits without adjusting the required number of cycles.
- 8.3** If an operator is capable of obtaining consistent results when qualifying for the hand method, but the average of his results does not agree within the prescribed limits of the average of three results by the mechanical shaker method, he shall adjust the number of shaking cycles sufficiently to cause his results to agree with those by the mechanical shaker method. Determine the required adjustment in the shaking cycles by the following method:
- 9.3.1** Estimate the adjusted number of shaking cycles required. Increase the number of cycles to obtain a lower sand equivalent test result or decrease the number of cycles to obtain a higher sand equivalent test result. Perform three tests at the adjusted number of cycles. Strive to maintain the prescribed shaking rate of 180 cycles per minute. Compare the average of the three test results using the adjusted number of strokes with the average obtained by the mechanical shaker method. If necessary, readjust the number of shaking cycles until the average result of three tests at the adjusted number of cycles is within  $\pm 4$  points of the average obtained by the mechanical shaker.
- 9.4** The  $\pm 4$  points is a minimum qualification and should not be considered perfection. Each operator should strive to perfect his technique to obtain results equivalent to those of the mechanical shaker method.
- 8.5** Operators should be required to perform qualification test whenever their results tend to vary appreciably from those obtained using the mechanical shaker method. Qualification tests should be made at regular intervals to assure a reasonable degree of accuracy and standardization of test results.