

**CURRENT DATE OF REVISION  
MT 200 SECTION  
SOIL AND AGGREGATE**

<b>Test Method No.</b>	<b><u>Title</u></b>	<b><u>Pages</u></b>	<b><u>Date of Publication or Revision</u></b>
MT 200	Vacant (Use AASHTO R 58)		
<a href="#">MT 201</a>	<a href="#">Sampling Roadway Materials .....</a>	7 pp	Oct 2013
<a href="#">MT 202</a>	<a href="#">Sieve Analysis for Fine and Coarse Aggregate .....</a>	9 pp	Nov 2011
MT 203	Vacant (Use AASHTO T 19)		
MT 204	Vacant (Use AASHTO T 84)		
MT 205	Vacant (Use AASHTO T 85)		
MT 206	Vacant (ELIMINATED)		
<a href="#">MT 207</a>	<a href="#">Centerline Soil Survey.....</a>	10 pp	Jun 2004
MT 208	Vacant (Use AASHTO T 89 and AASHTO T 90)		
MT 209	Vacant (Use AASHTO T 96)		
<a href="#">MT 210</a>	<a href="#">Moisture-Density Relations of Soils Using 5.5 lb. Rammer and 12 In. Drop</a>	1 pp	Dec 2016
MT 211	Vacant (Use AASHTO T 134)		
<a href="#">MT 212</a>	<a href="#">Determination of Moisture and Density of In-Place Materials.....</a>	5 pp	Dec 2016
MT 213	Vacant (Use AASHTO T 176)		
MT 214	Vacant (Use AASHTO M 145)		
MT 215	Vacant (moved to MT 122)		
<a href="#">MT 216</a>	<a href="#">Method of Sampling and Testing Cement Treated Base .....</a>	5 pp	Oct 2013
MT 217	Vacant (Use AASHTO T 335)		
<a href="#">MT 218</a>	<a href="#">Determining Relative Compaction and Percent Moisture .....</a>	2 pp	Jun 2004
<a href="#">MT 219</a>	<a href="#">Controlling Compaction Using a Control-Strip Test-Section Technique with Nuclear Gauges .....</a>	3 pp	Jun 2004
MT 220	Vacant (Use AASHTO T 100)		
MT 221	Vacant (Use AASHTO T 255)		
MT 222	Vacant (Use AASHTO T 191)		
MT 223	Vacant (Use AASHTO T 112)		
MT 224	Vacant (ELIMINATED)		
MT 225	Vacant (ELIMINATED)		
<a href="#">MT 226</a>	<a href="#">Maximum Acceptable Deviations in Sieve Analysis of IA Samples .....</a>	1 pp	Dec 2016
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<b><u>Test Method No.</u></b>	<b><u>Title</u></b>	<b><u>Pages</u></b>	<b><u>Date of Publication or Revision</u></b>
MT 230	Moisture-Density Relation of Soils Using a 10 lb Rammer and 18 In. Drop .	1 pp	Dec 2016
MT 231	Vacant (ELIMINATED)		
MT 232	Soil Corrosion Test.....	3 pp	Dec 2016
MT 233	Vacant (Use AASHTO T 327)		

**METHODS OF SAMPLING AND TESTING**  
**MT 201-13**  
**SAMPLING ROADWAY MATERIALS**

**1 General**

- 1.1 Sampling for evaluation of potential aggregate sources should be performed by a responsible, trained and experienced person. Because of the wide variety of conditions under which sampling may be done, it is not possible to describe detailed procedures applicable to all circumstances.
- 1.2 The sample bags must be tightly-woven and durable so that the required amount of sample can be shipped without rupture of the bag or loss of fine material through the fabric. Also, when tied, as in 1.3, the bag must be sealed tightly enough to prevent loss or contamination of the material.
- 1.3 Samples shall be double-tied as close to the gravel as possible with the necessary papers between the double tie. This procedure insures a good sample together with a legible laboratory sheet.

**2 Referenced Documents*****MT Materials Manual***

MT 101 Making and Curing Concrete Compressive and Flexural Strength Field Test Specimens  
MT 202 Sieve Analysis of Fine and Coarse Aggregate  
MT 207 Centerline Soil Survey  
MT 210 Moisture Density Relation of Soils Using a 5.5 lb. Rammer  
MT 218 Determining Relative Compaction and Percent Moisture  
MT 230 Moisture Density Relation of Soils Using a 10 lb. Rammer  
MT 601 Materials Sampling, Testing and Acceptance Guide  
MT 607 Procedure for Reducing Filed Samples to Testing Size

**3 Number of Samples**

- 3.1 The frequency of sampling as described in this procedure is the minimum required and more should be taken if deemed necessary.

**4 Pre-construction Proposed Surfacing Sampling**

- 4.1 Proposed surfacing samples should represent a vertical cross-section of the proposed source.
  - 4.1.1 Describe each site or area investigated with each test hole, boring or test pit clearly located (horizontally and vertically) with reference to some established coordinate system or permanent monument on an area map or sketch.
  - 4.1.2 Log each test hole, boring, test pit or cut-surface exposure with the field description and location of each material encountered clearly shown by Montana Department of Transportation symbols and word descriptions used on Form 30. An example of Form 30 is in MT 207.
  - 4.1.3 Each aggregate layer that is included in the sample should be noted along with the depth of the water table if it is encountered should be shown on the log of test holes.
- 4.2 Overburden or clay seams may be sampled separately.
- 4.3 Rocks larger than 6 inches (150mm) in diameter shall not be included in the sample. However, the estimated percentage of rock larger than 12 inches (300mm); between 6 and 12 inches (150 and 300mm); between 4 and 6 inches (100 and 150mm); and less than 4 inches (100mm) in diameter shall be shown on the Prospected Area Report.

- 4.4 Representative samples shall be taken on the following basis:
  - 4.4.1 Each sample shall be a minimum of 150 pounds (68 Kg).
  - 4.4.2 Not less than 3 samples shall be taken from any proposed source.
  - 4.4.3 Up to 50,000 cubic yards (38,230 cubic meters) - a minimum of 3 samples.
  - 4.4.4 50,000 to 100,000 cubic yards (38,230 to 76,460 cubic meters) - 3 to 5 samples.
  - 4.4.5 100,000 to 150,000 cubic yards (76,460 to 114,690 cubic meters) - 5 to 8 samples.
  - 4.4.6 150,000 to 200,000 cubic yards (114,690 to 152,920 cubic meters) - 8 to 10 samples.
  - 4.4.7 Providing the material is uniform, one sample may represent material from as many as ten test holes in large areas if provisions 4.4.1 through 4.4.6 above are met.
  - 4.4.8 For large sources, a suggested sampling sequence is to take samples around the perimeter of the source with additional samples taken toward the middle to check for uniformity. Each proposed source is unique, however, and the final sampling sequence shall be determined by the District Materials Supervisor or Area Lab Supervisor.
- 4.5 The District or Area laboratory will determine the gradation, LL, PL, PI, soil class and 24-hour volume swell and submit to the Materials Bureau on a form 123. Also, a visual examination by the Materials Supervisor will be made. An interpretation of these results will determine if the material in the proposed source is worthy of further consideration.
  - 4.5.1 Predominately Unacceptable - If the tests show the material to be predominately unsatisfactory and material of a better quality is available, no further consideration shall be given this source.
  - 4.5.2 Uniformly Acceptable - If the tests indicate the material is uniformly satisfactory, at least one sample for every six tested in the District or Area laboratory (a minimum of three) shall be sent to the Materials Bureau. Each sample shall consist of 1-75 lb. (34 Kg) split for wear, gradation and other correlations (see note 1). Also, a 300 lb. composite sample for Mix design testing shall be submitted for these areas. Additionally, one 180 lb. (32 Kg) composite sample per source is required for Sodium Sulfate and Micro-Deval testing.
  - 4.5.3 Spotty sources - If the tests indicate the material is spotty, at least one sample for every six tested in the District or Area laboratory (a minimum of one) for each of the areas (satisfactory, questionable, and unsatisfactory) shall be sent to the Materials Bureau for wear test, gradation check, evidence of disintegration, and other correlations. Also, a 300 lb. composite sample for Mix design testing shall be submitted for these areas. Additionally, one 180 lb. (32 Kg) composite sample per source is required for Sodium Sulfate and Micro-Deval testing.

Number of Representative Pounds from Each Hole to Make Composite				
Holes	Sodium Sulfate		Micro Deval	
	Lbs.	Kg	Lbs.	Kg
2	120	54	60	27
5	24	11	12	5
10	12	5	6	3
15	8	4	4	2

*Note 1 – Each area within a source that exhibits different physical characteristics should be sampled completely as per 4.5.2. In a large volume area one sample may be a composite of a series of holes of uniform material (example: sample number 1 may be a composite of holes 1 through 6; sample number 2 - holes 7 through 12; sample number 3 - holes 13 through 20, etc.) The example cited above is to be used as a guide only.*

- 4.5.4 Material for each portion of the composite sample shall be obtained by quartering, splitting, recombining and splitting again according to MT 607 so that a homogenous mix is obtained. The material will be split so that no more than 77 lbs. (35 Kg) are placed in one bag.
- 4.5.5 The Core Drill Section, under the direction of the Geotechnical Section, can be utilized in problem areas where conventional equipment is inadequate. Assistance, either geologic or drilling, can be provided usually within a period of a month or six weeks.

## **5 Laboratory Form No. 99**

- 5.1 The "Field Sample Analysis Report" Form No. 99 is to be used in reporting district or area laboratory tests. This information will be transferred to the "Available Surfacing Material Report" in Helena and will be available to prospective bidders, along with the usual Materials Bureau test results.
- 5.2 The District Materials Supervisor or Area Lab Supervisor is to use his experience and engineering judgment to give a summation of all information such as the past history of the source and his comments and recommendations regarding the laboratory test data which would include a statement as to which holes were represented by the Sodium Sulfate and Micro-Deval samples. This information will be placed on the bottom portion of Lab Form No. 99. However, the acceptance or rejection of the source will be the responsibility of the Materials Bureau in Helena when all testing is complete.

## **6 Laboratory Form No. 92**

- 6.1 The field information on Laboratory Form No. 92 shall include a correct legal description of the deposit. In some cases, it may be necessary to have a survey party retrace the boundary lines and make section line ties before right-of-way negotiations can be completed. Where deposits are located adjacent to the highway right-of-way, the boundary lines of the deposit should be tied to the centerline and shown on Laboratory Form No. 92 so that a legal description can be prepared without any further field work. Under some circumstances, the Department of Transportation will obligate by purchase or option surfacing material sources for future construction projects and maintenance use.
- 6.2 Form No. 92 "Prospected Area Report" must be completely filled out especially with reference to definite location, total yardage represented by the samples, ownership, and depth of overburden. The haul distance shall be reported to the nearest one-tenth mile over the shortest and most practical route from the deposit to a definite station on the project.
- 6.3 A sketch shall be attached Form No. 92 showing the boundary lines of the deposit with all dimensions and ties neatly plotted to a scale that is indicated on the sketch. All test holes shall be numbered and shown in their correct location.
- 6.4 In those cases where areas are being explored on which data has been previously submitted, a new "Prospected Area Report" shall accompany the new sampling showing any laboratory numbers previously assigned.

## **7 Reports on Proposed Surfacing Sources**

- 7.1 The Materials Bureau will issue a final report based on an evaluation of the district or area laboratory test data, the recommendations of the District Materials Supervisor or Area Lab Supervisor, and an interpretation of tests performed by the Materials Bureau.

## **8 Preconstruction Binder Samples**

- 8.1 Binder samples shall be taken incidental to all proposed gravel source exploration. A 25 lb. (11 Kg) sample from each distinct type proposed for use shall be taken and tested in the district or area laboratory. Binder samples need not be sent to the Materials Bureau unless an unusual problem arises.

**9 Size of Samples: Required for District, Area and Materials Bureau Testing**

9.1 The sample size depends on 100% of the aggregate passing the specified sieve size. The amounts specified in the table below provide adequate material for routine testing (gradation, LL, PI, volume swell, etc.). Minimum Field Test sample sizes are in MT 202.

SPECIFIED 100% PASSING SIEVE SIZE	MINIMUM WEIGHT OF SAMPLE (See Note 2)
4.75 mm (4 Mesh)	14 Kg (30 lb.)
9.5 mm (3/8 Inch)	14 Kg (30 lb.)
12.5 mm (1/2 Inch)	14 Kg (30 lb.)
16.0 mm (5/8 Inch)	14 Kg (30 lb.)
19.0 mm (3/4 Inch)	14 Kg (30 lb.)
25.0 mm (1 Inch)	35 Kg (77 lb.)
37.5 mm (1½ Inch)	35 Kg (77 lb.)
50 mm (2 Inch)	35 Kg (77 lb.)
63 mm (2½ Inch)	35 Kg (77 lb.)

*Note 2 – The sample shall be obtained by quartering or splitting to insure a representative sample. If necessary, the representative sample shall be split again so that no more than 77 lbs. (35 Kg) are placed in two bags.*

**10 Sampling from Stockpiles**

10.1 When such sampling is necessary, every effort should be made to enlist the services of power equipment to develop a separate, small sampling pile composed of materials drawn from various levels and locations in the main pile after which several increments may be combined to compose the field sample.

10.2 Coarse Aggregate Stockpiles – Where power equipment is not available, samples from stockpiles should be made up of at least three increments taken from the top third, at the midpoint, and at the bottom third of the volume of the pile. A board shoved vertically into the pile just above the sampling point aids in preventing further segregation.

10.3 Fine Aggregate Stockpile – A suggested sampling procedure for fine aggregate would be to remove the outer layer, which may have become segregated and take the sample from the material beneath. Sampling tubes approximately 1¼ inches (30-mm) minimum by 6 feet (2-m) minimum in length may be inserted into the pile at random locations to extract a minimum of five increments of material to form the sample.

**11 Production Sampling**

11.1 Production samples shall be taken in three equal increments from a stopped belt or with an automatic sampling device and combined to make the sample. Such samples shall be reduced to testing size, according to MT 607, Method A or Method B.

**12 Windrow Sampling (Cement Treated Base and Cold In-Place Recycle)**

12.1 Samples should be composed of a number of samples taken at various points along the windrow, combined and reduced to testing size according to MT 607, Method A or Method B.

**13 Pug Mill – Mixed Aggregate Sampling**

13.1 Samples for gradation and fracture testing shall be taken from a minimum of three increments from the processed material on the roadway after lay down.

13.2 Samples for crushed cover material gradation and fracture will be taken at the most convenient point before application determined by the engineer.

13.3 Samples for other specified properties will be taken at the point of production.

**14 Sampling from Roadway**

- 14.1 Samples from the roadway (minimum of three increments) should be taken for the full depth of the material, taking care to exclude any underlying material. Where necessary, place templates on the existing roadway to separate the underlying material from the sample. The sample shall be taken from the processed material on the roadway after laydown.
- 14.2 District or Area labs will determine the gradation, LL, PL, PI and soil class for Soil Survey "R" Value samples. The results will be reported on a form 123 which will accompany the sample to the Materials Bureau.

**15 "Special Borrow"**

- 15.1 District or Area labs will determine the gradation, LL, PL, PI and soil class for Special Borrow "R" Value samples. The results will be reported on a form 123 which will accompany the sample to the Materials Bureau.

**16 Reduction of Sample Size by Quartering or Splitting**

- 16.1 The procedure for reducing the size of field sample of aggregate is described in MT 607.

**17 Required Production Samples other than Aggregates for Plant Mix**

- 17.1 Field testing for Acceptance shall conform to the frequency as shown in MT 601, under "Aggregate Surfacing".

**18 Independent Assurance Samples**

- 18.1 The District or Area laboratories shall take Independent Assurance samples in accordance with the frequency shown in MT 601. The same sample shall be tested by each lab, with all the material returned to the sample.
- 18.2 If discrepancies occur between the District or Area laboratory and the Acceptance samples, the District or Area laboratory will investigate and change any procedures or equipment found to be causing the differences.
- 18.3 If differences are found to exist between the District or Area laboratory and the Materials Bureau, the Materials Bureau will have the authority to investigate all of the testing procedures and make any changes found necessary.

**19 Plant Mix Aggregates**

- 19.1 Sampling will be in accordance with the sample size and frequency described in MT 601 and the following:
- 19.2 WHEN STOCKPILED - In order to establish a stockpile average, the samples shall be secured and tested as the stockpile is being produced.
- 19.3 BATCH TYPE HOT PLANT- A representative sample of dried aggregate shall be provided by means of an approved sampling device.
- 19.4 DRYER DRUM HOT PLANT - A representative composite sample shall be provided, by means of an approved sampling device, at a point just prior to the aggregate entering the dryer drum mixer.
- 19.5 CONTINUOUS FLOW HOT PLANT - A representative sample of dried aggregate shall be provided by means of an approved sampling device.

**20 Aggregates for Design**

- 20.1 MAINTENANCE MIX DESIGN - The amount of material submitted to the Materials Bureau for a proposed mix design shall be as follows: Plant Mix Aggregate - 300 lbs. (136 Kg), Seal and Cover Aggregate - 150 lbs. (68 Kg).
- 20.2 The sample shall be prepared in the district or area laboratory as described in 19.2 and 19.3.
- 20.3 Non-Quality Assurance Projects
  - 20.3.1 When a satisfactory stockpile average has been established, a sieve analysis shall be performed, in the District or Area laboratory, on a representative sample of the stockpiled material.
  - 20.3.2 Compare the sieve analysis obtained in paragraph 19.2 above, to the established stockpile average.
  - 20.3.3 If the minus 4 mesh portion of the sample is within plus or minus 2% and the minus 200 mesh portion is within plus or minus 1% of the stockpile average, the sample may be submitted to the Materials Bureau for a mix design, without further preparation.
  - 20.3.4 If the sample does not meet the above criteria, it will be necessary to adjust the gradation, in the District or Area laboratory, to allowable variations described in paragraph 20.2.3 above, before it is shipped to the Materials Bureau.
  - 20.3.5 The stockpile average shall be shown on the laboratory work sheet that accompanies the sample.

**21 Mineral Filler**

- 21.1 One 2.3 Kg (5 lb.) sample per project of mineral filler will be sampled and submitted to the Materials Bureau for testing and acceptance.

**22 Compaction Samples**

- 22.1 The District or Area laboratory shall run at least one sample from each different soil type using the methods described in MT 210 or MT 230. It will not be necessary to submit compaction samples to the Materials Bureau. If the material being sampled consists of fine material, 30 pounds (14 Kg) shall be obtained. If the material consists of coarse and fine material, the sample shall be large enough to yield 30 lbs. (14 Kg) of the fine material (minus 4 mesh).

**23 Field Density Tests**

- 23.1 Field density tests shall be taken in accordance with MT 601, under "Density Control, Embankment" and MT 218 (Determining Relative Compaction and Percent Moisture).

**24 Concrete Aggregates**

- 24.1 Concrete aggregate samples shall be submitted in accordance with MT 601.

**25 Concrete Test Specimens**

- 25.1 Concrete compressive and flexural strength test specimens will be made and cured in accordance with MT 101.

**26 Cement Treated Base**

- 26.1 Cement Treated Base shall be sampled in accordance Section 12.1 or Section 14.1, and MT 601.

**27 Field Construction Sampling**

- 27.1 Samples for soil classification and “R” value shall be obtained from the top 2 feet (0.6 meters) of the sub-grade. Sample frequency will be one sample every 1000 feet (305 meters) for projects with 3 or more cuts or fills per mile. If the project has fewer than 3 cuts or fills per mile the sample distance is extended to 2000 feet (610 meters).
- 27.2 District/Area lab personnel will determine the soil classification. If the soil class is not equal to or better than that used by the Surfacing Design Unit to determine the typical section, then samples for “R” value determination are to be submitted to the Materials Bureau in Helena.
- 27.3 Samples for soil classification and/or “R” value are not required when the top two feet of subgrade is constructed with Special Borrow tested and accepted at the borrow source. However, samples may be obtained from the roadway and tested to ensure the in-place material meets the contract requirements. Take samples whenever the material delivered to the roadway appears to differ from samples used for pit acceptance. Sample frequency is at the discretion of the Project Manager.

*Note 3 – These samples are as a design check only. Sampling every 1000 feet (305 meters) is a general guide and some discretion should be used. For example, it may be advisable to take more samples in fill sections than cut sections, or if there is an obvious change in the soil conditions or soil class, etc. No samples will be required for typical sections with a design “R” of 5 or less or for soils classified as A-6 or A-7.*



**METHODS OF SAMPLING AND TESTING**  
**MT 202-11**  
**SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES**  
*(Modified AASHTO T 11 AND T 27)*

**1 Scope**

- 1.1 This method covers the determination of the particle size distribution of fine and coarse aggregates by sieving.
- 1.2 Material passing the 4.75 mm (no. 4) sieve will be washed. Clay particles and other aggregate particles that are dispersed by the wash water, as well as water-soluble materials, will be removed from the aggregate during testing.

**2 Referenced Documents****AASHTO**

- M 231 Weighing Devices Used in the Testing of Materials  
T 11 Materials Finer Than 75- $\mu$ m (No. 200) Sieve in Mineral Aggregates by Washing  
T 27 Sieve Analysis of Fine and Coarse Aggregates

**MT Materials Manual**

- MT 201 Sampling Roadway Materials  
MT 405 Wire Cloth Sieves for Testing Purposes  
MT 607 Reducing Field Samples of Aggregate to Testing Size

**3 Definitions**

- 3.1 *Constant Mass* – Constant mass has been reached when there is less than a 0.1 percent change in mass over a monitored drying time. For an oven ( $110 \pm 5^\circ \text{C}$  ( $230 \pm 9^\circ \text{F}$ )), an additional 30 minutes of drying. For an uncontrolled heating source such as hot plates, an additional 20 minutes of drying, or microwaves, an additional 10 minutes of drying.

**4 Apparatus**

- 4.1 *Balance* – The scale or balance for the coarse 4.75 mm (plus 4 mesh) material shall have a sensitivity of 0.01 pounds or 0.01 kilograms. The scale or balance for the fine 4.75 mm (minus 4 mesh) material shall have a sensitivity of 0.1 gram.
- 4.2 *Sieves* – The sieve cloth shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. Suitable sieve sizes shall be selected to furnish the information required by the specifications covering the material to be tested. The sieves shall conform to the requirements of MT 405, Wire Cloth Sieves for Testing Purposes.
- 4.2.1 *Sieves* – A nest of two sieves, the lower being a 75- $\mu$ m (No. 200) sieve and the upper being a sieve with openings in the range of 2.36 mm (No. 8) to 1.18 mm (No. 16), both conforming to the requirement of MT 405.
- 4.3 *Container* – A container sufficient in size to contain the sample covered with water and to permit vigorous agitation without inadvertent loss of any part of the sample or water.
- 4.4 *Heat Source* – A heat source capable of drying samples in accordance with Section 5.
- 4.5 *Mechanical Sieve Shaker* – A mechanical sieving device shall create motion of the sieves to cause the particles to bounce, tumble, or otherwise turn so as to present different orientations to the sieving surface. The sieving action shall be such that the requirement for sieving thoroughness as described in Section 7.3 is met within a reasonable amount of time.

**5 Preparation of Samples**

- 5.1 Samples for sieve analysis shall be prepared in accordance with MT 607, Reducing Field Samples of Aggregates to Testing Size. The samples shall be the mass desired when dry. The selection of samples of an exact predetermined mass shall not be permitted.
- 5.2 Dry the sample to a constant mass. For control purposes, particularly where rapid results are desired, it is generally not necessary to dry coarse aggregate to a constant mass for the sieve analysis test. The results are insignificantly affected by the moisture content unless the nominal maximum size is smaller than 12.5 mm (½ in.), or the coarse aggregate contains appreciable material finer than 4.75 mm (No. 4); or the coarse aggregate is highly absorptive (a lightweight aggregate, for example). Samples may be dried at higher temperatures associated with the use of hot plates or other uncontrolled heat sources without affecting results, provided steam escapes without generating pressures sufficient to fracture the particles, and temperatures are not so great as to cause chemical breakdown of the aggregate.

*Note 1 – Samples taken for Liquid Limit, Plastic Limit, and Plasticity Index shall be air dried or dried at a temperature no greater than 140°F or 60°C.*

*Note 2 – Air drying is an acceptable method.*

- 5.3 Representative samples will be graded to determine the percentage of fine material adhering to the coarser fractions.
- 5.4 *Fine Aggregate* – The test sample of fine aggregate shall weigh, after drying, approximately the following amount:

Aggregate with at least 95% passing a 2.36 mm (No. 8) sieve . . . 100g  
 Aggregate with at least 85% passing a 4.75 mm (No. 4) sieve  
 and more than 5% retained on a 2.36 mm (No. 8) sieve . . . . . 500g

- 5.5 *Coarse Aggregate* – The mass of the test sample of coarse aggregate shall conform with the following:

Specified 100% Passing Sieve Size		Min. Field Test Sample Size*	
mm	(in)	Kg	(lb)
*9.5	(3/8)	6.8	(15)
*12.5	(1/2)	6.8	(15)
*19.0	(3/4)	9.1	(20)
*25.0	(1)	11.3	(25)
*37.5	(1½)	15	(33)
50	(2)	20	(44)
63	(2½)	35	(77)

*Note 3 – For cover material, concrete aggregate, and samples that require a wear, cleanliness value test, the sample size sent to Helena must be doubled.*

- 5.6 *Coarse and Fine Aggregate Mixtures* – The mass of the test sample of coarse and fine aggregate mixtures shall be the same as for coarse aggregate.

**6 Procedure for Calculating Clinging Fines**

- 6.1 Follow the procedure in Section 5 for the original test. Save the plus 4.75 mm (4 mesh) material.
- 6.2 Wash the plus 4.75 mm (4 mesh) material over a protected 75 µm (200 mesh) screen. In most cases it is not necessary to rewash the minus 4.75 mm (4 mesh) material. Dry and re-screen over the original sized screens. Use the original mass of sample taken for the calculation of the plus 4.75 mm (4 mesh) percentages.

- 6.3 Obtain the difference between the original plus 4.75 mm (4 mesh) material and the washed plus 4.75 mm (4) material. Record for use in calculations of the minus 4.75 mm (4 mesh) material. To convert from the pounds of minus 4 mesh material to grams, multiply by 453.6.

Example:  $(0.39 \text{ pounds}) \times (453.6) = 176.9 \text{ grams}$ .

Use the percentage difference passing the 4.75 mm (4 mesh) divided by the before wash weight to get the reciprocal for multiplication.

Example:  $(1.55\%)/176.9 \text{ g} = 0.00876$

- 6.4 The total percent clinging fines is the difference in percent of the plus 4.75 mm (4 mesh) screen sizes.

Example:  $55.61\%(\text{dry}) - 54.06\%(\text{washed}) = 1.55\%$  (report as 1.6%)

## 7 Procedure for Aggregate without Clinging Fines

- 7.1 The total sample as prepared in Section 5 shall be separated into a series of sizes. To determine compliance with the specifications for the material under test, avoid overloading the screens.
- 7.2 Coarse Aggregate: Plus 4.75 mm (4 Mesh) Material – The individual mass of the plus 4.75 mm (4 mesh) portion of the sample, retained on each screen, shall be determined and recorded to the nearest 0.01 of a pound or 0.01 kilogram.
- 7.2.1 The individual portions shall be saved until the entire plus 4.75 mm (4 mesh) portion of the sample has been screened, weighed and the weights recorded, before any of the material is discarded.
- 7.2.2 The total amount of material finer than the plus 4.75 mm (4 mesh) sieve may be determined by subtracting the total mass of material retained on the plus 4.75 mm (4 mesh) sieve from the total mass of the initial dry sample being tested.
- 7.3 Fine Aggregate: Minus 4.75 mm (4 Mesh) Material – At the completion of the sieving as described in Section 7.2, the entire minus 4.75 mm (4 mesh) portions shall be thoroughly mixed and reduced to a minimum of 500 grams.
- 7.3.1 After drying the sample to a constant mass and weighing, place the test sample in the container and add sufficient water to cover it. A detergent, dispersing agent, or other wetting solution may be added to the water to assure a thorough separation of the material finer than the 75  $\mu\text{m}$  (No.200) sieve from the coarser particles (Note 4). Agitate the sample with sufficient vigor to result in complete separation of all particles finer than the 75  $\mu\text{m}$  (No. 200) sieve from the coarser particles, and to bring the fine material into suspension. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, arranged with the coarser sieve on top. Take care to avoid, as much as feasible, the decantation of coarser particles of the sample.

*Note 4 – There should be enough wetting agent to produce a small amount of suds when the sample is agitated. The quantity will depend on the hardness of the water and the quality of the detergent. Excessive suds may overflow the sieves and carry some material with them.*

- 7.3.2 Add a second change of water (without wetting agent) to the sample in the container, agitate, and decant as before. Repeat the operation until the wash water is clear.

*Note 5 – If mechanical washing equipment is used, the charging of water, agitating, and decanting may be a continuous operation.*

*Note 6 – A spray nozzle or a piece of rubber tubing attached to a water faucet may be used to rinse any of the material that may have fallen into the sieves. The velocity of the water, which may be increased by pinching the tubing, should not be sufficient to cause any splashing of the sample over the sides of the sieves.*

- 7.3.3 Return all material retained on the nested sieves by flushing to the washed sample. Dry the washed aggregate to a constant mass.
- 7.3.4 Following the washing of the sample and flushing any materials retained on the 75  $\mu\text{m}$  (No. 200) sieve back into the container, no water should be decanted from the container except through the 75  $\mu\text{m}$  sieve, to avoid loss of material. Excess water from flushing should be evaporated from the sample in the drying process.
- 7.3.5 The individual weights of each size of the minus 4.75 mm (4 mesh) portion retained on each sieve shall be determined and recorded to the nearest 0.1 gram.
- 7.3.6 The individual portions shall be saved until the entire minus 4.75 mm (4 mesh) portion of the sample that was washed has been screened, weighed, and the weights recorded, before any of the material is discarded.

## **8 Sieving Procedure**

- 8.1 Nest the sieves in order of decreasing size of opening from top to bottom and place the sample, or portion of the sample if it is to be sieved in more than one increment, on the top sieve. Agitate the sieves by hand or by mechanical apparatus for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy of sieving described in Section 8.3.
- 8.2 Limit the quantity of material on a given sieve so that all particles have an opportunity to reach sieve openings a number of times during the sieving operation. Table 1 shows the maximum allowable quantity of material that can be retained on each individual sieve at the completion of the sieving operation. In no case shall the quantity retained be so great as to cause permanent deformation of the sieve cloth.
  - 8.2.1 Prevent an overload of material on an individual sieve by splitting the sample into two or more portions, sieving each portion individually. Combine the masses of the several portions retained on a specific sieve before calculating the percentage of the sample on the sieve.
- 8.3 Continue sieving for a sufficient period and in such manner that, after completion, not more than 0.5 percent by mass of the total sample passes any sieve during one minute of continuous hand sieving. Perform as follows: Hold the individual sieve, provided with a snug-fitting pan and cover, in a slightly inclined position in one hand. Strike the side of sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turn the sieve about one sixth of a revolution at intervals of about 25 strokes. In determining sufficiency of sieving for sizes larger than the 4.75 mm (No. 4) sieve, limit the material on the sieve to a single layer of particles. If the size of the mounted testing sieves makes the described sieving motion impractical, use 203 mm (8 in.) diameter sieves to verify the sufficiency of sieving.
- 8.4 Unless a mechanical shaker is used, hand sieve particles obtained on the 75 mm (3 in) by determining the smallest sieve opening through which each particle will pass by rotating the particles, if necessary, in order to determine whether they will pass through the particular opening, however, do not force the particles to pass through an opening.
- 8.5 The efficiency of the mechanical shaker shall be checked periodically by comparing results with the hand method. This practice will help determine the length of time required for the mechanical bshaker to adequately separate material sizes.

Table 1 – Maximum Allowable Quantity of Material Retained on a Sieve, Kg (lb)

Sieve Opening Size	Nominal Dimensions of Sieve				
	8 in dia	10 in dia	12 in dia	14 x 14 in dia	16 x 24 in dia
125 mm (5 in)	a	a	a	a	67.4 (148.6)
100 mm (4 in)	a	a	a	30.6 (67.5)	53.9 (118.8)
90 mm (3 1/2 in)	a	a	15.1 (33.3)	27.6 (60.8)	48.5 (106.9)
75 mm (3 in)	a	8.6 (19.0)	12.6 (27.8)	23.0 (50.7)	40.5 (89.3)
63 mm (2 1/2 in)	a	7.2 (15.9)	10.6 (23.4)	19.3 (42.6)	34.0 (75.0)
50 mm (2 in)	3.6 (7.9)	5.7 (12.6)	8.4 (18.5)	15.3 (33.7)	27.0 (59.5)
37.5 mm (1 1/2 in)	2.7 (6.0)	4.3 (9.5)	6.3 (13.9)	11.5 (25.4)	20.2 (44.5)
25.0 mm (1 in)	1.8 (4.0)	2.9 (6.4)	4.2 (9.5)	7.7 (17.0)	13.5 (29.8)
19.0 mm (3/4 in)	1.4 (3.1)	2.2 (4.9)	3.2 (7.1)	5.8 (12.8)	10.2 (22.5)
12.5 mm (1/2 in)	0.89 (2.0)	1.4 (3.1)	2.1 (4.6)	3.8 (8.4)	6.7 (14.8)
9.5 mm (3/8 in)	0.67 (1.5)	1.1 (2.4)	1.6 (3.5)	2.9 (6.4)	5.1 (11.2)
4.75 mm (No 4)	0.33 (0.7)	0.54 (1.2)	0.80 (1.8)	1.5 (3.3)	2.6 (5.7)

a = Sieves as indicated have less than 5 full openings and should not be used for sieve testing.

## 9 Calculations

- 9.1 Calculate the cumulative weight passing and the percentages to the nearest 0.01 percent on the basis of the total mass of the initial dry sample.
- 9.2 *Coarse Aggregate: Plus 4.75 mm (4 Mesh) Material* – For each of the various sieves, the individual cumulative weights must be converted to total weight passing. The total weight passing is divided by the total weight of the initial dry sample multiplied by 100, which will result in the percent passing. (See the example on the following worksheets).
- 9.3 *Fine Aggregate: Minus 4.75 mm (4 Mesh) Material* - Calculating the percentages of the minus 4.75 mm (4 mesh) portion of the sample is simplified by using a reciprocal. The reciprocal is determined by dividing the percent of material passing the minus 4.75 mm (4 mesh) sieve by the weight of the minus 4.75 mm (4 mesh) sample before washing. This reciprocal, when multiplied by the various total weights passing, results in the percent passing, in relation to the total sample. (See the example on the following worksheets).

## 10 Report

- 10.1 Unless otherwise required, the results of the sieve analysis shall be reported as the total percentages passing each sieve size and reported to the nearest whole number for all material coarser than the 75  $\mu$ m (200 mesh) and reported to one tenth of one percent for the 75  $\mu$ m (200 mesh). Percentages shall be calculated on the basis of the total mass of the initial dry sample, including any material finer than the 75  $\mu$ m (200 mesh) sieve.

## 11 Hot Plant Mix Aggregates

- 11.1 Plant mix aggregates shall be governed by the provisions of MT 202, except that sampling will be in accordance with MT 201, which provides that the samples be obtained by means of an approved sampling device.

# Montana Department of Transportation

Materials Lab. No. \_\_\_\_\_ UPN \_\_\_\_\_ Contract No. \_\_\_\_\_  
 Dist. Lab. No. \_\_\_\_\_ Sample \_\_\_\_\_ Hole/IA# \_\_\_\_\_ Contract Item # \_\_\_\_\_  
 Project No. \_\_\_\_\_  
 Project Name \_\_\_\_\_  
 Date Sampled \_\_\_\_\_ Date Rec. Helena \_\_\_\_\_ Kind of Deposit \_\_\_\_\_  
 Sampled By \_\_\_\_\_ Witnessed by \_\_\_\_\_ Address \_\_\_\_\_  
 Submitted By \_\_\_\_\_ Title \_\_\_\_\_ Date \_\_\_\_\_  
 Quantity \_\_\_\_\_ Area by Stationing \_\_\_\_\_  
 Area is in \_\_\_\_\_ Sec. \_\_\_\_\_ T- \_\_\_\_\_ R- \_\_\_\_\_  
 Lab. No. \_\_\_\_\_ County \_\_\_\_\_  
 Supplier \_\_\_\_\_ Address \_\_\_\_\_  
 Sta. and/or Tons Production Sample \_\_\_\_\_ Lift No. \_\_\_\_\_  
 Examined for \_\_\_\_\_

<b>Constant Mass</b> (500 gram sample):				Initial Wt. <b>524.3</b> grams	Check Wt. <b>518.6</b> grams	Second Check Wt. <b>518.6</b> grams
Wt. of Sample Taken	<b>40.83</b> lbs.	100.00	%	LL	PL	PI
Wt. Retained 4-Mesh	<b>26.92</b> lbs.	<b>65.93</b>	%	Wear	%	Fld. Agg. Chart No.
Wt. Passing 4-Mesh.	<b>13.91</b> lbs.	<b>34.07</b>	%	Fracture	%	Sp.Gr. (F) [ (C)
Before Wash	<b>518.6</b>	After	<b>425.3</b>	LBW	<b>93.3</b>	Max. Dens.
						Soil Class
						Opt. Moist
						Wt./Ft.
						Dust Ratio
						Sand Equiv.
Wt. Ret.	"	Wt Pass	Pct	Spec	<b>Volume Swell</b>	
					Age	Treat
					%Swell	Spec.
					Specimen Condition	
	3"					
	2½"					
	2"					
	1½"		<b>100</b>		<b>"R-Value"</b>	
<b>3.63</b>	1"	<b>37.2</b>	<b>91</b>		Extrude Pressure	
<b>9.42</b>	¾"	<b>31.41</b>	<b>77</b>		Expansion Pressure	
<b>16.18</b>	½"	<b>24.65</b>	<b>60</b>		Equilibrium	
<b>20.04</b>	⅜"	<b>20.79</b>	<b>51</b>		<b>Micro-Deval / Sodium Sulfate</b>	
<b>26.92</b>	4M	<b>13.91</b>	<b>34</b>		Micro-Deval Loss	% Sodium Sulfate Loss
<b>146.5</b>	8M/10M	<b>372.1</b>	<b>24</b>		<b>Adhesion</b>	
<b>279.6</b>	40M	<b>239.0</b>	<b>16</b>		% Adhesion	Bitumen Adhesive Agent
<b>375.2</b>	80M	<b>143.4</b>	<b>9</b>			
<b>423.9</b>	200M	<b>94.7</b>	<b>6.2</b>			
<b>425.1</b>	Pan Wt.					
<b>0.0657</b>	Reciprocal		<b>0.04% is less than 0.3%</b>			
					<b>Checked &amp; Approved</b>	<b>Date</b>
						<b>Name</b>

Distribution List	
<input type="checkbox"/>	District Administrator
<input type="checkbox"/>	District Lab Supervisor
<input type="checkbox"/>	Area Lab Supervisor
<input type="checkbox"/>	Engr Project Manager
<input type="checkbox"/>	Maintenance Superintendent
<input type="checkbox"/>	Construction
<input type="checkbox"/>	Preconstruction
<input type="checkbox"/>	County File
<input type="checkbox"/>	Surfacing Design
<input type="checkbox"/>	Helena
<input type="checkbox"/>	Master Lab File
<input type="checkbox"/>	

Independent Assurance Comparison			
Sieve	Field	Dist	Helena

REMARKS: See the following page for a written explanation of calculations used for this form (F123-E).

**Calculations used on form F123-E**

**PLUS 4.75 mm (+4 MESH) MATERIAL** - The total weight passing each sieve divided by the total weight of the initial sample taken (40.83 lbs.), multiplied by 100, results in the percent passing. EXAMPLE:  $13.91 \div 40.83 = 0.34 \times 100 = 34\%$  The value is rounded and recorded to the nearest whole number.

**MINUS 4.75 mm (-4 MESH) MATERIAL** – (By Reciprocal Method). This sample is dried to a constant mass before and after washing. A reciprocal is determined by dividing the percent of material passing the 4 mesh (34.07%) by the mass of the minus 4 mesh sample (518.6 grams). This reciprocal (0.0657) is multiplied by the cumulative weight passing for each sieve size.

EXAMPLE:  $518.6 - 146.5 = 372.1$ ;  $372.1 \times 0.0657 = 24.45\%$  and is rounded down to and is recorded as 24%. The rounding is either up or down to the nearest whole number with the exception of the 200 mesh which is carried to one tenth of a percentage (6.2%). The result represents the percent passing in relation to the total sample.

The adjusted cumulative mass retained in the pan plus the Loss By Wash (LBW) mass should be within 0.3% of original dry mass of the total sample. EXAMPLE:  $425.1 + 93.3 = 518.4$ ,  $518.6 - 518.4 = 0.2$ ,  $(0.2/518.6) \times 100 = 0.04\%$

# MONTANA DEPARTMENT OF TRANSPORTATION

## Field Aggregate Chart - Sample for Clinging Fines

Project No.: \_\_\_\_\_ Contract No.: \_\_\_\_\_ Project Name: \_\_\_\_\_ Mat'ls. Suprv.: \_\_\_\_\_  
 Contract Item # \_\_\_\_\_ UPN : \_\_\_\_\_ Material # : \_\_\_\_\_  
 County: \_\_\_\_\_ Laboratory Pit No.: \_\_\_\_\_ Test For: \_\_\_\_\_  
 Pit Location: \_\_\_\_\_ Section: \_\_\_\_\_ Township: \_\_\_\_\_ Range: \_\_\_\_\_

Test No. \_\_\_\_\_ Lot No. \_\_\_\_\_ Date \_\_\_\_\_ Stationing \_\_\_\_\_ Lift \_\_\_\_\_ Lane \_\_\_\_\_  
 Sampled By \_\_\_\_\_ Tested By \_\_\_\_\_

Constant Mass	Wt. 1	_____	Wt. 2	_____	Wt. 3	_____	Constant Mass	Wt. 1	_____	Wt. 2	_____	Wt. 3	_____
Wt. of Sample Taken		<b>25.23</b> Lbs.				100%	Wt. of Orig. Sample Taken		<b>25.23</b> Lbs.				
Wt. Retained 4-Mesh		<b>11.59</b> Lbs.				<b>45.94%</b>	Difference in Weight						
Wt. Passing 4-Mesh		<b>13.64</b> Lbs.				<b>54.06%</b>	Passing 4 - Mesh		<b>0.39</b> Lbs				<b>1.55%</b>
Before Wash	<b>520.5</b>		After Wash	<b>448.0</b>		LBW	<b>72.5</b>	Before Wash	<b>176.9</b>		After Wash		LBW

Cum. Wt. Ret.	Size	Tot. Wt. Pass	Percent	Spec.	Cum. Wt. Ret.	Size	Tot. Wt. Pass	Percent	Spec.	Actual Grading % Passing	Size	% Clinging Fines
_____	4 1/2"	_____	_____	_____	_____	4 1/2"	_____	_____	_____	_____	_____	_____
_____	4"	_____	_____	_____	_____	4"	_____	_____	_____	_____	4 1/2"	_____
_____	3 1/2"	_____	_____	_____	_____	3 1/2"	_____	_____	_____	_____	4"	_____
_____	3"	_____	_____	_____	_____	3"	_____	_____	_____	_____	3 1/2"	_____
_____	2 1/2"	_____	_____	_____	_____	2 1/2"	_____	_____	_____	_____	3"	_____
_____	2"	_____	_____	_____	_____	2"	_____	_____	_____	_____	2 1/2"	_____
_____	1 1/2"	_____	_____	_____	_____	1 1/2"	_____	_____	_____	_____	2"	_____
_____	1 1/4"	_____	_____	_____	_____	1 1/4"	_____	_____	_____	_____	1 1/2"	_____
_____	1"	_____	_____	_____	_____	1"	_____	_____	_____	_____	1 1/4"	_____
<b>0</b>	5/8 3/4"	<b>25.23</b>	<b>100</b>	_____	<b>0</b>	5/8 3/4"	<b>25.23</b>	<b>100</b>	_____	_____	1"	_____
<b>1.29 lbs</b>	1/2"	<b>23.94</b>	<b>94.89</b>	_____	<b>1.22 lbs</b>	1/2"	<b>24.01</b>	<b>95.16</b>	_____	<b>100</b>	5/8 3/4"	<b>0</b>
<b>4.69 lbs</b>	3/8"	<b>20.54</b>	<b>81.41</b>	_____	<b>4.43 lbs</b>	3/8"	<b>20.80</b>	<b>82.44</b>	_____	<b>95.16</b>	1/2"	<b>0.27</b>
<b>* 11.59 lbs</b>	4 M	<b>13.64</b>	<b>54.06</b>	_____	<b>* 11.20 lbs</b>	4 M	<b>14.03</b>	<b>55.61</b>	_____	<b>82.44</b>	3/8"	<b>1.03</b>
<b>219.7 g</b>	8/10 M	<b>300.8</b>	<b>31.25</b>	_____	<b>19.9 g</b>	8/10 M	<b>157.0</b>	<b>1.38</b>	_____	<b>55.61</b>	4 M	<b>1.55</b>
<b>375.8 g</b>	40 M	<b>144.7</b>	<b>15.03</b>	_____	<b>48.4 g</b>	40 M	<b>128.5</b>	<b>1.13</b>	_____	<b>32.63</b>	8/10 M	_____
<b>420.5 g</b>	80 M	<b>100.0</b>	<b>10.39</b>	_____	<b>90.0 g</b>	80 M	<b>86.9</b>	<b>0.76</b>	_____	<b>16.16</b>	40 M	_____
<b>447.9 g</b>	200 M	<b>72.6</b>	<b>7.54</b>	_____	<b>174.9 g</b>	200 M	<b>2.0</b>	<b>0.02</b>	_____	<b>11.15</b>	80 M	_____
_____	Pan/Total	_____	_____	_____	_____	Pan/Total	_____	_____	_____	<b>7.56</b>	200 M	_____
_____	Reciprocal	<b>0.1039</b>	_____	_____	_____	Reciprocal	<b>0.0088</b>	_____	_____	_____	Pan/Total	_____
_____		_____	_____	_____	_____		_____	_____	_____	_____	Reciprocal	_____

\* ±4 Mesh Sample Split and Sieved

Dust Ratio _____%	Dust Ratio _____%
Moisture _____%	Moisture _____%
Fracture _____%	Fracture _____%
Liquid Limit _____	Liquid Limit _____
Plasticity Index _____	Plasticity Index _____

**NOTE: Report the % Clinging Fines to the tenth, 1.6%**

Dust Ratio \_\_\_\_\_%  
 Moisture \_\_\_\_\_%  
 Fracture \_\_\_\_\_%  
 Liquid Limit \_\_\_\_\_  
 Plasticity Index \_\_\_\_\_

Checked by \_\_\_\_\_ Date \_\_\_\_\_ Entered by \_\_\_\_\_ Date \_\_\_\_\_

REMARKS: See the following page for a written explanation of calculations used for this form (F104C-E).

## Calculations used on form F104C-E

PLUS 4.75 mm (+4 MESH) MATERIAL - The total weight passing each sieve divided by the total weight of the initial sample taken (25.23 lbs.), multiplied by 100, results in the percent passing. EXAMPLE:  $13.64 \div 25.23 = 0.5406 \times 100 = 54.06\%$

MINUS 4.75 mm (-4 MESH) MATERIAL – (By Reciprocal Method). This sample is dried to a constant mass before and after washing. A reciprocal is determined by dividing the percent of material passing the 4 mesh (54.06%) by the mass of the minus 4 mesh sample (520.5 grams). This reciprocal (0.1039) is multiplied by the cumulative weight passing for each sieve size. EXAMPLE:  $520.5 - 219.7 = 300.8$ ;  $300.8 \times 0.1039 = 31.25\%$  and is rounded down to and is recorded as 31%. The rounding is either up or down to the nearest whole number with the exception of the 200 mesh which is carried to one tenth of a percentage (7.5%). The result represents the percent passing in relation to the total sample.

For the Actual Grading % Passing of the +4 MESH, use the second gradation.

To calculate the % of Clinging Fines on each sieve (change in percentage), take the percent from the +4 MESH of the second gradation and subtract the percent from the +4 MESH of the first gradation. EXAMPLE  $95.16 - 94.89 = 0.27\%$

In order to calculate the Actual Grading % Passing the MINUS 4.75 mm (-4 MESH), the percent passing in the second gradation is added to the percent passing the first gradation. EXAMPLE:  $31.25 + 1.38 = 32.63$

The reciprocal for the second sieve analysis is calculated by taking the % of clinging fines on the +4 MESH and dividing it by the before wash weight of the second gradation. EXAMPLE:  $1.55 \div 176.9 = 0.0088$

The adjusted cumulative mass retained in the pan plus the Loss By Wash (LBW) mass should be within 0.3% of original dry mass of the total sample. EXAMPLE:  $447.9 + 72.5 = 520.4$ ,  $520.5 - 520.4 = 0.1$ ,  $(0.1 / 520.5) \times 100 = 0.02\%$



**METHODS OF SAMPLING AND TESTING**  
**MT 207-04**  
**CENTERLINE SOIL SURVEY**

**1 Introduction**

- 1.1 A centerline soil survey is an essential part of preliminary highway engineering. Information on the engineering properties and distribution of soils, rock and groundwater must be obtained before a reasonable and economic highway design can be developed. A soil survey is not intended to take the place of a thorough Geotechnical Foundation investigation.
- 1.2 The soil survey work depends on many factors which include scope of the proposed project, types and variability of materials found on the project, groundwater conditions, adverse geologic features, etc. Often field conditions found during the soil survey will increase or decrease the amount of work needed to supply the necessary information for design. The soil survey and the geotechnical investigation must be coordinated in order to preclude duplication of effort.

**2 Referenced Documents****AASHTO**

M 145 Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes  
 T 190 Resistance R-Value and Expansion Pressure of Compacted Soils

**MT Materials Manual**

MT 210 Moisture-Density Relations of Soils Using a 5.5 lb. Rammer  
 MT 230 Moisture-Density Relations of Soils Using a 10 lb. Rammer

**3 Apparatus**

- 3.1 *Sampling tools*  
 Hand shovels, picks, etc.  
 Hand augers, post hole diggers  
 Power augers and drills, etc.  
 Backhoes
- 3.2 *Instruments*  
 Survey equipment  
 Nuclear moisture and density testing device  
 Camera & film
- 3.3 *Miscellaneous*  
 Stakes and lath  
 Sample bags (17"X28" canvas 75 lb. capacity cloth)  
 Sealed containers (jars or plastic bags)  
 Field notebooks and forms

**4 General Procedure**

- 4.1 *General Procedure:* Following is the general procedure which should be followed in conducting any soil survey. The complexity of the soil survey will depend upon many factors as discussed in Section 1.2 above.
- 4.2 Reconnaissance of the proposed project should be conducted with pertinent existing information in hand. Additional information available may include but is not limited to the following items:
- Maintenance records  
 Construction records  
 Topographic & geologic maps  
 Historic use of the area  
 U.S. Department of Agriculture Soil Conservation Service  
 County soil survey reports  
 Utility company maps & locations

City and county plat maps  
 City, county and state health department information  
 Information from landowners and businesses  
 Aerial photography

#### 4.3 *Preliminary Survey Plan*

- 4.3.1 A preliminary plan should be determined prior to fieldwork. This should be based upon available information and intended scope. Approximate sample site locations should be determined to enable proper soil profile determination and adequate sampling. This plan will likely change as information is gained during the actual construction of the test sites.
- 4.3.2 Boring records should be kept in a systematic manner and referred to new centerline stationing and elevations for each project. Such records should include and be recorded on Forms 30 and 111.

Describe each site or area investigated, with each test hole, boring, or test pit clearly located (horizontally and vertically) with reference to some established coordinate system or permanent monument.

Log each test hole, boring, test pit, or cut-surface exposure with the field description and location of each material encountered clearly shown by Montana Department of Highways' symbols and word descriptions used on Form 30.

*Note – Color photographs of samples, and exposed strata may be of considerable value to the Department. Each photograph should include a date and an identifying number or symbol.*

Identify all soils based on AASHTO M 145 Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purpose.

Record seepage and water-bearing zones and free water-table depth found in each test hole, boring or test pit.

Identify artifacts and items of cultural and historical significance.

Note items concerning environmental hazards or other worthy notes.

- 4.3.3 Identify vertical and/or horizontal change of original ground where instability problems exist (landslides, subsidence, etc.).

#### 4.4 *Soil Profile Determination and Sampling*

- 4.4.1 Boring or test pits should be taken for laboratory analysis from all areas which may supply appreciable quantities of earthwork, and known borrow areas. Embankment areas should be tested for areas of swamp conditions or loosely compacted soils that will result in embankment settlements. The spacing of these investigations will depend upon the geologic complexity of the project area and upon the importance of soil and rock parameters to the project design. The depth should be a minimum of five feet below the proposed top of subgrade elevation or to borrow area depth.

#### 4.5 *Sampling*

- 4.5.1 Accurately identify each sample with the project identification, location, date, test site number and depth below reference ground surface from which it was taken. Place identification inside the container, securely close the container, protect it to withstand rough handling, and mark it with proper identification on the outside of the container. Keep samples for natural moisture determination in sealed containers to prevent moisture loss. When drying of samples may affect classification or engineering properties, protect them to minimize moisture loss.

- 4.5.2 Soil and water samples should be taken from the probable, proposed, or existing centerline of pipe, channel bottom and bridge locations as well as probable borrow areas, to determine pH, resistivity and sulfate (SO<sub>4</sub>) content of the soil and water. In areas of bad soils (resistivity less than 500), additional samples should be taken.

Sample Size not less than 5 lbs. (2.3 Kg.)

Sample Size, Water 1 quart.

- 4.5.3 Evaluate performance of existing installations in the immediate vicinity of the proposed site, relative to their historical performance and environmental impact. Photos of relevant installations properly labeled are helpful.

- 4.5.4 Representative disturbed samples for laboratory classification tests of soil, rock, and local construction material should be supplemented by undisturbed specimens.

- 4.5.5 Standard traffic control is required while working on the PTW.

#### 4.6 *Testing*

- 4.6.1 Testing analysis should be performed on all samples for the following items and recorded on Form 111.

Soil class by AASHTO M 145

Liquid limit

Plastic limit

Percent of material passing the 10 mesh, 40 mesh, and 200 mesh sieve size.

Maximum dry density and optimum moisture content by MT 230 for A-1 soils, MT 210 for all other soils

In-place density and moisture content

"R" value by AASHTO T 190, all soils except A-6 and A-7's.

Depth to water table

### 5 **Field Procedure**

- 5.1 *Overlay, New and Reconstruction Projects*

Survey data required for all projects is as follows:

The PTW should be cored at least 5' into the subgrade and sampled in the driving lanes (not the shoulder) as frequently as necessary.

Typical sampling frequency is one per 1/2 mile, more or less as conditions dictate.

Note and log the mat thickness.

Note and log base thickness and subgrade. Sample and determine moisture content, record soil class (AASHTO M 145), moisture, density and "R" value (AASHTO T 190).

Perform a culvert inspection; take chemical corrosion samples where necessary. Take photos at locations of bad pipe.

Review the existing project and record its past performance. A narrative summary should be provided with the soil survey.

Problem areas must be shown and recommendations for sub-excavation and the proposed depth of sub-excavation should be noted.

Anticipated borrow material should be sampled and tested for R values and corrosion.

Projects, where the intent is to overlay the existing plant mix, should be cored and the cores submitted to the Materials Bureau for evaluation. A typical sampling frequency is one (1) core per lane mile with a minimum of five (5) cores per project. The frequency can and should be adjusted as conditions warrant. The cores will be evaluated to determine the in-place condition of the PMS and a report issued to Surfacing Design.

## 5.2 *New and Reconstruction Projects Only*

Additional survey data for new and reconstruction projects only are as follows:

Review planning reports and anticipate alignment and grades.

Test holes in the field should be located to provide engineering soil properties where appreciable quantities of excavation will occur. Depth will be determined by the new grade line with holes extending about five feet below the proposed subgrade line. Typical sampling frequency is one per 1/2 mile, more or less as conditions dictate.

Tests should include samples of each soil strata encountered and the in place moisture, the chemical-corrosive properties, soil class (AASHTO M 145), "R" value (AASHTO T 190), and the specific gravity for each strata.

Determine in place densities for shrink and swell determinations if frozen conditions do not exist.

A log of the test holes should be kept and the test holes plotted on a profile sheet.

Data obtained should be reviewed to determine if additional test sites (i.e., areas of refusal, inadequate depth, or of questionable frequencies) are required.

Topsoil depth and availability should be noted.

Any anticipated borrow material should be sampled for "R" value, chemical-corrosive properties, and moisture density purposes.

If centerline is following close to the PTW and material in present embankment will be used, additional R-values and chemical-corrosive properties should be taken beneath the PTW driving lanes.

Potential borrow areas that have better quality soils (A-4(0) or better) should be investigated to determine their use in the top 2' of the subgrade especially in areas where surfacing materials are scarce.

## 6 **Interpretation of Results**

6.1 Interpret the results of an investigation only in terms of actual findings and make every effort to collect and include all field and laboratory data from previous investigations in the same areas. Extrapolation of data into local areas not surveyed and tested can be done only where geologically uniform subsurface conditions of soil and rock are known to exist. Engineering properties of the soils and rocks encountered on important projects should not be predicted wholly on field identifications or classification but should be checked by laboratory and field tests made on samples collected.

6.2 The recommendations for design parameters can be made only by professionals who have specialized in the field of soils and foundations or highway engineering, and who are familiar with the problems for which the study is being made.

## 7 Report

7.1 A soil survey investigation report should:

7.1.1 Locate the area investigated in terms pertinent to the project. This may include sketch maps or aerial photos on which the test holes, pits, and sample areas are located, as well as topographic items relevant to the determination of the various soil and rock types, such as contours, streambeds, sink holes, cliffs, etc. Where feasible, include a geologic map of the area investigated in the report.

7.1.2 Include copies of all borings, test-hole logs and laboratory test results.

7.1.3 Describe and relate the findings obtained by following the format of Section 4, General Procedure.

7.1.4 Provide preliminary shrink/swell recommendations. Shrink/swell information obtained from adjacent projects in the area should be included.

7.1.5 Provide recommendations relative to availability of better quality soils (A-4(0) or better) that could be used in the top 2' of the subgrade to reduce more costly surfacing material and to improve drainage.

Provide recommendations for additional testing required by core drill, seismic, etc., for materials inaccessible because of depth, topography, etc.

7.1.6 Each soil survey shall be submitted and distributed as follows:

- 1 copy to Preconstruction Bureau
- 1 copy to Geotechnical & Materials Bureau
- 1 copy to Surfacing Design - Materials Bureau
- 2 copies to be retained by the District

**DRAINAGE EVALUATION FORM  
MT 207**

This form should be submitted with each soil survey. Each area of concern on the project should be noted.

Project No. \_\_\_\_\_ Designation: \_\_\_\_\_

Date \_\_\_\_\_ Submitted by: \_\_\_\_\_

Station(s) \_\_\_\_\_

Are the ditch lines clear of standing water? \_\_\_\_\_

\_\_\_\_\_

Are the ditch lines and pavement edges free from weed growth that may indicate a moisture concentration? \_\_\_\_\_

\_\_\_\_\_

After a rain,

a) Is there moisture standing in the joints or cracks? \_\_\_\_\_

b) Is there any evidence of pumping? \_\_\_\_\_

c) Is there water standing at the outer edge of the shoulder? \_\_\_\_\_

d) Is there evidence that the water may pond on the shoulder? \_\_\_\_\_

Are joint sealants or crack sealants in good condition and preventing water from entering the pavement? \_\_\_\_\_

\_\_\_\_\_

Are the cross drainage conduits closed by debris? \_\_\_\_\_

AC Pavements

Is there moisture related distress evident such as; Stripping, Rutting, Cracking in Wheelpath, Shoulder Dropoff/Heave, Pumping, Water Bleeding, Swelling?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

PCC Pavements

Is there moisture related distress evident such as; Pumping, Faulting, Corner Break, D-Cracking, Edge Joint Opening, Shoulder Dropoff/Heave, Punchout (CRCP only), Swelling, Slab Cracking?

\_\_\_\_\_

\_\_\_\_\_

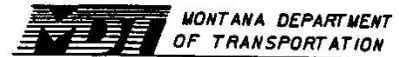
\_\_\_\_\_

\_\_\_\_\_

Is there evidence of springs and excessively wet areas? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Are there slides or slumps noted along the alignment? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Specific surface/subsurface drainage recommendations \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_



# LOG OF BORING

Geotechnical Section

Project Name: **EXAMPLE - ENGLISH** Project Number: **BR 549(0)**

Borehole Location: **STA. 13+95, 20.8 ft. Lt. PTW Centerline** Borehole Number: **EXAMPLE** Sheet **1** of **1**

Drilling Equipment: **CME 550** Hammer Type: **Automatic** Driller: **A. Driller** Logger: **A. Logger**

Drilling Fluid: **Water** Borehole Diameter (in): **8** Date Started: **1/1/98** Date Finished: **1/1/98**

Elevation and Datum: **Ground: 3739.80** Casing: \_\_\_\_\_ Notes: **Legal Description - 01S18E32DAC. Elevation and Station provided by District Survey.**

DEPTH (feet)	DRILL										MATERIAL DESCRIPTION	DEPTH (feet)	REMARKS					
	OPERATION	PRESSURE (psf)	RATE (fph)	CORE PERCENT RECOVERY	ROCK QUALITY DESIGNATION (ROD)	SAMPLE RECOVERY (%)	STANDARD PENETRATION TEST	DRY DENSITY (pcf)	MOISTURE CONTENT (%)	LIQUID LIMIT				PLASTIC LIMIT	GRAPHIC LOG			
0 - 5																		
5 - 10						100	5-10-5		15		NP							
10 - 15						100		100	30	53	18							
15 - 16						85	3-4-3		27									
16 - 20		500	15	100		100	37-50/0.4 ft.											
20 - 25		700	20	100		88												

Bottom of Hole Elevation = 3714.80 ft.

G.P.J. MTDOT.GDT. 3/25/98

LOG\_OF\_BORING

<b>Operation Types:</b> Auger Casing Advancer Core Barrel Drive Casing	<b>Sampler Types:</b> Split Spoon Shelby Bulk Sample Grab Sample	Penetrometer Vane Shear Special Samplers Testpit
--	--	---

WATER LEVEL OBSERVATIONS	
While Drilling	12.1 ft
Upon Completion of Drilling	9.8 ft
Time After Drilling	
Depth To Water (feet)	
Remarks:	Water table at 9.8 ft.

MT 207

MONTANA DEPARTMENT OF TRANSPORTATION

# LOG OF BORING



Geotechnical Section

Project Name: <b>SAMPLE - Metric</b>				Project Number: _____										
Borehole Location: _____				Borehole Number: -		Sheet <b>1</b> of <b>1</b>								
Drilling Equipment: _____				Hammer Type: _____		Driller: _____								
Drilling Fluid: _____				Borehole Diameter (mm): _____		Date Started: _____								
Elevation and Datum: Ground: _____ Casing: _____				Notes: _____										
DEPTH (m)	DRILL		CORE PERCENT RECOVERY	ROCK QUALITY DESIGNATION (RQD) SAMPLE	RECOVERY (%)	STANDARD PENETRATION TEST SPT	DRY DENSITY (kN/m <sup>3</sup> )	MOISTURE CONTENT (%)	LIQUID LIMIT	PLASTIC LIMIT	GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (m)	REMARKS
	OPERATION	PRESSURE (MPa)												
2														
4														
6														
8														
10														

LOG OF BORING BLANK-M GPJ MTDOT.GDT 1/13/98

**Operation Types:**

- Auger
- Casing Advancer
- Core Barrel
- Drive Casing

**Sampler Types:**

- Split Spoon
- Shelby
- Bulk Sample
- Grab Sample

**Penetrometer**

- Vane Shear
- Special Samplers
- Testpit

**WATER LEVEL OBSERVATIONS**

While Drilling  $\nabla$  \_\_\_\_\_ m Upon Completion of Drilling  $\nabla$  \_\_\_\_\_ m

Time After Drilling \_\_\_\_\_

Depth To Water (m) \_\_\_\_\_

Remarks: \_\_\_\_\_



**METHODS OF SAMPLING AND TESTING**  
**MT 210-16**  
**METHOD OF TEST FOR THE MOISTURE-DENSITY RELATIONS OF SOILS**  
**USING A 5.5 LB. (2.5 KG) RAMMER AND A 12 IN. (305 MM) DROP**  
***(Modified AASHTO T 99)***

MT 210 is identical to AASHTO T 99 except for the following stipulations:

1. Replace Section 1.5 with the following:

If the specified oversized particle maximum percentage is exceeded (except for material that meets the criteria described in MT 218, Section 4.6.), the replacement method should be used. The replacement method maintains the same percentage of coarse material (passing a 50 mm sieve and retained on a 4.75 mm sieve) in the moisture-density sample as in the original field sample. The material retained on the 19.0 mm sieve shall be replaced as follows: sieve an adequate quantity of the representative soil over the 50 mm and 19.0 mm sieve. Weigh the material retained on the 19.0 mm sieve. Replace this material with an equal mass of material passing the 19.0 mm sieve and retained on the 4.75 mm sieve. Take the material for replacement from the extra portion of the sample.



**METHODS OF SAMPLING AND TESTING**  
**MT 212-16**  
**DETERMINATION OF MOISTURE AND DENSITY OF IN-PLACE MATERIALS**  
*(Modified AASHTO T 310 and T 355)*

**1 Scope**

- 1.1 This test method describes the procedures for determining the moisture and/or density of in-place materials, either in the natural state or after compaction, by the use of nuclear density/moisture gauge.
- 1.2 Alternatively, moisture may be determined in the laboratory by AASHTO T 265, Laboratory Determination of Moisture Content of Soils.

**2 Referenced Documents****AASHTO**

- T 265 Laboratory Determination of Moisture Content of Soils  
T 310 In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods  
T 355 In-Place Density of Asphalt Mixtures by Nuclear Methods

**MT Materials Manual**

- MT 210 Moisture-Density Relations of Soils Using A 5.5 Lb Rammer and a 12 In Drop  
MT 230 Moisture-Density Relations of Soils Using A 10 Lb Rammer and a 18 In Drop

**3 Apparatus**

- 3.1 *Nuclear moisture/density gauge* containing radioactive sources, electronics and rechargeable batteries
- 3.2 *Standard Count Reference Block*
- 3.3 *AC Charger 115v/60Hz and DC Adapter 12v negative ground*
- 3.4 *Transport case* designed and labeled for each specific gauge
- 3.5 *Scraper Plate/Drill Rod Guide*
- 3.6 *Drill Rod and Drill Rod Extractor*
- 3.7 *Operators Manual and Gauge Booklet*
- 3.8 *Sieve, 30 mesh* for seating sand
- 3.9 *Thermoluminescent Dosimeter (TLD) Badge*

**4 Calibration**

The nuclear moisture/density gauges are calibrated by the MDT Materials Bureau for testing density of PCC and AC pavements. The gauges are also calibrated for both density and moisture of most soils and soil aggregate mixtures. The calibrations are stored electronically within the gauge.

**5 Operational Considerations**

- 5.1 A manufacturer's instructional manual is furnished with each nuclear device and must be consulted for operational procedures. These procedures vary between gauges and must be followed carefully.
- 5.2 Nuclear gauges shall **only be distributed** to personnel who have received the required 8 hour radiation safety and nuclear gauge operation course.

- 5.2.1 Gauge operators must attend a 2 to 4 hour refresher course at intervals not to exceed three (3) years. This training will be provided by MDT.
- 5.2.2 District Materials Supervisors must ensure that each gauge operator has completed an approved operator training course, that their card is up to date and in their possession, and that a radiation monitoring device (TLD Badge) is properly utilized when handling nuclear gauges.
- 5.3 Gauge operators should be very familiar with the Operator's Instruction Manual.
- 5.4 Gauge operators should always be aware of battery charge status and follow battery care instructions in Operator's Manual.
- 5.5 The gauge electronics must be turned on to warm up for a minimum of 15 minutes before taking the daily standard count or testing. Leave the power on all day during testing.
- 5.6 The Nuclear Gauge Transport form shall be kept with the nuclear gauge at all times. When transporting a gauge, the certification shall be filled out, visible and within reach of the driver.
- 5.7 Additional Operational Considerations and Radiation Safety are provided in the Appendix.

## 6 Standardization

- 6.1 Standard counts shall be taken and recorded each day that gauges are put into use and should be taken in the same environment as the actual measurement counts (i.e., at the construction site). The standardization should be performed with the gauge at least 10 m (30 ft) away from other nuclear density/moisture gauges and clear of large masses of water or other items that may affect the reference count rates.
- 6.2 If the daily standard counts are more than 1% for density or 2% for moisture from the average of the previous four counts, procedures should be thoroughly examined and the counts taken again. If these counts also fail, problems with the gauge or procedure are indicated and the appropriate District or Area Laboratory should be contacted.

## 7 Stability Test

- 7.1 A Stability Test should be performed whenever the accuracy of the gauge is in doubt.
- 7.2 A Stability Test consists of 20, one-minute Standard Counts.
- 7.3 Calculations (Using Actual Gauge Readings)
  - 7.3.1 Determine the Average Reading (*AVG*)

$$AVG = \frac{\sum_{i=1}^N X}{N}$$

Where:

AVG = Average

X = Reading

N = number of readings

7.3.2 Calculate the Standard Deviation (SD)

$$SD = \sqrt{\frac{\sum_1^N (X - AVG)^2}{N}}$$

Where:

SD = Standard Deviation

X = Reading

N = number of readings

7.3.3 Calculate the Stability Ratio

$$Stability\ Ratio = \frac{SD}{\sqrt{AVG}}$$

7.4 If the ratio falls outside of the indicated ranges, procedures should be checked and the stability test taken again. If another failure occurs, contact the appropriate District or Area Lab.

<b>PASSING RATIOS</b>	
<b><i>Moisture</i></b>	<b><i>Density</i></b>
0.18-0.35	0.18-0.35

## 8 Procedure

8.1 *Soil and Soil-Aggregate (Direct Transmission Method)*

8.1.1 Follow AASHTO T 310 Sections 9.1 – 9.3 and 9.5, collecting at least two (2) readings. The final result will be the average of all the readings.

8.2 *Asphalt Mixtures*

8.2.1 Follow AASHTO T 355 Section 9

## 9 Calculations

9.1 Use the appropriate [Compaction Form](#) for recording field determinations with Nuclear Devices.

9.2 Wet density, dry density, and moisture can be read directly from the gauge scales in pounds per cubic foot (lb/ft<sup>3</sup>). Percent moisture can also be read directly from the gauge.

9.3 Percent Compaction Calculation

$$\% \text{ Compaction} = \frac{\text{Field Dry Density } (\frac{\text{lb}}{\text{ft}^3})}{\text{Proctor Dry Density}} \times 100$$

Note 1 – Proctor Dry Density from MT 210 or MT 230.

9.4 Compare field moisture to optimum moisture from the Proctor determination.

## APPENDIX

### A.1 Radiation Safety

A.1.1 Each nuclear gauge operator must wear a TLD badge attached to the front of his/her clothing or belt at waist level. The District Materials Supervisors issue these badges.

*Note 2 – A TLD badge is a device that monitors a person's potential exposure to radiation.*

A.1.1.1 These TLD badges must not be transferred from one operator to another.

A.1.1.2 When not in use, TLD badges should be stored at least 30 feet from nuclear gauges, out of direct sunlight, and away from excessive heat or dampness. **Badges left near gauges are especially susceptible to unfounded high readings.**

A.1.1.3 Whenever a TLD badge has a high reading, the individual to whom the badge was issued will be notified and must fill out a report and submit it to the Materials Bureau within five days. It is important that all facts and details be presented accurately and conscientiously including diagrams, distances and times. Statements from supervisors and witnesses are also valuable.

A.1.1.4 The District Materials Supervisor will keep an up-to-date record consisting of the individual's name, the date the badge was issued, the serial number of the gauge they are using, and the project to which the gauge is assigned. This information, along with the TLD badges will be mailed to the Materials Bureau within ten days after the end of the quarter.

A.1.2 The leak testing of all nuclear gauges will be performed by personnel in the Materials Bureau or other individuals designated by the Radiation Safety Officer to perform such tests. An up-to-date record of the results of these tests shall also be maintained by the Materials Bureau.

### A.2 Transportation

A.2.1 The nuclear gauges require careful handling. The vehicle in which they are transported should be capable of keeping them dry and provide complete security from unauthorized personnel. It should also be equipped with a carrying rack to which the instrument cases can be strapped and locked.

### A.3 Storage

A.3.1 Storage areas should be locked and posted with radiation caution signs.

A.3.2 When the equipment is not being used, it should be stored in a separate dry room or garage. The temperature in the storage area should be above freezing and the batteries in the device should be fully charged. Never store a device in an area where personnel are working or will be working. Radiation caution signs shall be posted at the entrance door of any storage area.

A.3.3 Radiation levels surrounding the storage area shall not exceed two (2) millirems per hour. To help ensure low radiation levels outside the storage area, a gauge should be stored as near the center of the room as practical. Gauges should not be stored above, below or adjacent to a work area. The best way to assure radiation safety is to limit the number of gauges in a storage area. The largest number of gauges to be stored in one area is determined by the outside radiation level which shall not exceed 2 millirems per hour. The Materials Bureau in Helena will check the outside area to see if the radiation levels are acceptable.

A.3.4 Store the gauge fully charged. Battery charging during storage is not necessary but gauges should be given a full charge prior to initial use at the beginning of the construction season.

### A.4 Maintenance

A.4.1 The Materials Bureau should be notified immediately when any breakdowns occur. It will be decided at that time whether the gauge should be sent to the Materials Bureau for repairs.

A.4.2 Clean and maintain the gauge regularly as recommended in the Operator's Manual.

**METHODS OF SAMPLING AND TESTING**  
**MT 216-13**  
**METHOD OF SAMPLING AND TESTING CEMENT TREATED BASE**  
**(Montana Test Method)**

**1 Scope**

- 1.1 This method describes procedures for making, curing, and testing cylindrical specimens from representative samples of Cement Treated Base (CTB).

**2 Referenced Documents****AASHTO**

- T 19 Bulk Density ("Unit Weight") and Voids in Aggregate  
 T 134 Moisture-Density Relations of Soil-Cement Mixtures  
 T 231 Capping Cylindrical Concrete Specimens

**ASTM**

- D1633 Standard Test Method for Compressive Strength of Molded Soil-Cement Cylinders

**MT Materials Manual**

- MT 201 Sampling Roadway Materials  
 MT 212 Determination of Moisture and Density of In-Place Materials  
 MT 228 Method of Establishing Field Target Density for Cement Treated Base Density Control  
 MT 405 Wire Cloth Sieves for Testing Purposes  
 MT 601 Materials Sampling, Testing and Acceptance Guide

**3 Apparatus**

- 3.1 *Molds* - Use solid-wall, metal cylinders manufactured with dimensions and capacities shown in 3.1.1. They must have a detachable collar assembly approximately 2.375 in. (60 mm) in height, to permit preparation of compacted specimens of soil-cement mixtures of the desired weight and volume. The mold and collar assembly must be constructed so that it can be fastened firmly to a detachable base plate made of the same material.

*Note 1 – Alternate types of molds with capacities as stipulated herein may be used, provided the test results are correlated with those of the solid-wall mold on several soil types and the same moisture-density results are obtained. Records of such correlations shall be maintained and readily available for inspection when alternate types of molds are used.*

- 3.1.1 A 4 in. (101.6 mm) mold having a capacity of  $1/30 \pm 0.0003$  cu. ft. ( $943 \pm 8$  cm<sup>3</sup>) with an internal diameter of  $4.000 \pm 0.016$  in. ( $101.6 \pm 0.41$  mm) and a height of  $4.584 \pm 0.005$  in. ( $116.43 \pm 0.13$  mm).

- 3.1.2 *Molds Out of Tolerance Due to Use* - A mold that fails to meet manufacturing tolerances after continued service may remain in use provided those tolerances are not exceeded by more than 50 percent; and the volume of the mold, calibrated in accordance with AASHTO T 19, Section 8 (Calibration of Measure), is used in the calculations.

3.2 *Rammer*

- 3.2.1 *Manually Operated* - Metal rammer having a flat circular face of 2.000 in. (50.8 mm) diameter, a manufacturing tolerance of  $\pm 0.01$  (0.25 mm) and weighing  $5.50 \pm 0.02$  lb. ( $2.495 \pm 0.009$  kg). The in-service diameter of the flat circular face shall be not less than 1.985 in. (50.42 mm). Use a rammer equipped with a suitable guide-sleeve to control the height of drop to a free fall of  $12.00 \pm 0.06$  in. ( $305 \pm 2$  mm) above the elevation of the soil. The guide-sleeve must have at least 4 vent holes, no smaller than  $3/8$  in. (9.5 mm) diameter spaced approximately 90 degrees (1.57 radius) apart and approximately  $3/4$  in. (19 mm) from each end, and provide sufficient clearance so the free fall of the rammer shaft and head is unrestricted.

- 3.2.2 *Mechanically Operated* - A metal rammer equipped with a device to control the height of drop to a free fall of  $12.00 \pm 0.06$  in. ( $305 \pm 2$  mm) above the elevation of the soil and uniformly distributes such drops to the soil surface (Note 2). The rammer must have a flat circular face 2.000 in. (50.8 mm) diameter, a manufacturing tolerance of  $\pm 0.01$  (0.25 mm) and weighing  $5.50 \pm 0.02$  lb. ( $2.495 \pm 0.009$  kg).

*Note 2 – Calibrate the rammer apparatus with several soil-cement mixtures. Adjust the mass of the rammer, if necessary, to give the same moisture-density results as with the manually operated rammer. It may be impractical to adjust the mechanical apparatus so the free fall is 12 in. (305 mm) each time the rammer is dropped, as with the manually operated rammer. To make the adjustment of free fall, the portion of loose soil to receive the initial blow should be slightly compressed with the rammer to establish the point of impact from which the 12 in. (305 mm) drop is determined. Subsequent blows on the layer of soil-cement may all be applied by dropping the rammer from a height of 12 in. (305 mm) above the initial-setting elevation, or when the mechanical apparatus is designed with a height adjustment for each blow, all subsequent blows should have a rammer free fall of 12 in. (305 mm) measured from the elevation of the soil-cement as compacted by the previous blow.*

- 3.2.3 *Rammer Face* – Use the circular face rammer. If necessary, use a sector face rammer as an alternative. Indicate the type of face used other than the 2 in. (50.8 mm) circular face in the report. The alternate must have an area equal to that of the circular face rammer.

- 3.3 *Sample Extruder* - A jack, lever, frame, or other device adopted for the purpose of extruding compacted specimens from the mold.

- 3.4 *Balances and Scales* - A balance or scale of at least 25 lb. (11.5 kg) capacity having sensitivity and readability to 0.01 lb. (5 grams). Also, a balance of at least 3 lb. (1 kg) capacity having sensitivity and readability to 0.003 oz. (0.1 gram). Use balances or scales of the same units shown in the contract.

- 3.5 *Heat Source* - Oven, hot plate or alternate heating source.

- 3.6 *Straightedge* - A hardened steel straightedge at least 10 in. (254 mm) in length. Use a straightedge with one beveled edge. At least one longitudinal surface (used for final trimming) must be plane within 0.01 in. per 10 in. (0.25 mm per 250 mm) (0.1 percent) of length within the portion used for trimming the soil. (Note 3)

*Note 3 – The beveled edge may be used for final trimming if the edge is true within a tolerance of 0.01 in. per 10 in. (0.25 mm per 250 mm) (0.1 percent) of length; however, with continued use, the cutting edge may become excessively worn and not suitable for trimming the soil to the level of the mold. The straightedge should not be so flexible that trimming the soil surface with the cutting edge will concave the soil surface.*

- 3.7 *Sieves* – 2 in. (50 mm),  $\frac{3}{4}$  in. (19.0 mm), No. 4 (4.75 mm) sieves conforming to the requirements of [MT 405](#).

- 3.8 *Mixing Tools* – Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

- 3.9 *Container* – A flat, round pan for moisture absorption by soil-cement mixtures about 12 in. (305 mm) in diameter and 2 in. (50 mm) deep.

- 3.10 *Moisture Containers* - Suitable containers made of material resistant to corrosion and not subject to change in weight or disintegration on repeated heating and cooling. Use containers with close-fitting lids to prevent loss of moisture from samples before initial weighing and to prevent absorption of moisture from the atmosphere following drying and before final weighing. One container is needed for each moisture content determination.

- 3.11 *Butcher Knife* - A butcher knife approximately 10 in. (250 mm) in length, for trimming the top of the specimens.

#### 4 CTB Mix Design

- 4.1 Verify that the contractor has submitted a cement treated base mix design to the Materials Bureau at least 10 business days before scheduled placement. Confirm with the Materials Bureau that the design is approved for use before allowing placement on the project.

#### 5 Acceptance

- 5.1 *In-Place Densities* – Test for compaction in accordance with Specifications 304.03.5. Determine in-place densities in accordance with [MT 212](#). Establish a corrected moisture curve by correcting the nuclear moisture reading to oven-dry moisture contents.
- 5.2 *Field-Made Compression Specimens* – Mold a minimum of one set of compressive strength specimens for every 750 cubic yards (575 cubic meters) of CTB in accordance with [MT 601](#). A set consists of three compressive strength specimens molded in accordance with Section 6 of this procedure. It is desirable that these specimens represent the material placed at the locations of the in-place densities so moisture-density comparisons can be made. Two specimens from each set will be tested at 7 days to determine strength acceptance. The remaining specimens will be broken at 28 days to identify strength gain. A copy of the sample record containing moisture content, cementitious material content, and density must accompany each set of compressive strength specimens in the shipping boxes.
- 5.3 *Acceptance Samples of Aggregate* - Sample for gradation analysis in accordance with Specification 304.03.1.

#### 6 Molding Specimens in the Field

- 6.1 Sample the CTB mixture placed on the roadway from a representative location in accordance with [MT 201](#). Obtain approximately one cubic foot of material and place in suitable container(s) lined with a plastic bag. Once the sample is complete, close the bag and place a lid on the container(s). This is done to reduce any possibility of moisture loss from the sample. Transport the sample to the place of molding as quickly as possible in order to minimize hydration (excessive hydration can reduce the lubrication properties and result in less than maximum density and therefore lower strengths). Remix the sample before and during molding to ensure uniformity and prevent segregation.
- 6.2 Immediately form a specimen by compacting the mixture in the mold in accordance with AASHTO T 134, Section 5.5 (with the collar attached). Trim the specimen in accordance with AASHTO T 134, Section 5.6. Uniformly distribute the material by spading along the inside of the mold with a spatula for each lift placed in the mold and before compaction. After compaction of each lift, scarify or roughen the top of the layer in order to obtain a good bond between lifts.
- 6.3 During compaction, obtain a representative sample of the mixture, weighing not less than 500 grams. Weigh the sample immediately and dry until further drying does not alter the weight greater than 0.1 percent, constant mass. Determine the moisture content as a check against design moisture content.
- 6.4 Weigh the compacted specimen to check against design density before beginning the initial cure. (Note 4)

*Note 4 – Once the specimen has been struck off to the required smoothness and weighed, cover the top of the mold with plastic and place the compaction collar back on the mold, leaving the plastic in place. Tighten the collar so that the plastic will make an airtight seal around the rim of the mold and the surface of the specimen. This is done to prevent moisture loss from the specimen during the initial cure. Once all specimens have been molded and sealed with plastic, place in a cure box to protect the specimens from temperature extremes and from direct sunlight. Maintain a temperature range of 60° F to 80° F during the initial cure in the field. The location for the initial cure must be horizontally level, rigid, and free from vibration or other disturbances.*

- 6.5 Maintain a running average of densities and moistures in accordance with [MT 228](#) to establish density control.
- 6.6 Form two additional specimens in the same manner as the first as rapidly as possible. Identify two specimens as 7-day compression specimens, and the third as a 28-day compression specimen. (Note 5)

*Note 5 – A satisfactory method of identifying the specimens for the 7-day or 28-day breaks is to wrap a piece of masking tape around the specimen. Indicate on the masking tape the date made, stationing & lane, type of test, etc.*

- 6.7 Cure the compacted specimens in the molds a minimum of 24 hours. Extract the specimens from the molds, place in the shipping box packed in damp sawdust, and transport to the Materials Bureau as soon as possible so that the final cure can be accomplished in the moist cure room for the remainder of the curing period.

## 7 Compressive Strength Determination

- 7.1 Determine the diameter using two diameter measurements to the nearest 0.01 inches (0.25 mm) taken at 90 degrees to one another near mid height of the specimen. Prior to placing compressive strength specimens in the compression machine, verify that both ends of the specimen are plane to within 0.002 in (0.05 mm). If an end of the specimen is outside of the 0.002 in. (0.05 mm) tolerance, cap that end of the specimen in accordance with AASHTO T 231.
- 7.2 Determine the 7 day unconfined compressive strength in accordance with ASTM D1633 except as modified herein. Omit the requirement for immersing cured specimens in water for 4 hours prior to testing.
- 7.3 Maintain free moisture on the outsides of specimens to prevent drying until testing is complete (except for the ends of the specimens when sulfur capping). When capping with sulfur, be certain that the ends of the specimen are dry enough to prevent small pockets of steam from forming within the capping compound.

## 8 Calculation

- 8.1 Calculate the unit compressive strength of the specimen by dividing the maximum load by the cross-sectional area.

$$S = \frac{lbf}{\pi r^2}$$

Where:

$S$  = Strength

$lbf$  = Maximum Load

$r$  = Radius of Specimen

- 8.2 For purposes of this method, determine strength of specimens using a height (uncapped) divided by diameter ratio of 1.15. This is standard and is not to be corrected by a length to diameter correction factor.

**9 Report**

- 9.1 The field technician is to report the following:  
Sample Date the cylinder was made  
Percent cement rounded to the nearest tenth  
Percent fly ash rounded to the nearest tenth  
Depth of material placed rounded to the nearest tenth of a ft (m)  
Station where sample was taken  
Density rounded to the nearest tenth of lbs per ft<sup>3</sup> (kg per m<sup>3</sup>)  
Moisture content rounded to the nearest tenth of a percent
- 9.2 The lab technician is to report the following:  
Date the cylinder was broken  
Diameter of the cylinder rounded to the nearest hundredth of an inch (mm)  
Load rounded to the whole number in lbs per ft (kg per m)  
Compressive strength rounded to the nearest whole number in lbs per in<sup>2</sup> (MPa)

Report the average strength of the two 7-day cylinders rounded to the nearest whole number.



**METHODS OF SAMPLING AND TESTING**  
**MT 218-04**  
**METHOD OF TEST FOR**  
**DETERMINING RELATIVE COMPACTION AND PERCENT MOISTURE**  
**(Montana Test Method)**

**1 Scope**

- 1.1 This procedure is intended as a guide for comparing in-place moisture and density to optimum moisture and maximum density, respectively, in order to determine compliance with standard specifications and contract special provisions.

**2 Referenced Documents**

***MT Materials Manual***

MT 210 Moisture-Density Relations of Soils Using a 5.5 lb. Rammer  
MT 212 Determination of Moisture and Density of In-Place Materials  
MT 230 Moisture-Density Relations of Soils Using a 10 lb. Rammer

**3 In-Place Moisture and Density**

- 3.1 The in-place moisture and density shall be determined in accordance with MT 212.

**4 Optimum Moisture and Maximum Density**

- 4.1 The optimum moisture and maximum density shall be determined in accordance with MT 210 or MT 230, Method A, B, C, or D, whichever is applicable, using the following criteria as a guide.
- 4.2 When the material under test is a soil or aggregate consisting of entirely minus 4 mesh (4.75 mm), Method A or B will be used.
- 4.3 When the material under test is a soil or aggregate with a maximum size of 3/4 inch (19.0 mm), Method C or D will be used.
- 4.4 When the material under test is a soil or aggregate with a maximum size of 2 inches (50 mm), Method D will be used.
- 4.5 When the material under test is a soil or aggregate with a maximum size of 4 inches (100 mm) and no more than 50% of the material under test is retained on the 4 mesh (4.75 mm), Method D will be used.
- 4.6 When the material under test is a soil or aggregate with a maximum size larger than 2 inches (50 mm) and more than 50% of the material under test is retained on the 4 mesh (4.75 mm), the material will not be required to meet 95% density within 2% optimum moisture.
- 4.6.1 A screen analysis must be provided on representative samples from each lift of the embankment area to prove that more than 50% of the material is retained on the 4 mesh (4.75 mm) sieve.
- 4.6.2 Nuclear M/D readings must be taken on each lift in the embankment area to demonstrate that uniform relative density has been achieved.
- 4.6.3 Notes must be made on the [Summary of Compaction Data \(Form 1006\)](#) showing the results obtained in paragraphs 4.6.1 and 4.6.2.

## 5 Calculation

- 5.1 Determine the relative compaction by dividing the in-place density (pounds per cubic foot) by the maximum density (pounds per cubic foot) and multiplying by 100.
- 5.2 A direct comparison of the in-place moisture and the optimum moisture will determine compliance with specifications.

## 6 Family of Curves

- 6.1 A "family of curves" is a term applied to a number of moisture-density curves which are plotted on one cross-section sheet, using the same ordinates and abscissas as dry weights pounds per cubic foot and moisture contents, respectively. The family of curves is plotted, initially, from values obtained by the sampling and testing of the various soil types during the Preconstruction Soils Survey and every effort must be made to sample and identify all of the various soil types that will be encountered on the project. Each new soil type, or mixture of soils, encountered on the project during construction, will be represented by a moisture-density curve, which is added to the "family".

*Note 1 – New curves drawn through plotted one-point determinations shall not become a permanent part of the family of curves until verified by a full moisture-density relationship.*

## 7 One Point Proctors

- 7.1 A "one point Proctor" is an abbreviated standard Proctor compaction test and is used in conjunction with the family of curves. Rather than determining the moisture and density points for an entire curve, a single point is determined for the purpose of selecting the curve, which represents the soil being compacted, from the family of curves.
- 7.1.1 One-point Proctors shall be run whenever there is any doubt that the soil being compacted is from a location on the project, which is represented, by one of the curves in the family of curves.
- 7.1.2 Frequently soils may be mixed by heavy equipment excavating and hauling to the embankment site and a one-point Proctor may not fit any of the established curves. In these cases a new curve will have to be prepared from the mixture and added to the family of curves.
- 7.1.3 It is necessary to run the one-point Proctor as close to optimum moisture as possible. The point should be within plus or minus three percent of optimum on most curves and within plus or minus two percent of optimum on sharp breaking curves. If the point is established on either side of optimum and some distance from the peak of the curve, it may very well fit more than one curve in the family of curves, or none at all and it will be impossible to select the proper curve.
- 7.1.4 The moisture and density results obtained by the one-point Proctor are plotted on the family of curves and, when obtained near optimum, will fall near one of the curves in the family of curves, provided that particular type of soil or mixture of soils has been tested for optimum moisture and maximum density. The peak of the curve selected shall be considered the optimum moisture and maximum density of the material represented by the one-point Proctor.

*Note 2 – If the one-point plotted within or on the family of curves does not fall in the 80 to 100 percent of optimum moisture range, compact another specimen, using the same material, at an adjusted moisture content that will place the one-point within this range.*

## 8 Numbering Check Samples

When a check sample is taken it will be assigned the same number as the sample being checked, with the addition of a letter suffix. For example, if sample number 38 failed to meet specifications, the first check sample would be numbered 38-A, the second check sample would be 38-B.

**METHODS OF SAMPLING AND TESTING**  
**MT 219-04**  
**METHOD OF TEST FOR**  
**CONTROLLING THE COMPACTION OF SURFACING AGGREGATES AND PLANT MIX PAVING**  
**USING A CONTROL-STRIP TEST-SECTION TECHNIQUE WITH NUCLEAR GAUGES**  
**(Montana Test Method)**

**1 Scope**

- 1.1 This test method is intended to control the density of compacted courses of surfacing aggregates and plant mix pavement using nuclear gauges.

**2 Referenced Documents**

***MT Materials Manual***

MT 212 Determination of Moisture and Density of In-Place Materials  
MT 230 Moisture-Density Relations of Soils using a 10 lb. Rammer  
MT 311 Marshall Method for Field Control of Hot Mix Asphalt Paving

**3 Definitions**

- 3.1 *Control-Strip A - Surfacing Aggregates* – A section approximately three hundred (300) feet long by the typical section width of two lanes on a firm sub-grade.
- 3.2 *Control-Strip B - Plant Mix Paving* – A section approximately three hundred (300) feet long by one paver width on a firmly compacted base. Please refer to Table 1 on page 3 as a guide for maximum rolling times.
- 3.3 *Test-Section Surfacing Aggregates* – Individual sections each approximately two thousand (2000) feet long, as constructed, on which the surfacing aggregates will be placed, using the same layer thickness, compaction watering and procedures used in constructing the Control-strip A above.
- 3.4 *Test-Section Plant Mix Paving* – Individual sections each approximately two thousand (2000) feet long by one paver width on which plant mix material will be placed, using the same layer thickness, compaction and procedure used in construction the Control-strip B above.

**4 Apparatus**

- 4.1 *Nuclear moisture/density gauge* containing radioactive sources, electronics and rechargeable batteries
- 4.2 *Standard Count Reference Block*
- 4.3 *AC Charger 115v/60Hz and DC Adapter 12v negative ground*
- 4.4 *Transport case* designed and labeled for each specific gauge
- 4.5 *Scraper Plate/Drill Rod Guide*
- 4.6 *Drill Rod and Drill Rod Extractor*
- 4.7 *Operators Manual and Gauge Booklet*

**5 Operational Procedures**

- 5.1 *Control-Strip Surfacing Aggregates* – At the beginning of compaction operations, the density requirements shall be determined by compacting a Control-Strip of an approved thickness. The procedure, MT-230 (Proctor Test) establishes the dry density for aggregates being used in the Control-strip. (Note 1)

*Note 1 – The moisture-density of the control strip will be determined by the use of approved nuclear equipment under field conditions.*

- 5.1.1 After each application of the roller, wet density and moisture determinations are made with the nuclear device at a minimum of three (3) random locations. These locations may be marked with a small quantity of minus 30 mesh dry sand - the finer the better. This sand should be screened from the material that is being compacted and dried to constant weight. This sand serves to identify each test location and is an aid for seating the nuclear device to preclude air voids between the bottom surface of the probe and the coarser aggregate particles that may be extruding above the surface of the lift. To avoid any errors in reading due to the build-up of sand beneath the nuclear device, approximately the same quantity of sand is used at each of the three test locations. The test locations are marked so that the same locations are tested after each pass.
- 5.1.2 An average dry density is computed and plotted on a chart of dry density versus the number of roller passes. Rolling is discontinued when the curve plotted for dry density versus roller passes levels off. When the density plot levels off, density and moisture readings are taken at seven additional locations. Ten test sites in the 300 feet long Control-Strip are calculated to yield satisfactory statistical results. The average dry density is computed from the ten sets of readings and this serves as the standard of compaction. A new Control-Strip is required when the aggregate characteristics change appreciably, the aggregate is produced from a different source, or there has been a change in the rolling equipment or procedures used. Each new lift will require a new Control-Strip to determine if there is any change in Control-Strip density. If a different nuclear device is used, a new Control-Strip might have to be established.
- 5.2 *Test-Sections Surfacing Aggregates* – The remainder of the project is divided into Test-Sections described above. After placing and compacting a lift of surfacing aggregate, employing the same thickness and procedures used in the Control-Strip, moisture and density readings are taken at ten randomly selected locations. Dry density determinations are made for each set of readings.
- 5.2.1 Whenever the minimum density results are not met, immediate corrective action must be taken by additional rolling or additional water and rolling. The densities of the completed Test-Sections must be determined without delay for applicable comparison (under the same conditions) with the Control-Strip density. (Note 2) Similarly, proper use of the most suitable roller can decrease time in attaining proper density in the Test-Section. The contractor should be encouraged to use various methods in establishing density in the Control-Strip.

*Note 2 – (Not a specification requirement) The effective use of water and the method used in compacting the Control-Strip can influence the time and the compactive effort required to attain satisfactory density.*

- 5.3 *Control Strip Plant Mix Paving* – All roller equipment will be approved by the engineer prior to the construction of the Control-Strip as specified in the Standard Specification. Whenever a Control-Strip is required on plant mix surfacing a comparison will be made between the established Control-Strip density and the Marshall density as determined by MT-311 (Marshall Method of Hot Mix Asphalt Paving). This should be done to ensure a reasonable Control-Strip density is established.
- 5.3.1 Three test sites will be randomly selected on the Control-Strip. Each site will be marked with minus 30 mesh dry seating sand used to seat the nuclear gauge. This sand should be screened from the material that is being compacted and dried to constant weight. Compaction of the Control-Strip shall commence as soon as possible after placement of the bituminous mixture and be uniform over the entire Control-Strip before the temperature of the mix falls below 175°F. A test will be taken on each test site with a nuclear gauge after each pass of the compaction equipment.
- 5.3.2 This procedure will continue until the density increase is less than one (1) pound per cubic foot at a temperature greater than 175°F. After completion of the rolling, then two more tests sites are established so that a total of five density tests are averaged for the Control-Strip density.

- 5.3.3 Each new lift will require a new Control-Strip to determine if there is any change in Control-Strip density. If a different nuclear device is used, a new Control-Strip might have to be established.
- 5.4 *Test Section Plant Mix Paving* – The remainder of the project is divided into 2000 ft. test sections. After placing and compacting a lift of Plant Mix Paving, employing the same thickness and procedures used in the Control-Strip, density readings are taken at five randomly selected locations. The average density of each test section will be evaluated based upon the results of five tests in each test section. Whenever the minimum density results are not met, immediate corrective action must be taken by additional rolling. The densities of the completed test sections must be determined without delay for applicable comparison (under the same conditions) with the Control-Strip density.

**6 Forms and Reports**

- 6.1 Use [Lab Form No. 1000A](#) for controlling the compaction of surfacing aggregates. This form may also be used for Control Strip paving.
- 6.2 [Lab. Form No. 1006-A](#), Summary of Compaction Data for Surfacing, is applicable for all types of nuclear devices. It is requested that the serial number of the device being used and the Laboratory Number of each pit, be entered on this form.

**Table 1. Maximum Available Rolling Times\***

Recommended Minimum Laydown Temperature						
Mat Thickness						
Base Temp.°F	½"	¾"	1"	1½"	2"	3" and Greater
+35-40	-	-	-	305	295	280
+40-50	-	-	310	300	285	275
+50-60	-	310	300	295	280	270
+60-70	310	300	290	285	275	265
+70-80	300	290	285	280	270	265
+80-90	290	280	275	270	265	260
+90	280	275	270	265	260	255
Maximum Available Rolling						
Time, minutes	4	6	8	12	15	15

\* Table from Superintendents Manual on Compaction of Hot Mix Asphalt Pavement (1978)  
 Where dashes appear in the table, conditions are such that it is doubtful that specification density can be achieved so work would cease. The table has come to be known as "cessation requirements."

As an example to illustrate the use of the table: assume we are placing a 1½" thick mat and the base temperature is between 50°F and 60°F. A laydown temperature of 295°F is needed to provide 12 minutes before the mat cools to an average temperature of 175°F. If it is a warmer day, with a base temperature of 70°F to 80°F, a laydown temperature of 280°F would provide 12 minutes of rolling time. On a day warm enough to have a base temp of 70°F to 80°F, the air temperature would probably be above 40°F and there would be some sunshine, so it would probably take 2 or 3 more minutes to cool to 175°F, probably 15 minutes.



**METHODS OF SAMPLING AND TESTING**  
**MT 226-16**  
**MAXIMUM ACCEPTABLE DEVIATIONS**  
**IN THE SIEVE ANALYSIS OF INDEPENDENT ASSURANCE SAMPLES**  
*(Montana Method)*

**1 Scope**

- 1.1 This method shall serve as a guide in evaluating the maximum acceptable deviations in the sieve analysis of **Independent Assurance** samples. If the individual grading percentages vary from the group average percentages by more than the amounts listed, the cause must be determined and the error remedied. Deviation percentages are based on the weight of the total sample.

**2 References*****MT Materials Manual***

MT 201 Sampling Roadway Materials

MT 602 Independent Assurance and Final Record Sampling

MT 607 Procedure for Reducing Field Samples of Aggregate to Testing Size

Sieve Size	Permissible Variation
4" (100 mm)	±3%
3" (75 mm)	±3%
2 1/2" (63 mm)	±3%
2" (50 mm)	±3%
1 1/2" (37.5 mm)	±3%
1" (25 mm)	±3%
¾" (19 mm)	±3%
5/8" (16.0 mm)	±3%
½" (12.5 mm)	±3%
3/8" (9.5 mm)	±3%
No. 4 (4.75 mm)	±2%
No. 8 (2.36 mm)	±2%
No. 10 (2.00 mm)	±2%
No. 16 (1.18 mm)	±2%
No. 30 (0.600 μm)	±2%
No. 50 (0.300 μm)	±2%
No. 100 (0.150 μm)	±2%
No. 200 (0.075 μm)	±1.5



**METHODS OF SAMPLING AND TESTING**  
**MT 228-13**  
**METHOD OF ESTABLISHING FIELD TARGET DENSITY FOR**  
**CEMENT TREATED BASE DENSITY CONTROL**

**1 Scope**

- 1.1 This method is the procedure for establishing the field target density and moisture for compaction control of cement treated base (CTB).

**2 Referenced Documents**

**AASHTO**

T 134 Moisture-Density Relations of Soil-Cement Mixtures

**MT Materials Manual**

MT 216 Method of Sampling and Testing Cement Treated Base

**3 Procedure**

- 3.1 At the start of CTB production, use the maximum density and optimum moisture determined by AASHTO T 134 and provided in the mix design as the target for compaction control.
- 3.2 When samples for MT 216 have been taken, use the specimens molded for compressive strength to determine density. Use the average density of the three specimens to represent each sample. Use additional material taken for MT 216 to determine moisture content. Once the field density and moisture have been determined for two samples, average the results. If the average results in an increase of 1.0 pounds per cubic foot (16.0 kg per cubic meter) or greater or a decrease of 1.5 pounds per cubic foot (24.0 kg per cubic meter) or greater, calculate a new maximum density and optimum moisture in accordance with AASHTO T 134 for the material produced. Apply the new maximum density retroactive to the start of CTB production on the project. Do not change the target moisture unless a new optimum moisture is determined by AASHTO T 134.
- 3.3 When field densities on four samples have been completed, average the four test values. If the average results in an increase of 0.5 pound per cubic foot (8.0 kg per cubic meter) or greater or a decrease of 1.0 pound per cubic foot (16.0 kg per cubic meter) or greater, calculate a new maximum density and optimum moisture in accordance with AASHTO T 134 for the material produced. Apply the new maximum density to all subsequent CTB produced. Do not change the target moisture unless a new optimum moisture is determined by AASHTO T 134.
- 3.4 As each additional field density and moisture is completed, add the results to the results of the previous three densities and moistures, and average. If the average results in an increase of 0.5 pound per cubic foot (8.0 kg per cubic meter) or greater or a decrease of 1.0 pound per cubic foot (16.0 kg per cubic meter) or greater, calculate a new maximum density and optimum moisture in accordance with AASHTO T 134 for the material produced. Apply the new maximum density to all subsequent CTB produced. Do not change the target moisture unless a new optimum moisture is determined by AASHTO T 134.



**METHOD OF SAMPLING AND TESTING**  
**MT 229-15**  
**PROCEDURE FOR SOLIDS - WATER - VOIDS RELATIONS**  
**OF SOIL MASSES (ZERO-AIR VOIDS)**

**1 Scope**

- 1.1 This method covers the compaction of soils by using the solids-water-voids (zero-air voids) chart. This method usually applies to the north central, eastern and southeastern areas of Montana but may apply to other areas of the state. It will be the responsibility of the District Materials Supervisor to monitor the applicability of this method.

**2 Referenced Documents**

***AASHTO***

T 100 Specific Gravity of Soils

***MT Materials Manual***

MT 210 Moisture Density Relations of Soils Using a 5.5 Lb. Rammer and a 12 Inch Drop

MT 230 Moisture Density Relations of Soils Using a 10 Lb. Rammer and a 18 Inch Drop

**3 Procedure**

- 3.1 Air voids are another method used to determine the compaction of soils. The zero-air voids method will usually apply to soils classified from A-4 to A-7. When the zero-air voids method is not applicable, the 95% of maximum density and  $\pm 2\%$  of optimum moisture will be used.
- 3.2 In order for this method to be accurate, it is necessary to find the specific gravity for the soils proposed for use. The most logical time to determine the specific gravity is during the pre-construction soil survey. However, due to the excavation process, which may result in a mixture of various soil strata, it may become necessary to perform additional specific gravity tests once the project is under contract. The specific gravity of soils is determined in accordance with AASHTO T 100. (An average specific gravity is determined for the soil samples secured within any individual project.)
- 3.3 Individual proctor tests determined during the pre-construction soil survey are plotted on the zero-air voids chart. If the plot of the peaks from the family of proctor curves from the preliminary soil survey falls on a line roughly parallel to the zero-air voids, the zero-air voids method should work. Tests that fall to the left of the 10% air voids line are generally single size granular particle soils or excessively wet condition type soils. With these soils, the 95% of maximum density and  $\pm 2\%$  of optimum moisture will be used.
- 3.4 Tests taken in the field that lie outside, or to the right of the 0% air voids line, not within the band, should be reviewed and treated as a failing test or possibly a bad reading by the density gauge. However, it is unusual to get tests that fall to the right of the 0% line. If tests consistently fall to the right of the 0% line, a specific gravity on the soil in question should be determined in accordance with AASHTO T100. Special Provision covers Proctor tests that plot outside the zero-air voids chart under compaction control. All proctor tests must be plotted on a zero-air voids chart to see if each test fits the zero-air voids chart.

## 4 Calculations

### 4.1 Formula for calculating % voids:

$$\% \text{ Voids} = 100 - \left( \left[ \frac{d(1 + [G_s(m/100)])}{(G_s)(W)} \right] \times 100 \right)$$

where:

#### **US Standard**

$d$  = Dry Density in lb/ft<sup>3</sup>

$G_s$  = Specific Gravity

$m$  = % moisture

$W$  = wt of water in lb/ft<sup>3</sup> or 62.42796

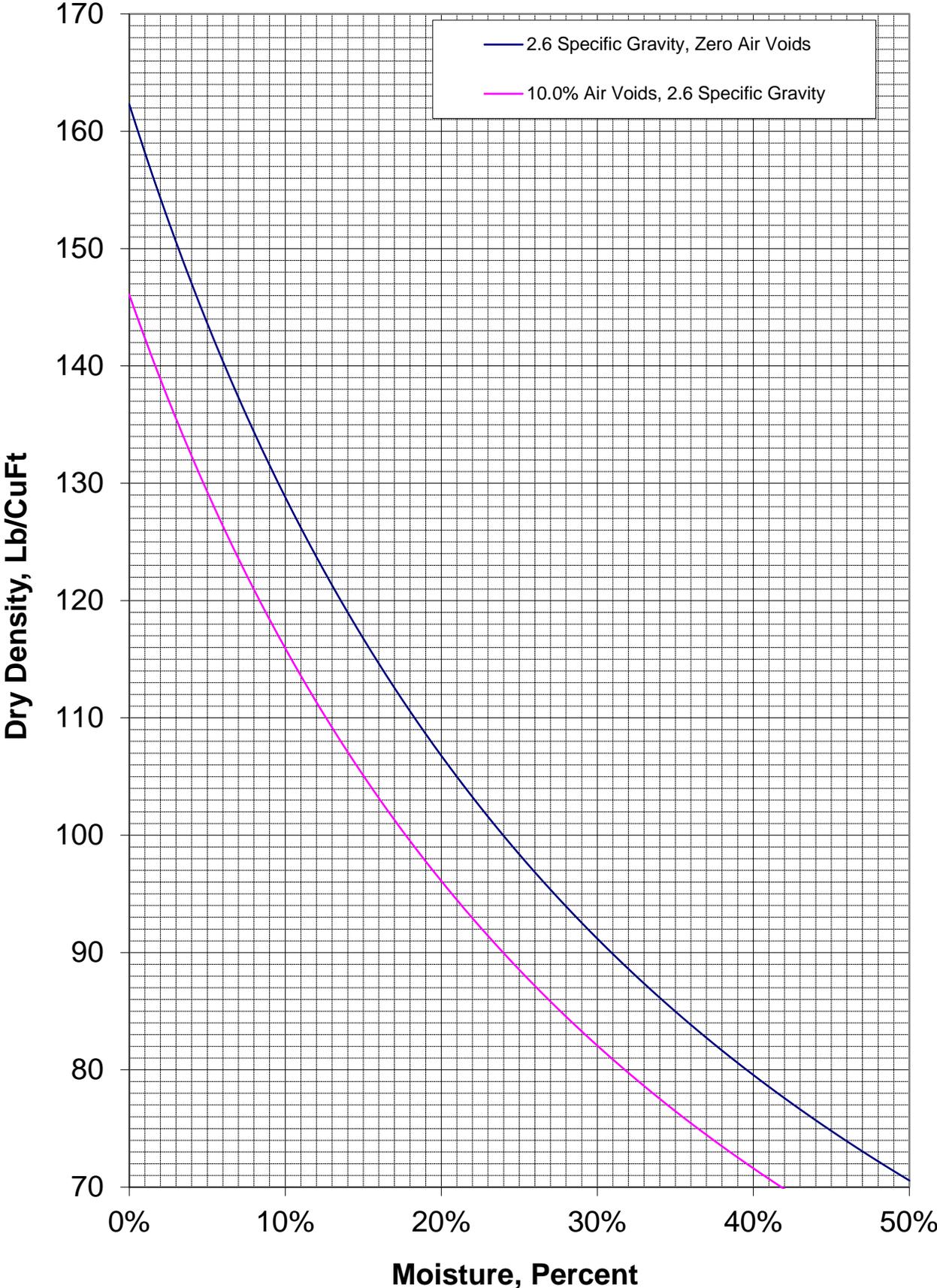
#### **Metric**

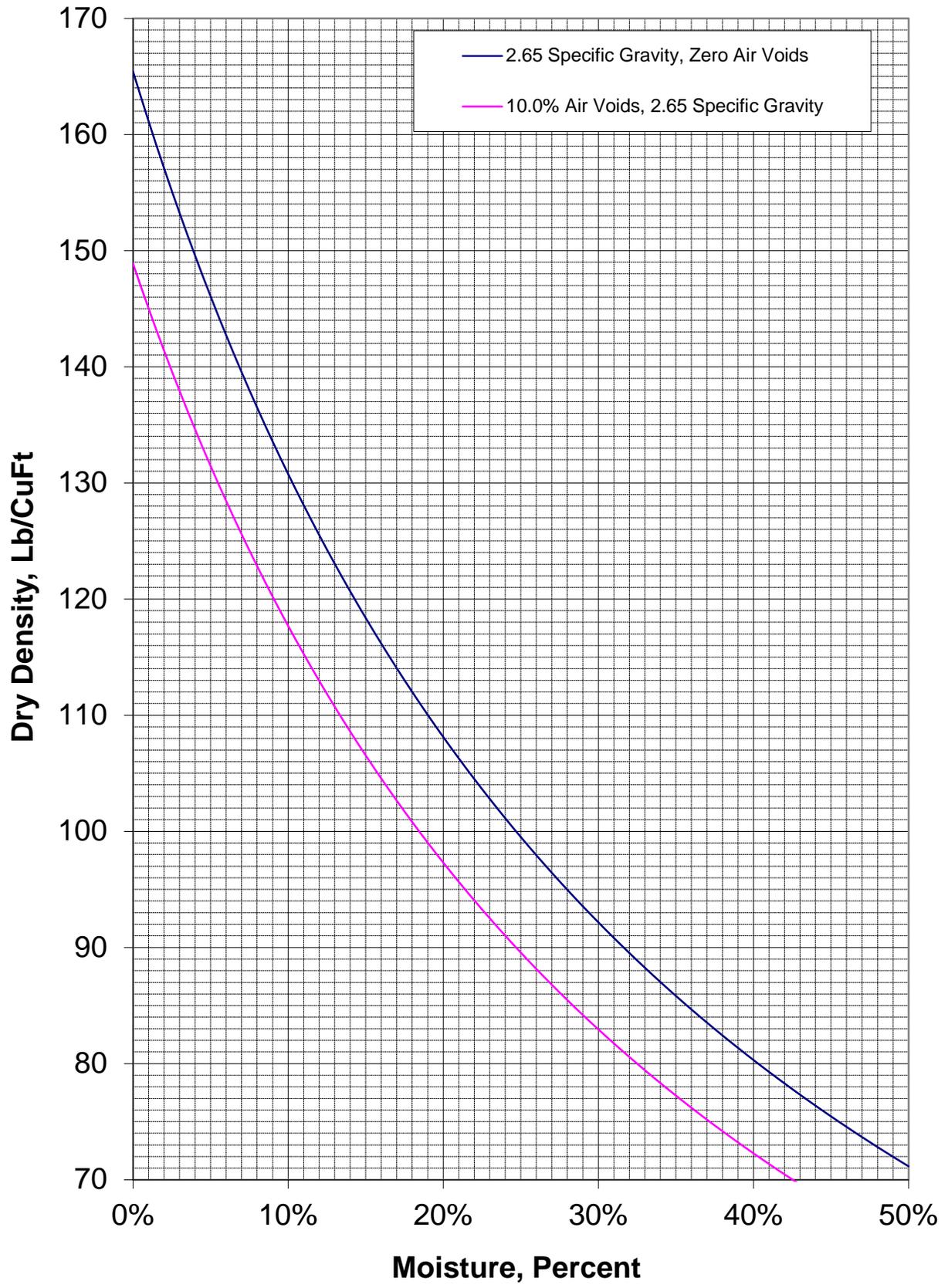
$d$  = Dry Density in Kg/m<sup>3</sup>

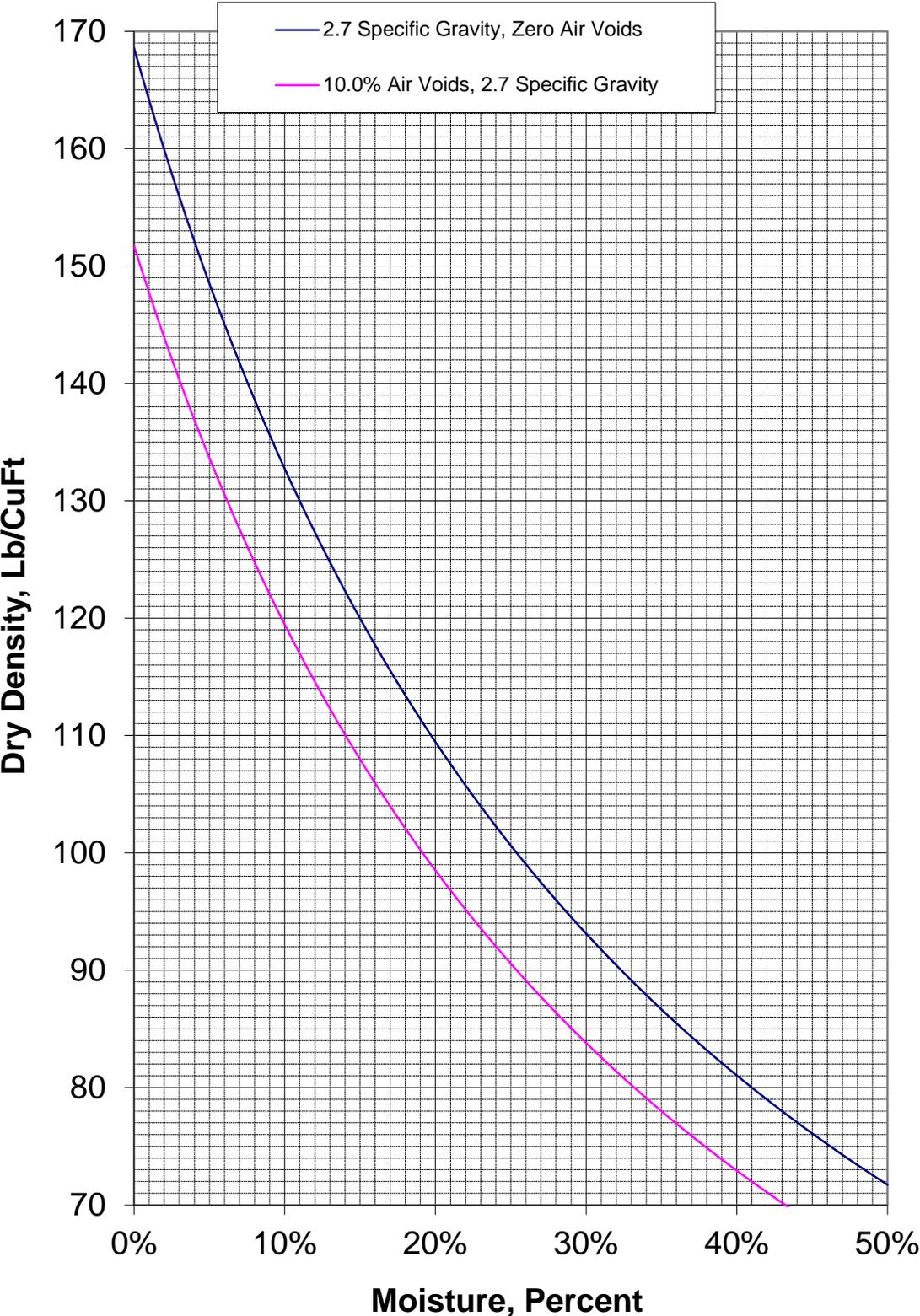
$G_s$  = Specific Gravity

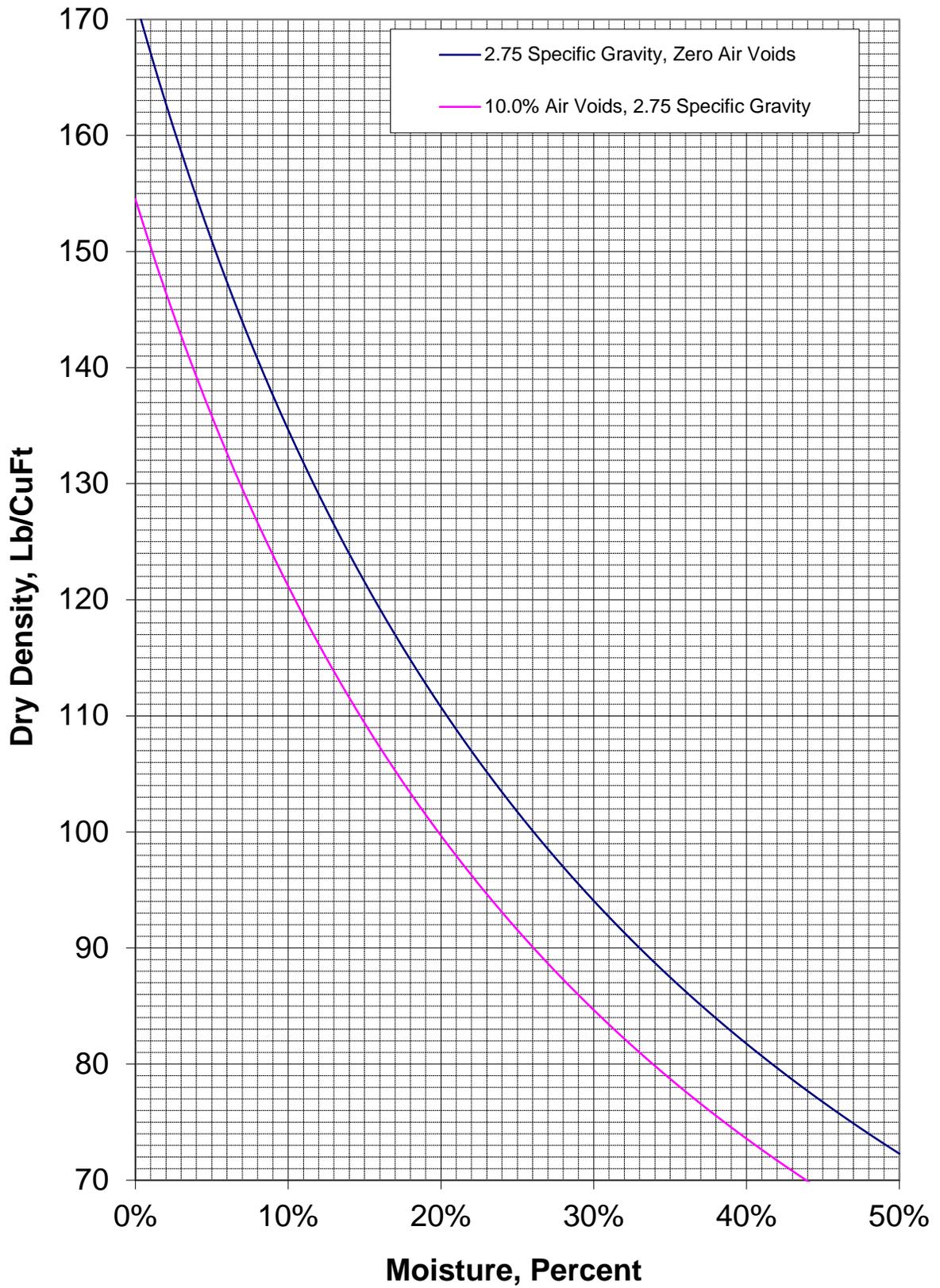
$m$  = % moisture

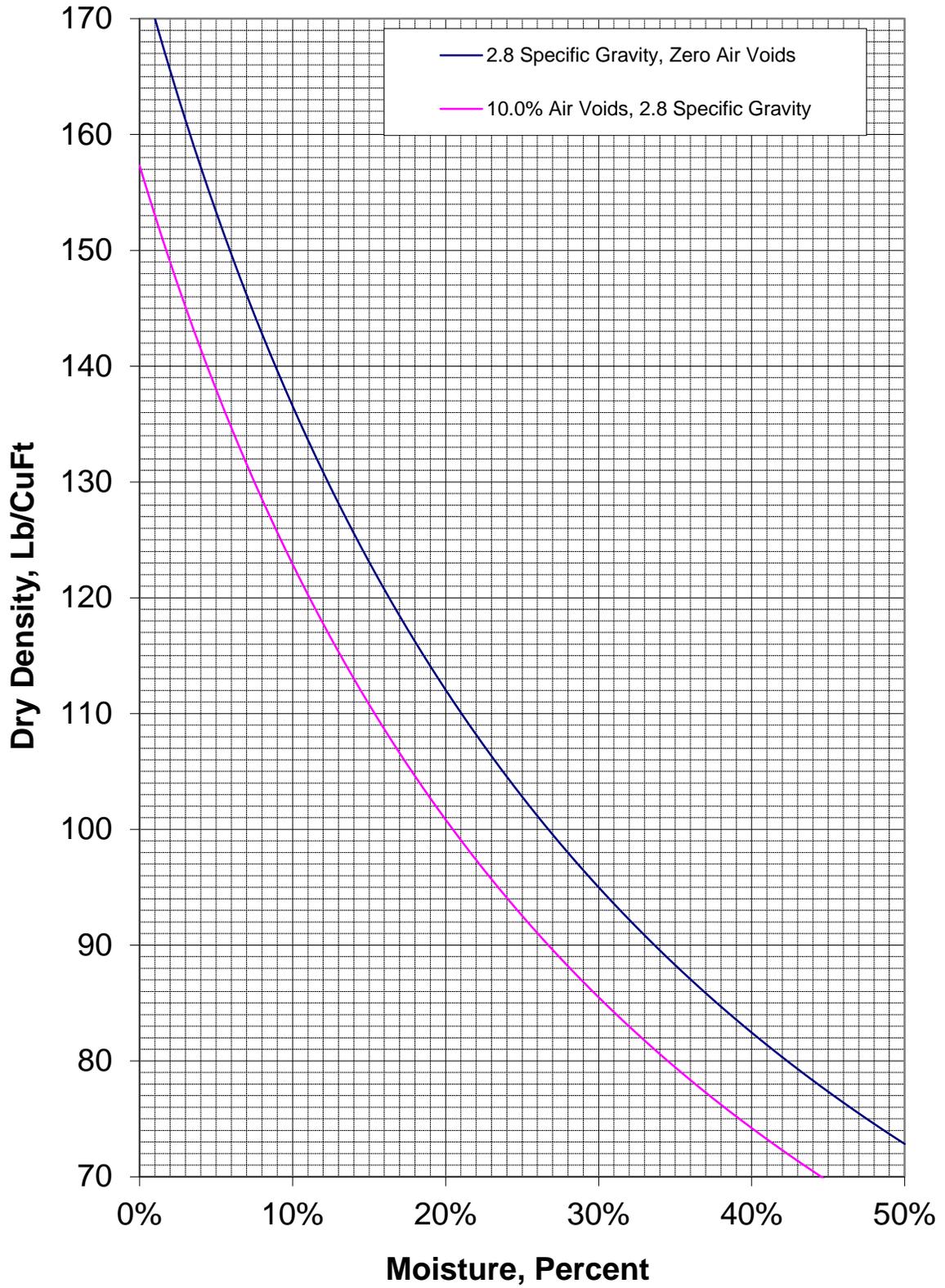
$W$  = wt of water in Kg/m<sup>3</sup> or 1000

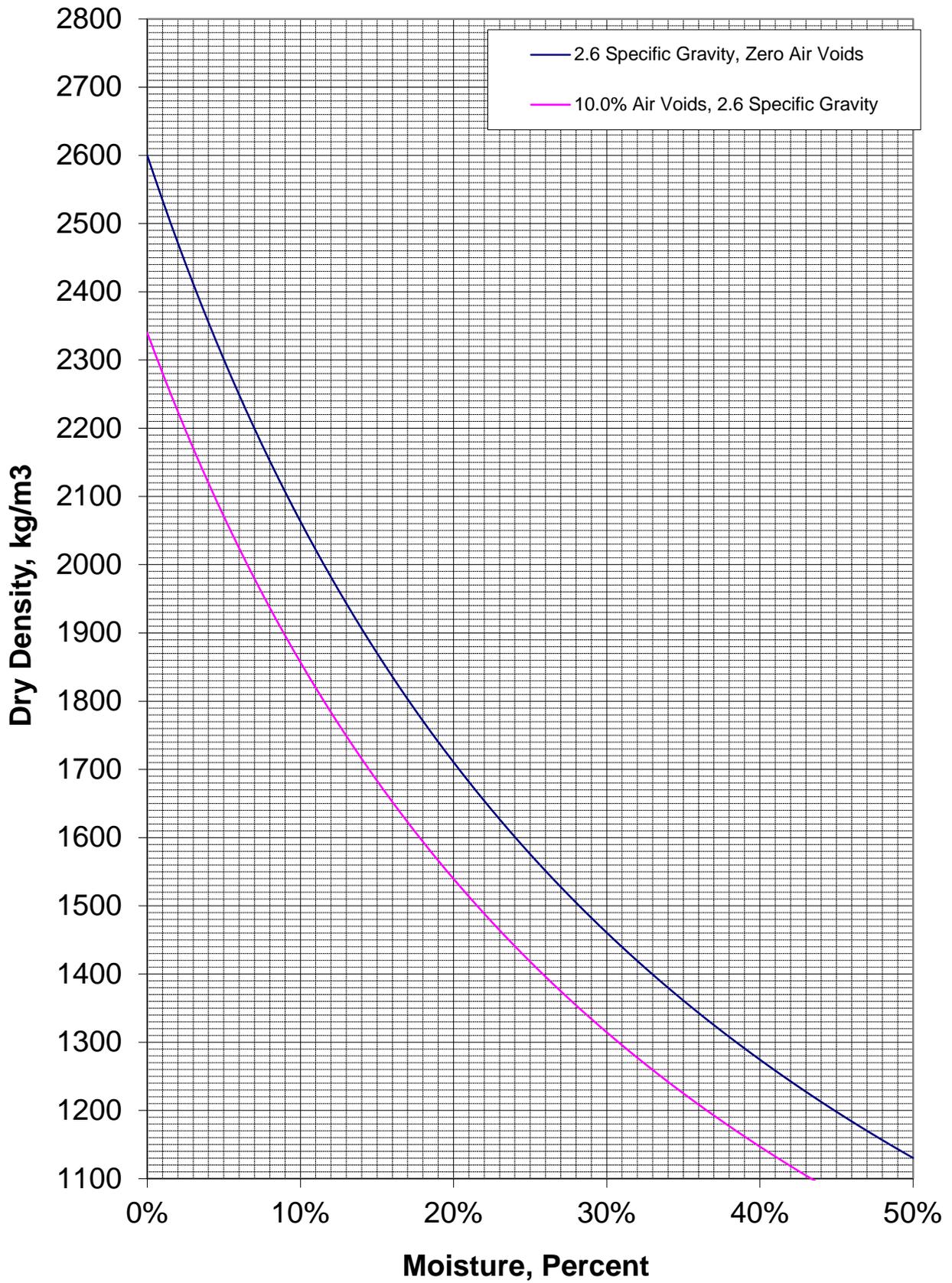


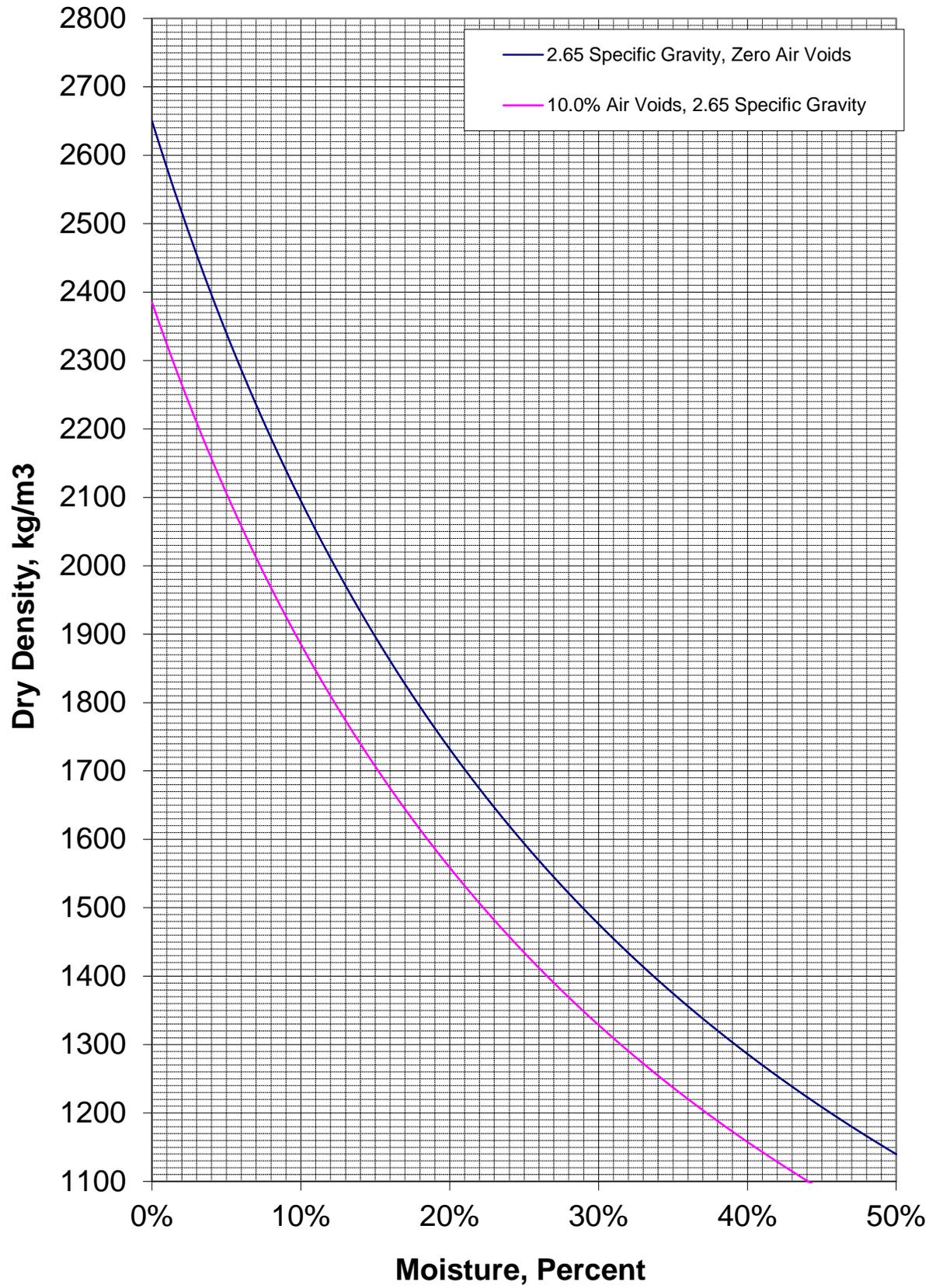


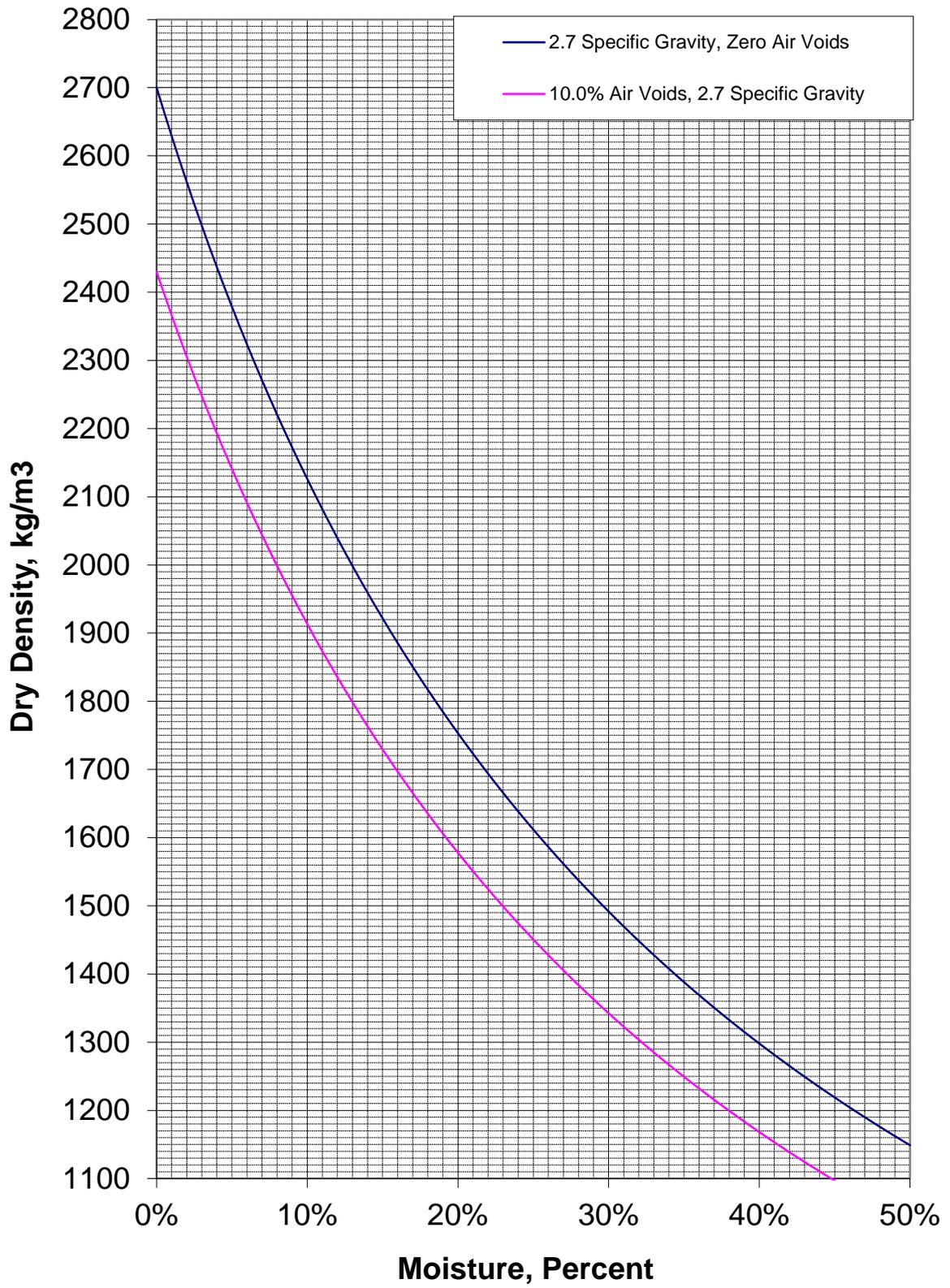


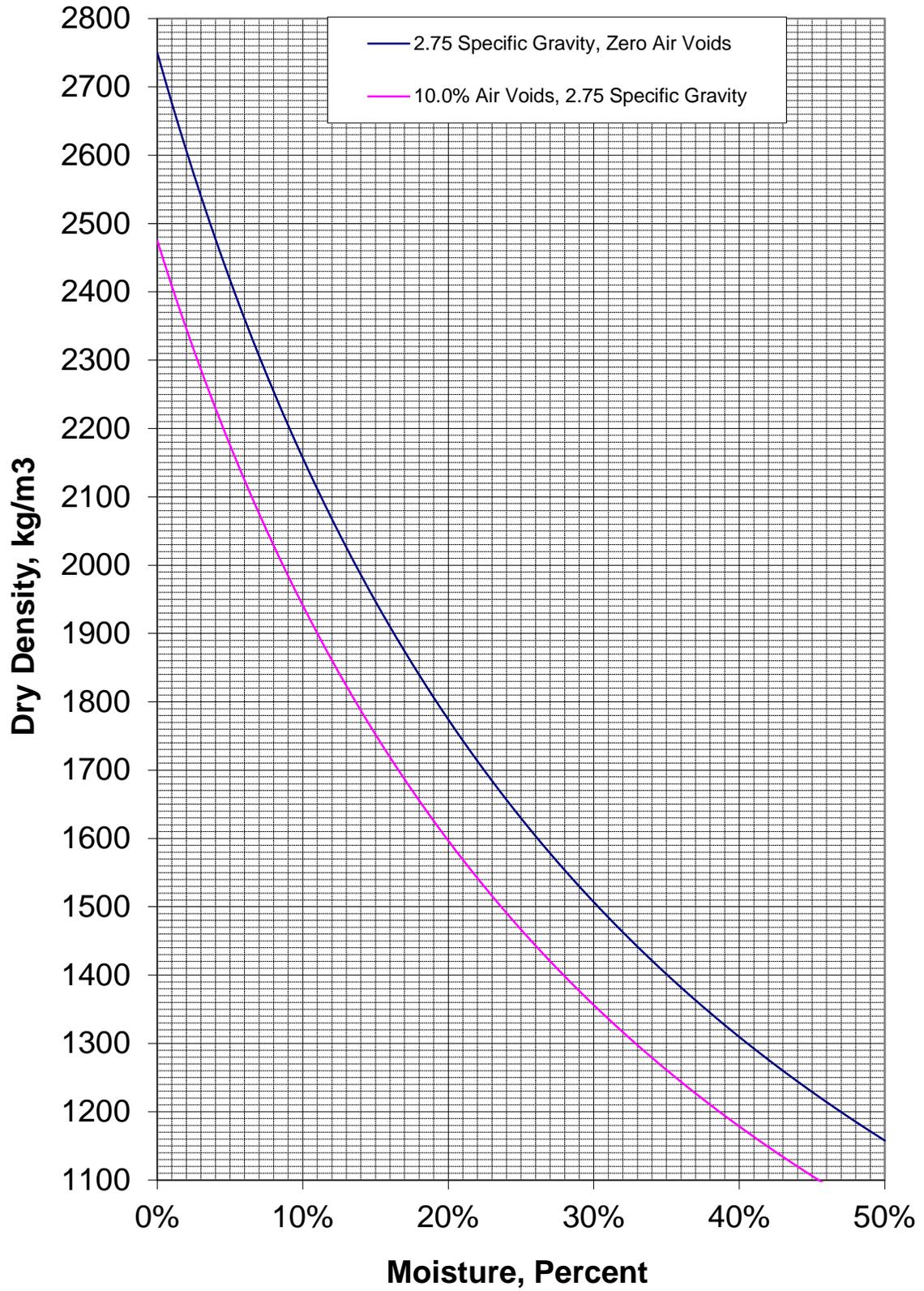


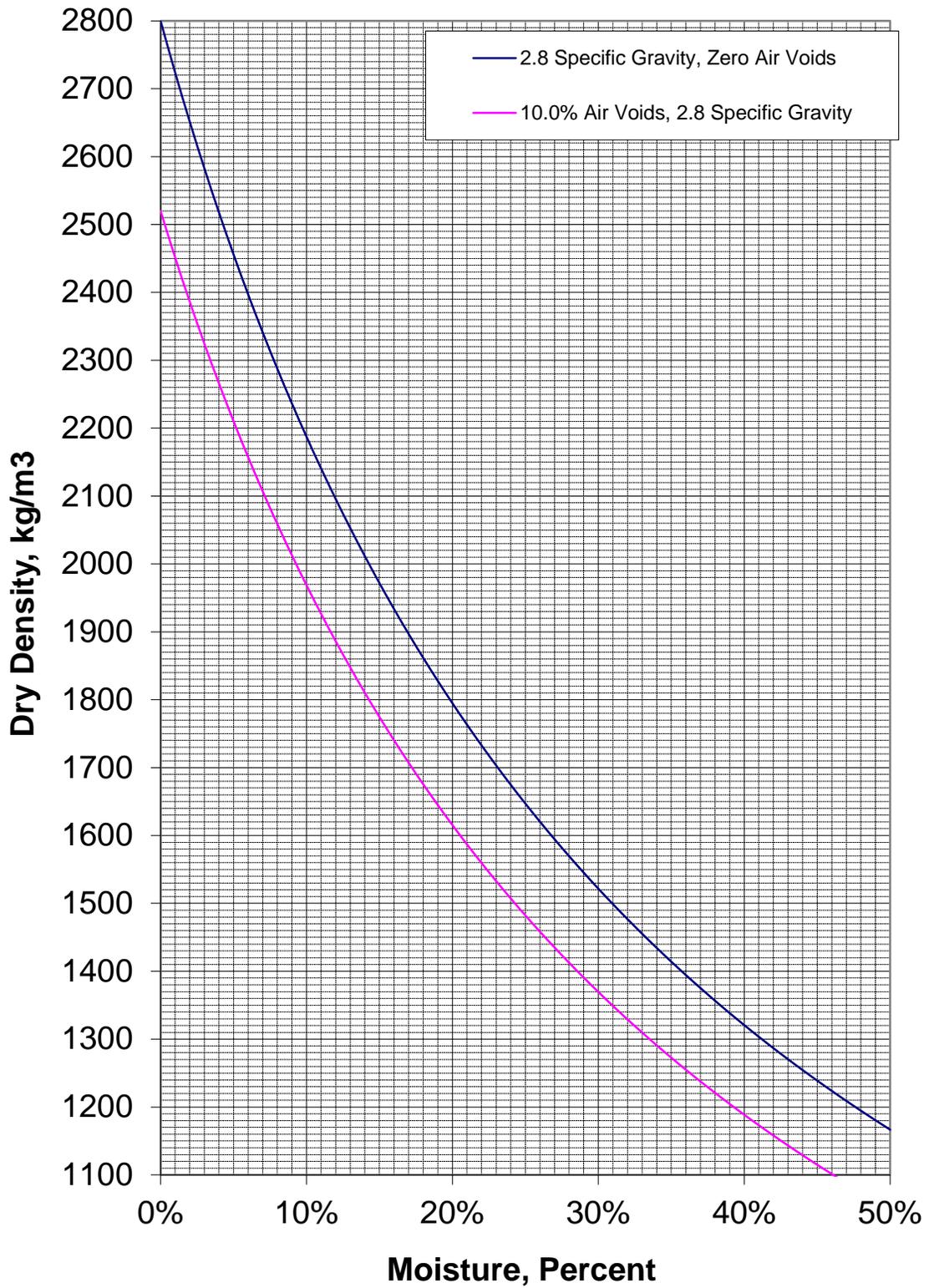












**METHODS OF SAMPLING AND TESTING**  
**MT 230-16**  
**METHOD OF TEST FOR THE MOISTURE-DENSITY RELATIONS OF SOILS**  
**USING A 10 LB. (4.54 KG) RAMMER AND A 18 IN. (457 MM) DROP**  
***(Modified AASHTO T 180)***

MT 230 is identical to AASHTO T 180 except for the following stipulations:

1. Replace Section 1.5 with the following:

If the specified oversized particle maximum percentage is exceeded (except for material that meets the criteria described in MT 218, Section 4.6.), the replacement method should be used. The replacement method maintains the same percentage of coarse material (passing a 50 mm sieve and retained on a 4.75 mm sieve) in the moisture-density sample as in the original field sample. The material retained on the 19.0 mm sieve shall be replaced as follows: sieve an adequate quantity of the representative soil over the 50 mm and 19.0 mm sieve. Weigh the material retained on the 19.0 mm sieve. Replace this material with an equal mass of material passing the 19.0 mm sieve and retained on the 4.75 mm sieve. Take the material for replacement from the extra portion of the sample.



**METHOD OF SAMPLING AND TESTING**  
**MT 232-16**  
**SOIL CORROSION TEST**  
**(Montana Method)**

**1 Scope**

- 1.1 This test method covers procedures and apparatus for determining the pH, conductivity and sulfate content of a soil in corrosion testing.
- 1.2 The intent of these tests is to supplement soil-resistivity measurements and thereby identify conditions under which the corrosion of metals in soil may be accentuated.
- 1.3 At the discretion of the Chief Chemist, MT 532 may be used to determine sulfate content of soils.

**2 Referenced Documents****AASHTO**

M 231 Weighing Devices Used in the Testing of Materials

**MT Materials Manual**

MT 532 Determination of Sulfate Content In Soils by Ion Chromatography

**3 Apparatus**

- 3.1 *Sieves* – A series of sieves of the following sizes: 1/4 in. (6.3 mm), No. 4 (4.75 mm), No. 10 (2.00 mm) and a pan
- 3.2 *Balance* – A balance with an accuracy of at least 0.1 percent and conforming to the requirements of AASHTO M 231
- 3.3 *Drying Apparatus* – A suitable device capable of drying samples at a temperature of 140°F (60°C)
- 3.4 *Pulverizing Apparatus* – Either a mortar and a rubber-covered pestle or any device suitable for breaking up the aggregations of soil particles without reducing the size of the individual grains.
- 3.5 *Sample Splitter* – A suitable riffle sample splitter or sample splitter for proportional splitting of the sample and capable of obtaining representative portions of the sample without appreciable loss of fines. The width of the container used to feed the riffle splitter should be equal to the total combined width of the riffle chutes. Proportional splitting of the sample on a canvas cloth is also acceptable.
- 3.6 *pH Meter* – With electrodes suitable for laboratory analysis
- 3.7 *Standard Buffer Solutions* – Buffer solutions with known pH values of 4.0, 7.0, 10.0
- 3.8 *Beakers* – 100 ml and 250 ml wide mouth glass beakers with a watch glass for cover
- 3.9 *Glass stirring rods*
- 3.10 *Conductivity Meter* - Suitable for laboratory or field analysis
- 3.11 *Muffle Furnace* – The muffle furnace shall be capable of operation at the temperatures required and shall have an indicating pyrometer accurate within  $\pm 25^{\circ}\text{C}$ , as corrected, if necessary, by calibration.
- 3.12 *Platinum Crucible* – Platinum crucibles for ordinary chemical analysis should preferably be made of pure unalloyed platinum of 15 to 30-ml capacity. Where alloyed platinum is used for greater stiffness or to avoid sticking of crucible and lid, the alloyed platinum should not decrease in mass by more than 0.2 mg when heated at 1200°C for one hour.

- 3.13 *Filter Paper* – Fast filter paper (Whatman #41) and slow filter paper (Whatman #42)

#### 4 Sample Preparation

- 4.1 The sample as received shall be in a moist condition for pH purposes. If the sample is too wet, it may be dried to a moist condition in air or a drying apparatus not to exceed 140°F (60°C) prior to sample selection (Note 1). A representative test sample to perform the pH test shall then be obtained with a sampler or by splitting or quartering.

*Note 1 – Samples dried in an oven or other drying apparatus at a temperature not exceeding 140°F (60°C) are considered to be air dried.*

#### 5 Determination of pH

- 5.1 Place a sufficient amount of soil into a 100 ml glass beaker or other suitable container to fill to the 80 ml mark.
- 5.2 Stir enough distilled water into the sample to produce a soil slurry and then cover with a watch glass.
- 5.3 Let the sample stand for a minimum of one hour, stirring every 10 to 15 minutes. This is to allow the pH of the soil slurry to stabilize.
- 5.4 Measure the temperature of the soil and adjust the temperature controller of the pH meter to that of the sample temperature. This adjustment should be done just prior to testing.
- 5.5 Calibrate the pH meter by means of the standard solutions provided.
- 5.6 Stir the sample with a glass rod immediately before immersing the electrode into the soil slurry solution and gently turn the beaker or container to make good contact between the solution and the electrode. **DO NOT** place the electrode into the soil, only into the soil slurry solution.
- 5.7 Immerse the electrode in the solution for at least 30 seconds to allow the meter to stabilize. If the meter has an auto read system, it will automatically signal when stabilized.
- 5.8 Read and record the pH value to the nearest tenth of a whole number.
- 5.9 Rinse the electrode well with distilled water, then dab lightly with tissues to remove any film formed on the electrode. Caution: Do not wipe the electrode as this may result in polarization of the electrode and consequent slow response.
- 5.10 Add approximately 1 gram of calcium carbonate (CaCO<sub>3</sub>) to the soil slurry and set aside for approximately 24 hours. Determine the marble pH by following sections 5.4 to 5.9.

#### 6 Determination of Conductivity

- 6.1 Place a sufficient amount of soil on a 100 mm watch glass to completely cover the watch glass. Let stand overnight to allow the sample to dry.
- 6.2 Sieve the dry sample over a No. 10 sieve (2.00 mm) and then pulverize the material remaining on the sieve (+2.00 mm) with a mortar and pestle in such a manner so as to break up the aggregations without fracturing the individual grains. If the sample contains brittle particles, pulverize carefully and with just enough pressure to free the finer material that adheres to the coarser particles.
- 6.3 Place a portion of the pulverized soil in a 100 ml beaker and add distilled water at a ratio of 1 part soil to 2 parts water and let stand for 30 minutes.
- 6.4 After conditioning, pour the water from the beaker into the sample container of the conductivity meter and determine the conductivity to the nearest 0.01 m. mhos.

**7 Determination of Sulfate Content**

- 7.1 Place 3 grams of the pulverized soil prepared in Section 6 into a 500 ml Erlenmeyer flask.
- 7.2 Add 150 ml of distilled water; stopper the flask and shake to mix.
- 7.3 Centrifuge the sample for 30 minutes.
- 7.4 Decant the liquid into a 250 ml beaker and add 2 ml of dilute Hydrochloric acid (50% strength), to flocculate the suspended particles. Cover with a watch glass and place onto a hot plate until the sample boils.
- 7.5 Remove the beaker from the hot plate and immediately filter through a fast filter paper (Whatman #41).
- 7.6 Add 10 ml of a 10% Barium Chloride ( $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$ ) solution to the filtered sample to determine the presence of sulfate. (The liquid will become milky in the presence of sulfate).
- 7.7 Cover the beaker with a watch glass and return to the hot plate until the sample boils.
- 7.8 Remove the beaker from the hot plate and immediately filter through a slow filter paper (Whatman #42). Wash the filter with several hot water rinses.
- 7.9 Place the filter paper in a tared 30 ml platinum crucible, place the crucible into a muffle furnace and slowly raise the temperature to  $1000^\circ\text{C}$  to burn off filter paper.
- 7.10 Remove the crucible from the muffle furnace and desiccate until cool. Weigh to the nearest 0.0001 grams and record weight as W.
- 7.11 Sulfate Calculation

$$\% \text{ Sulfate (SO}_4) = [(W * 0.4115) / S] * 100$$

Where:

W = Sulfate weight

S = Soil sample weight

**8 Report**

Include the following parameters in the report:

pH

Marble pH

Sulfate as %  $\text{SO}_4$

Conductivity in m. mohs