CURRENT DATE OF REVISION
MT 200 SECTION
SOIL AND AGGREGATE

Test Method No.	Title	Pages	Date of Publication or Revision
MT 200	Vacant *(Use AASHTO R 58 Dry Preparation of Disturbed Soil and Soil-Aggregate Samples for Test)*		
MT 201	Sampling Roadway Materials	7 pp	Oct 2013
MT 202	Sieve Analysis for Fine and Coarse Aggregate	1 pp	Jan 2025
MT 203	Eliminated *(Use AASHTO T 19 Bulk Density (Unit Weight) and Voids in Aggregate)*		
MT 204	Eliminated *(Use AASHTO T 84 Specific Gravity and Absorption of Fine Aggregate)*		
MT 205	Eliminated *(Use AASHTO T 85 Specific Gravity and Absorption of Coarse Aggregate)*		
MT 206	Vacant (ELIMINATED)		
MT 207	Bulk Sampling of Subsurface Investigations	5 pp	Apr 2021
MT 208	Eliminated *(Use AASHTO T 89 Determining the Liquid Limit of Soils and AASHTO T 90 Determining the Plastic Limit and Plasticity Index of Soils)*		
MT 209	Eliminated *(Use AASHTO T 96 Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine)*		
MT 210	Moisture-Density Relations of Soils Using 5.5 lb. Rammer and 12 In. Drop.	1 pp	Dec 2016
MT 211	Eliminated *(Use AASHTO T 134 Moisture-Density Relations of Soil-Cement Mixtures)*		
MT 212	Determination of Moisture and Density of In-Place Materials	5 pp	Jun 2024
MT 213	Eliminated *(Use AASHTO T 176 Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test)*		
MT 214	Eliminated *(Use AASHTO M 145 Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes)*		
MT 215	Vacant (moved to MT 122)		
MT 216	Method of Sampling and Testing Cement Treated Base	5 pp	Oct 2013
MT 217	Eliminated *(Use AASHTO T 335 Determining the Percentage of Fracture in Coarse Aggregate)*		
MT 218	Determining Relative Compaction and Percent Moisture	2 pp	Jun 2020
MT 219	Controlling Compaction Using a Control-Strip Test Section Technique with Nuclear Gauges	3 pp	Aug 2019
MT 220	Eliminated *(Use AASHTO T 100 Specific Gravity of Soils)*		
MT 221	Eliminated *(Use AASHTO T 255 Total Evaporable Moisture Content of Aggregate by Drying)*		
MT 222	Eliminated *(Use AASHTO T 191 Density of Soil In-Place by the Sand-Cone Method)*		
MT 223	Eliminated *(Use AASHTO T 112 Clay Lumps and Friable Particles in Aggregate)*		
MT 224	Vacant (ELIMINATED)		
MT 225	Vacant (ELIMINATED)		
MT 226	Maximum Acceptable Deviations in Sieve Analysis of IA Samples	1 pp	Dec 2016
MT 227	Eliminated *(Use AASHTO T 265 Laboratory Determination of Moisture Content of Soils)*		

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SOIL AND AGGREGATE

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, 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, 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 202-25
SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES
(*MODIFIED AASHTO T 11 AND T 27*)

MT 202 is identical to AASHTO T 11 and T 27 with the following additions:

1. Include the following reference:

   Western Alliance for Quality Transportation Construction (WAQTC)
   Field Operation Procedures (FOP) for AASHTO T 27 Sieve Analysis of Fine and Coarse Aggregates and AASHTO T 11 Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregate by Washing

2. Add the Method C wash procedure provided in the *WAQTC FOP for AASHTO T 27 and AASHTO T 11* as a wash option in addition to the washing procedures described in AASHTO T 27 Section 7.7.

METHODS OF SAMPLING AND TESTING
MT 207-21
BULK SAMPLING OF SUBSURFACE INVESTIGATIONS

1 Introduction

1.1 Subsurface investigations are 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.

1.2 Subsurface investigation 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 investigation will increase or decrease the amount of work needed to supply the necessary information for design. Borings conducted by multiple work units must be coordinated to preclude duplication of effort.

2 Referenced Documents

2.1 ***AASHTO***

M 145 Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes
T 84 Specific Gravity and Absorption of Fine Aggregate
T 85 Specific Gravity and Absorption of Coarse Aggregate
T 190 Resistance R-Value and Expansion Pressure of Compacted Soils
T 255 Total Evaporable Moisture Content of Aggregate by Drying

MT Materials Manual

MT 202 Sieve Analysis for Fine and Coarse Aggregate
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
MT 232 Soil Corrosion Test

3 Apparatus

3.1 *Sampling tools*

Hand shovels, picks, etc.
Hand augers, post hole diggers
Power augers and drills, etc.
Backhoes

3.2 *Instruments (optional)*

Survey equipment
Digital camera
GPS

3.3 *Miscellaneous*

Stakes and lath
Sample bags (17”X 28” canvas, 75 lb. capacity)
Sealed containers (jars or plastic bags)
Field notebooks and forms

4 Procedure A – Field Investigation Unit (FIU) Geotechnical Boring

4.1 General Procedure

Follow the general procedure outlined below when conducting geotechnical borings with the FIU. The complexity of the subsurface investigation will depend upon many factors as discussed in Section 1.2 above.

Note 1 – Geotechnical personnel will submit utility locate requests prior to boring operations.

4.2 Geotechnical and Pavement Bureau or District Materials staff may perform reconnaissance. Coordinate information gathering during the boring planning meeting associated with EPS Activity 455.

4.3 Preliminary investigation Plan

4.3.1 Develop a preliminary plan prior to field work during the EPS Activity 455 coordination meeting. Base the preliminary plan on available information and intended scope. Determine sample site locations to enable proper soil profile determination and adequate sampling. This plan will likely change as information is gained during the subsurface investigation process.

4.3.2 Geotechnical personnel will keep the boring records.

Geotechnical Bureau personnel will log each test hole, boring, test pit, or cut-surface exposure with the field description and location of each material encountered in accordance with the MDT Geotechnical Manual.

Note 2 – Color photographs of samples and exposed strata should be obtained and are of considerable value to the Department. Each photograph should include a date and an identifying number or symbol.

4.4 Bulk Sampling

Collect bulk samples for laboratory analysis from areas that may supply appreciable quantities of earthwork and known borrow areas. Geotechnical personnel will collect the appropriate bulk samples of disturbed material and District personnel may assist with this effort if they are available and onsite. The spacing of these investigations and sample collection intervals will depend upon the geologic complexity of the project area and upon the importance of soil and rock parameters to the project design. The required depth and sample collection should be in accordance with guidelines provided in the MDT Geotechnical Manual.

4.4.1 Clear the sample area of any surface debris (twigs, rocks, etc.). When possible, clear an appropriate area around the hole to prevent near-surface soil particles from falling down the hole and contaminating the sample.

When drilling with augers, samples may be collected from cuttings as they accumulate around the hole, taking care to clear unnecessary material as it accumulates and as layers change. Due to safety concerns, samples should only be obtained when augers have been stopped and are not turning.

4.4.2 Collect bulk samples representative of the strata encountered. Minimum sample sizes are described in MT 202. If a given soil layer is relatively thin, collecting a sample of adequate size may not be possible. Collect as much material as practicable.

Collect moisture samples and place them in sealed containers. The sample size is in accordance with AASHTO T 255. 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.

Collect samples, not less than 5 lbs., for corrosive testing in accordance with MT 232 and place them in sealed containers.

4.4.3 Accurately identify each sample with the project identification, location, date, test site number and depth below reference ground surface where it was collected. 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.

5 Procedure B – District Laboratory Boring

5.1 Rehabilitation Projects and Miscellaneous District Requests

5.1.1 Develop a preliminary plan prior to field work based upon district reconnaissance, available information, and intended scope. Determine approximate sample site locations 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.

Note 3 – District Materials Lab staff will contact 811 and confirm utility locations prior to boring operations.

Resources used to develop a preliminary plan may include, but is not limited to, the following items.

- Geotechnical and Pavement Bureau records
- Maintenance records
- Construction records
- Topographic and geologic maps
- Historic use information for the area
- USDA Soil Conservation Service
- County soil survey reports
- Utility company maps and locations
- City and county plat maps
- Information from landowners and businesses
- Aerial photography

5.1.2 Required survey data for all projects

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

5.13 Standard sampling frequency is typically one per ½ mile, or as conditions dictate.

Log each test hole, boring, test pit, or cut-surface exposure with the field description and location of each material encountered, in accordance with the MDT Geotechnical Manual. Record coordinates with survey equipment or GPS, if requested. Log the depth of each strata. Note and log the mat thickness. Note and log base thickness and subgrade. Indicate reason for termination of the boring hole (groundwater, refusal, bit length, stopped in same material, etc.).

5.2 Bulk Sampling

Collect bulk samples for laboratory analysis from all areas that may supply appreciable quantities of earthwork and known borrow areas. District staff will collect the bulk samples of disturbed material. Geotechnical staff will collect undisturbed samples of the same material. 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.

5.2.1 Clear the sample area of any surface debris (twigs, rocks, etc.). When possible, clear an approximately 6-inch radius around the hole to prevent near-surface soil particles from falling down the hole and contaminating the sample. Samples should be collected from tailings piles as they accumulate around the hole, taking care to clear unnecessary material as it accumulates and as layers change.

5.2.2 Collect bulk samples representative of the strata encountered. Minimum sample sizes are described in MT 202. If a given soil layer is relatively thin, collecting a sample of adequate size may not be possible. Collect as much material as practicable.

Collect moisture samples and place them in sealed containers. The sample size is in accordance with AASHTO T 255. 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.

Collect samples, not less than 5 lbs., for corrosive testing in accordance with MT 232 and place them in sealed containers.

5.2.3 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.

Provide a narrative summary with the investigation describing the bore hole and material characteristics.

5.3 New and Reconstruction Projects Only

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

Review planning reports and anticipate alignment and grades.

Locate test holes in the field 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, as conditions dictate and as indicated by field review.

Keep a log of the test holes and plot the test holes on a profile sheet.

Review data collected to determine if additional test sites (i.e., areas of refusal, inadequate depth, or questionable frequencies) are required.

Note topsoil depth and availability.

6 Testing (Procedures A and B)

6.1 Discuss appropriate testing for the project scope of work with the Geotechnical and Pavement Bureau personnel before any testing is performed. As applicable and based on the discussion, testing analysis should be performed on requested samples for the following items and recorded on the appropriate worksheets.

6.1.1 For **Procedure A**, provide test results to the Geotechnical Bureau for inclusion in the EPS Activity 460 report.

6.1.2 For **Procedure B**, record test results in the District Subsurface Investigation Report, as described in Section 8.

6.2 Bulk Samples

Perform a sieve analysis of fine and coarse materials in accordance with MT 202. Classify the soils in accordance with AASHTO M 145. Perform moisture-density relation analysis in accordance with MT 210 and MT 230.

Send applicable materials of greater quality than A-6 classification to the Materials Bureau for potential R-value testing in accordance with AASHTO T 190. R-value testing needs will be determined as discussed in section 6.1

If the District Lab chooses, specific gravity testing on fine and coarse materials may be performed in accordance with AASHTO T 84 and T 85, respectively.

6.3 Moisture Samples

Determine the total evaporable moisture content of the material in accordance with AASHTO T 255. Record this information in the Construction Report (see Section 8) and note if the moisture content at the time of sampling exceeds the optimum moisture content, as determined by MT 210 or MT 230.

7 Interpretation of Results

7.1 Interpret the results of the 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.

8 District Subsurface Investigation Report

8.1 Include the following in a Subsurface Investigation Report

8.1.1 Locate the area investigated in terms pertinent to the project. This may include sketch maps or aerial photos identifying the location of the test holes, pits, and sample areas, 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.

8.1.2 Coordinate reporting of field data with Geotech Bureau to complete Bore logs.

8.1.3 Upload copies of all borings, test-hole logs and laboratory test results to MDT's Document Management System (DMS). A DMS Help Guide for District Materials is available online. Notify the Geotechnical and Pavement Bureau and the District Preconstruction and Construction personnel that the information is available for viewing on DMS.

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 212-24
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)

$$AVG = \frac{\sum_1^N X}{N}$$

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.

PASSING RATIOS	
Moisture	***Density***
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. Rotate the gauge 90 or 180 degrees, pivoting it around the source rod. The final result will be the average of all the readings.

8.1.2 Native fines or fine sand used to fill the voids and smooth the surface should be minus 30 mesh material screened from the material that is being compacted and dried to a constant mass.

8.2 *Asphalt Mixtures*

8.2.1 Follow AASHTO T 355 Section 9

8.2.2 Native fines or fine sand used to fill the voids and smooth the surface should be minus 30 mesh material screened from the material that is being compacted and dried to a constant mass.

9 Calculations

9.1 Use the appropriate Embankment and Excavation Compaction – Summary of Test Data form (Form MDT-CON-203-03-3) 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/ft³). Percent moisture can also be read directly from the gauge.

9.3 Percent Compaction Calculation

$$\%\,Compaction = \frac{Field\ Dry\ Density\ (\frac{lb}{ft3})}{Proctor\ Dry\ Density}\ X\ 100$$

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

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

9.5 Record percent moisture and density readings to the nearest 0.1 percent (0.1%).

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
R 18 Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
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 601 Materials Sampling, Testing and Acceptance Guide

3 Apparatus

3.1 *Molds* - Use solid-wall, metal cylinders manufactured with dimensions and capacities described in Section 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 ± 0.0003 cu. ft. (943 ± 8 cm^3) with an internal diameter of 4.000 ± 0.016 in. (101.6 ± 0.41 mm) and a height of 4.584 ± 0.005 in. (116.43 ± 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 ± 0.01 (0.25 mm) and weighing 5.50 ± 0.02 lb. (2.495 ± 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 ± 0.06 in. (305 ± 2 mm) above the elevation of the soil. The guide-sleeve must have at least 4 vent holes, no smaller than ⅜ in. (9.5 mm) diameter spaced approximately 90 degrees (1.57 radius) apart and approximately ¾ 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 ± 0.06 in. (305 ± 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 ± 0.01 (0.25 mm) and weighing 5.50 ± 0.02 lb. (2.495 ± 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), ¾ in. (19.0 mm), No. 4 (4.75 mm) sieves conforming to the requirements of AASHTO R 18.

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^3 (kg per m^3)
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^2 (MPa)

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

METHODS OF SAMPLING AND TESTING
MT 218-20
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 moisture and/or density readings (MT 212) must be taken on each lift in the embankment area to demonstrate that uniform relative density has been achieved. Report percent moisture and density reading to the nearest whole percent.

4.6.3 Notes must be made on the Embankment and Excavation Compaction – Summary of Test Data form (Form MDT-CON-203-03-3) 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 219-19
METHOD OF TEST FOR CONTROLLING COMPACTION USING A CONTROL-STRIP TEST SECTION WITH NUCLEAR GAUGES
(*Montana Test Method)*

1 Scope

1.1 This test method is intended to control the density of compacted courses of embankment and borrow containing oversized particles and/or recycled asphalt pavement (RAP), pulverized bituminous surfacing, and cold recycled bituminous surfacing using nuclear gauges. Density control is performed in place after compaction. Cold recycled bituminous surfacing may be produced in-place or off-site in a central plant.

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 321 Determining Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures – “Rice Gravity

3 Definitions

3.1 *Control-Strip A - Embankment, Borrow, or Pulverized Bituminous Surfacing* – 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 - Cold Recycled Bituminous Surfacing* – A section approximately three hundred (300) feet long by one paver width on a firmly compacted base.

3.3 *Test Section - Embankment, Borrow, or Pulverized Bituminous Surfacing* - 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 - Cold Recycled Bituminous Surfacing* – Individual sections each approximately two thousand (2000) feet long by one paver width on which Cold Recycled Bituminous Surfacing will be placed, using the same layer thickness, compaction and procedure used in construction the Control-Strip B above.

3.5 *Constant Mass* – Constant mass has been reached when there is less than a 0.1 percent change in mass after additional drying time: for an oven at 110 ± 5° C (230 ± 9° F), an additional 30 minutes of drying; for an uncontrolled heating source such as hot plates, an additional 20 minutes of drying; or for microwaves, an additional 10 minutes of drying.

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 *Nuclear Gauge Operators Manual and Gauge Booklet*

5 Operational Procedures

5.1 *Control-Strip A - Embankment, Borrow, or Pulverized Bituminous Surfacing*

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 and density of the Control-Strip will be determined by 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. Density and moisture determinations for aggregate surfacing are to be taken at the appropriate depth relative to lift thickness using the "direct transmission" option with the nuclear gauge. 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 mass. 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 for Embankment, Borrow, or Pulverized Bituminous Surfacing*

The remainder of the project is divided into Test Sections as described above in Section 3.3. 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. Appropriate compaction equipment for the material should be used at all times.

5.3 *Control-Strip B - Cold Recycled Bituminous Surfacing*

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 cold recycled bituminous surfacing a comparison will be made between the established Control-Strip density and the Maximum Mixture Specific Gravity (Rice Gravity) as determined by MT 321. This should be done to ensure a reasonable Control-Strip density is established and is in line with the specified compaction percentage.

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 mass. Compaction of the Control-Strip shall commence as soon as possible after cold recycling of the mixture and be uniform over the entire Control-Strip. A test will be taken on each test site with a nuclear gauge after each pass of the compaction equipment. Density determinations for cold recycled bituminous surfacing are to be taken using the "backscatter" option with the nuclear gauge. When testing cold recycled bituminous surfacing in backscatter mode, consult the nuclear gauge operator's manual to determine if "Asphalt mode" should be enabled.

5.3.2 This procedure will continue until the density increase is less than one (1) pound per cubic foot. 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 must be established.

5.4 *Test Sections for Cold Recycled Bituminous Surfacing*

The remainder of the project is divided into 2000 ft. Test Sections. After placing and compacting a lift of cold recycled bituminous surfacing, 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 or re-recycling. 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 Form and Report

6.1 Use form MDT-CON-203-03-3 (Embankment and Excavation Compaction – Summary of Test Data) 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.

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 229-24
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 ±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 ±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:

$$V = 100 - \left(\left[\frac{d\left(1 + \left[G_s\left({}^{m}/_{100}\right)\right]\right)}{(G_s)(W)}\right] \times 100\right)$$

where:

US Standard

V = % Voids (report to nearest 0.1%)

d = Dry Density in lb/ft³ (report to nearest 0.1 lb/ft³)

Gs = Specific Gravity

m = % moisture (report to nearest 0.1%)

W = wt of water in lb/ft³ or 62. 42796

Metric

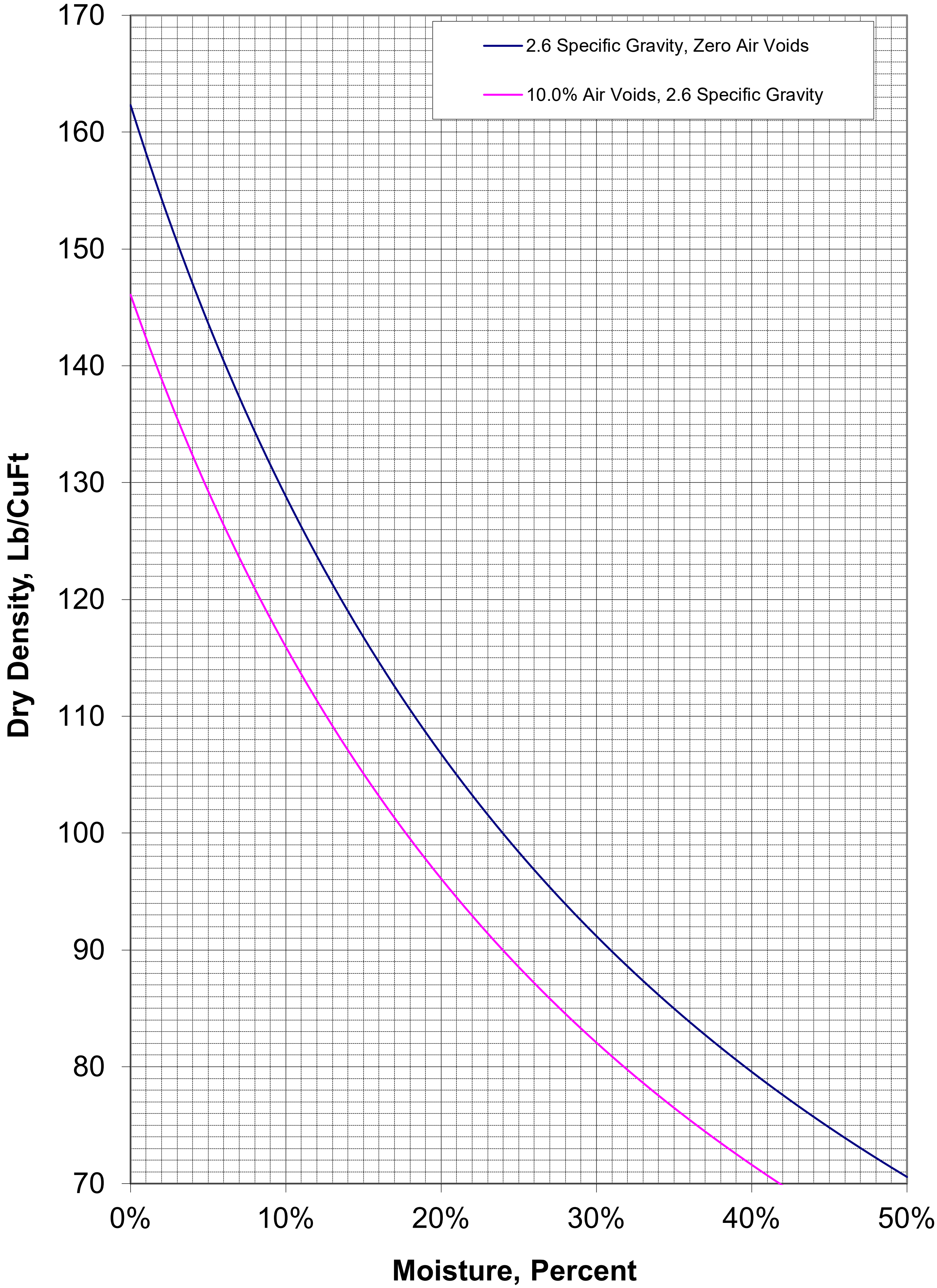
V = % Voids (report to nearest 0.1%)

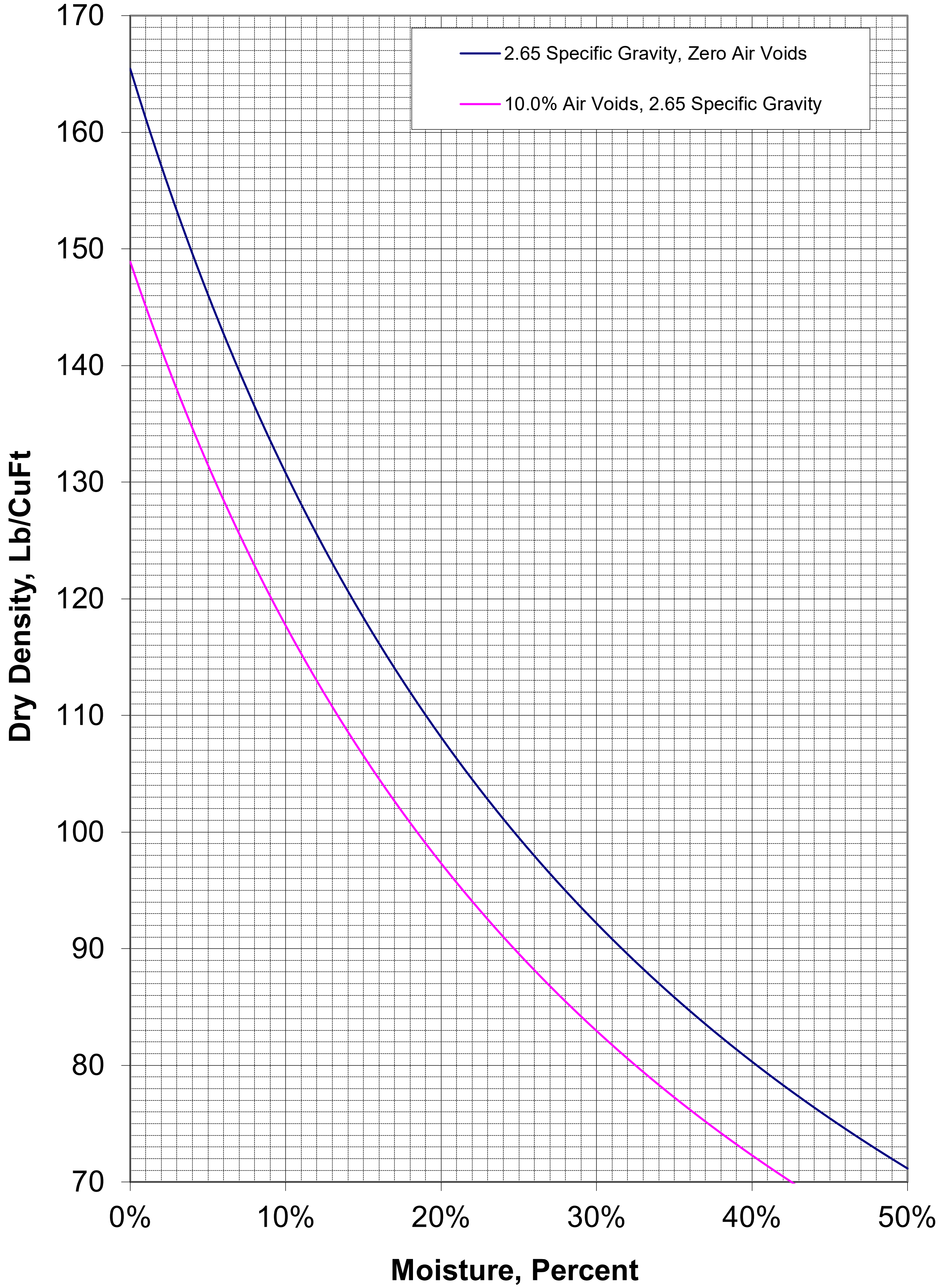
d = Dry Density in Kg/m³ (report to nearest 0.1 Kg/m³)

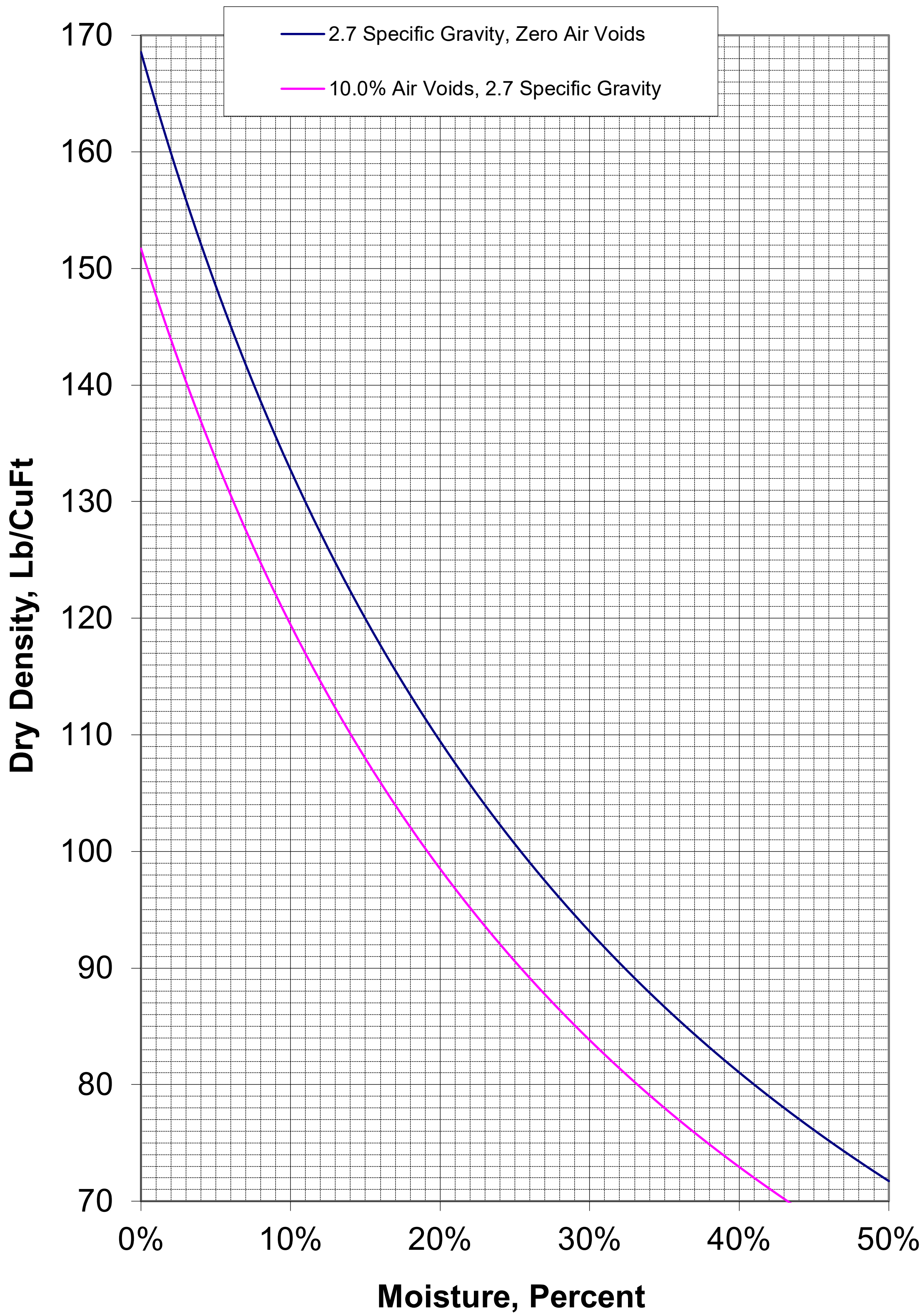
Gs = Specific Gravity

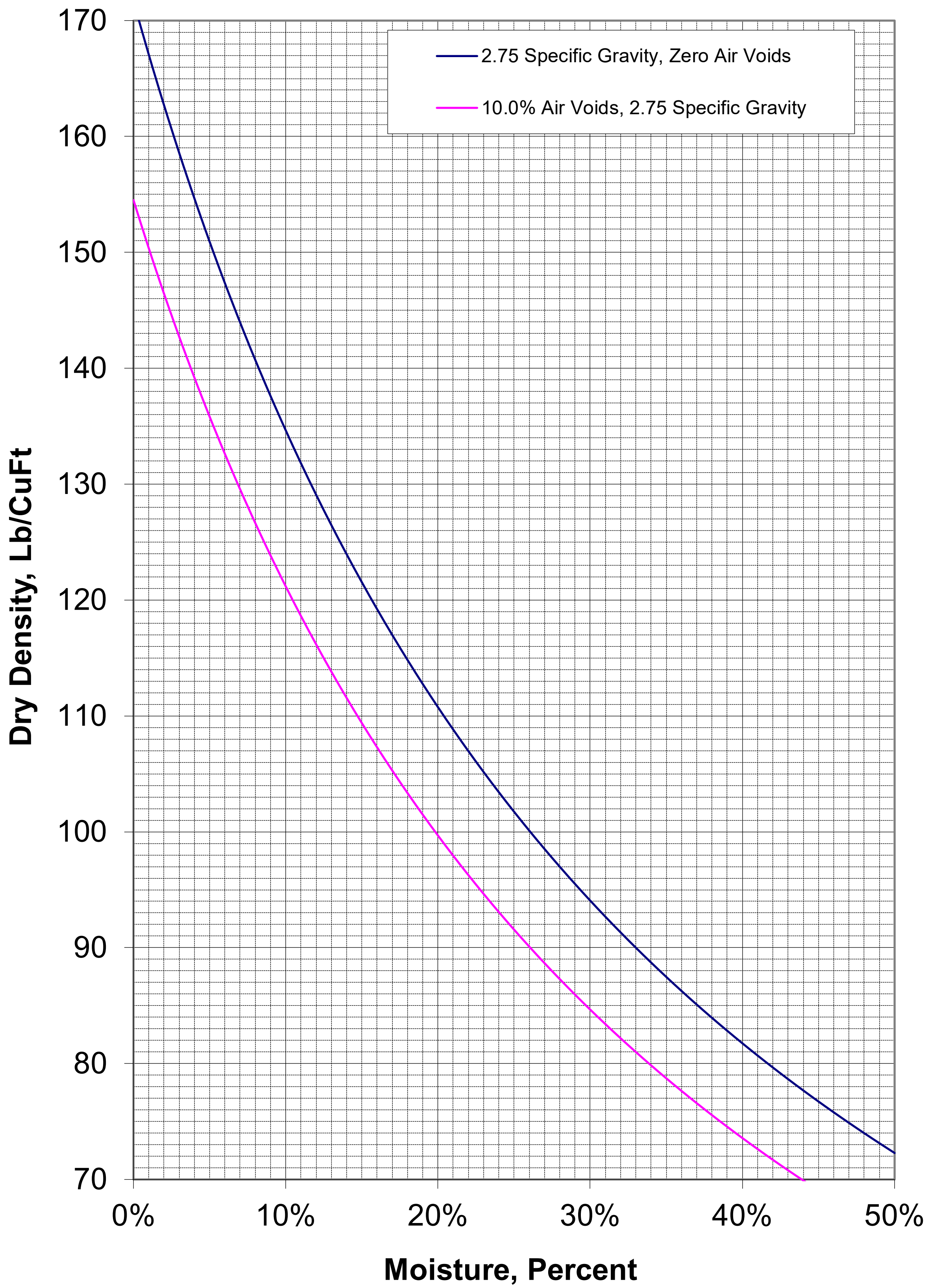
m = % moisture (report to nearest 0.1%)

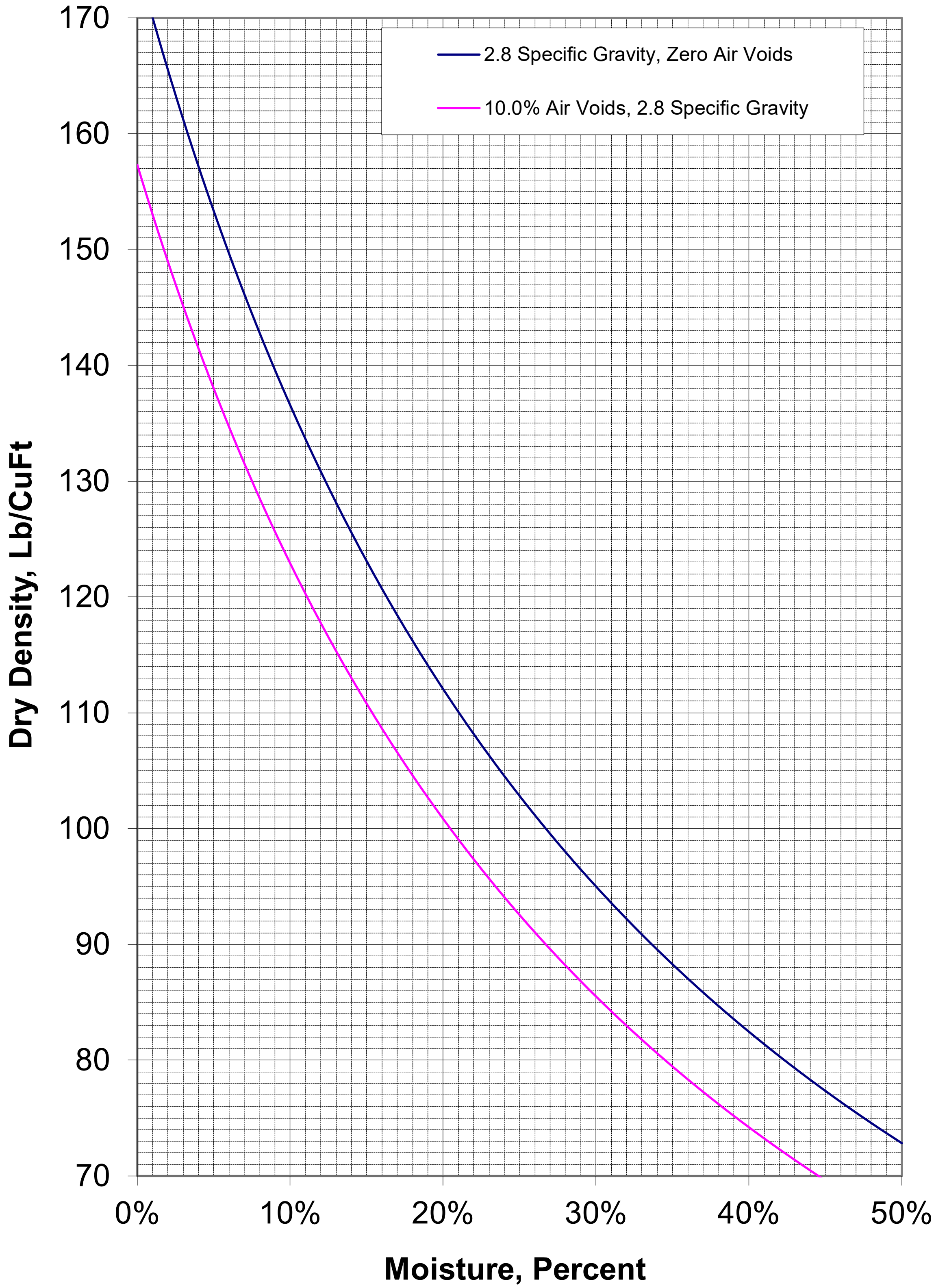
W = wt of water in Kg/m³ or 1000


2.6 Specific Gravity, Zero Air Voids
10.0% Air Voids, 2.6 Specific Gravity
Dry Density, Lb/CuFt
170
160
150
140
130
120
110
100
90
80
70
0%
10%
20%
30%
40%
50%
Moisture, Percent

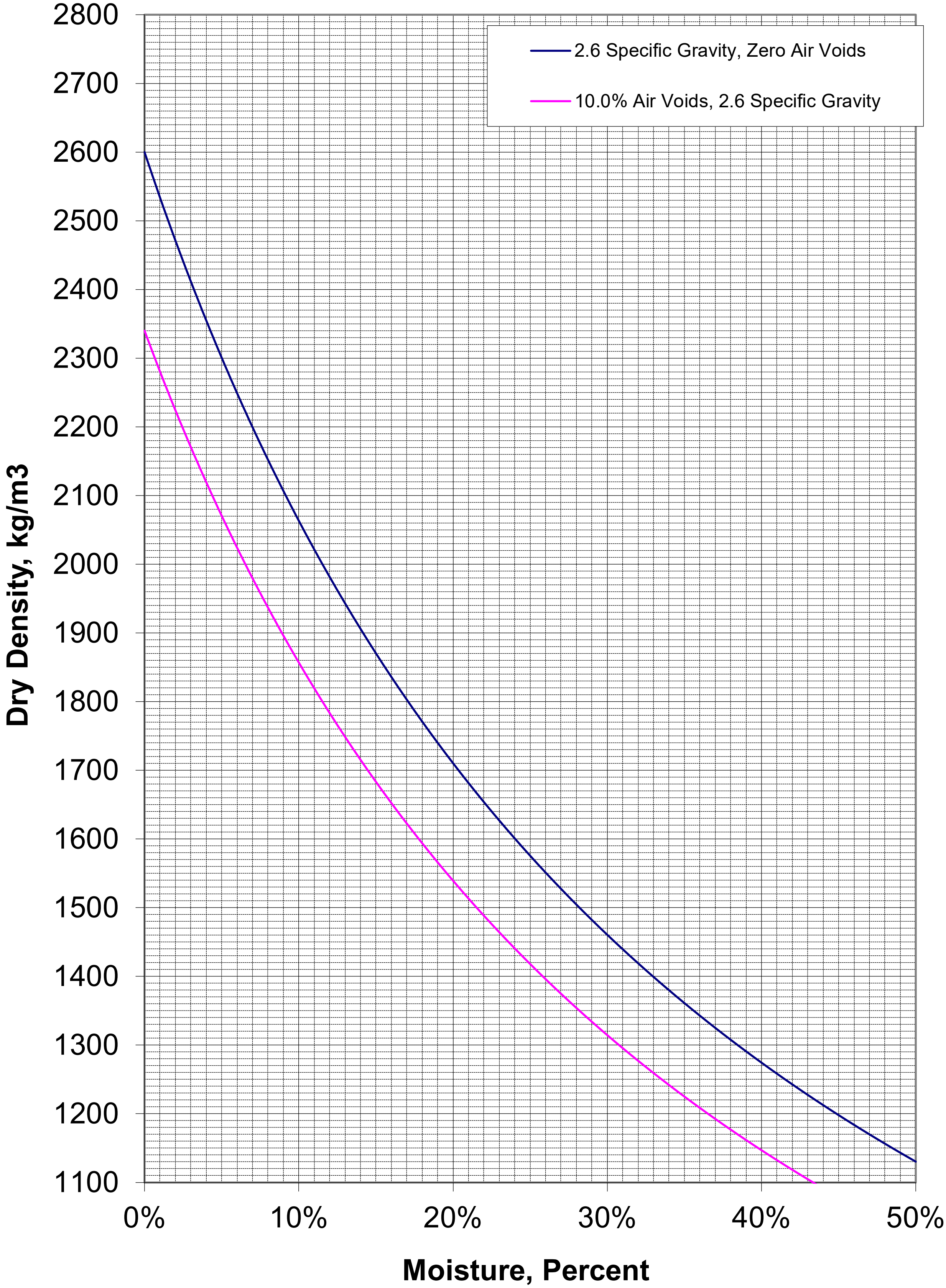

2.65 Specific Gravity, Zero Air Voids
10.0% Air Voids, 2.65 Specific Gravity
170
160
150
140
130
120
110
100
90
80
70
Dry Density, Lb/CuFt
0%
10%
20%
30%
40%
50%
Moisture, Percent

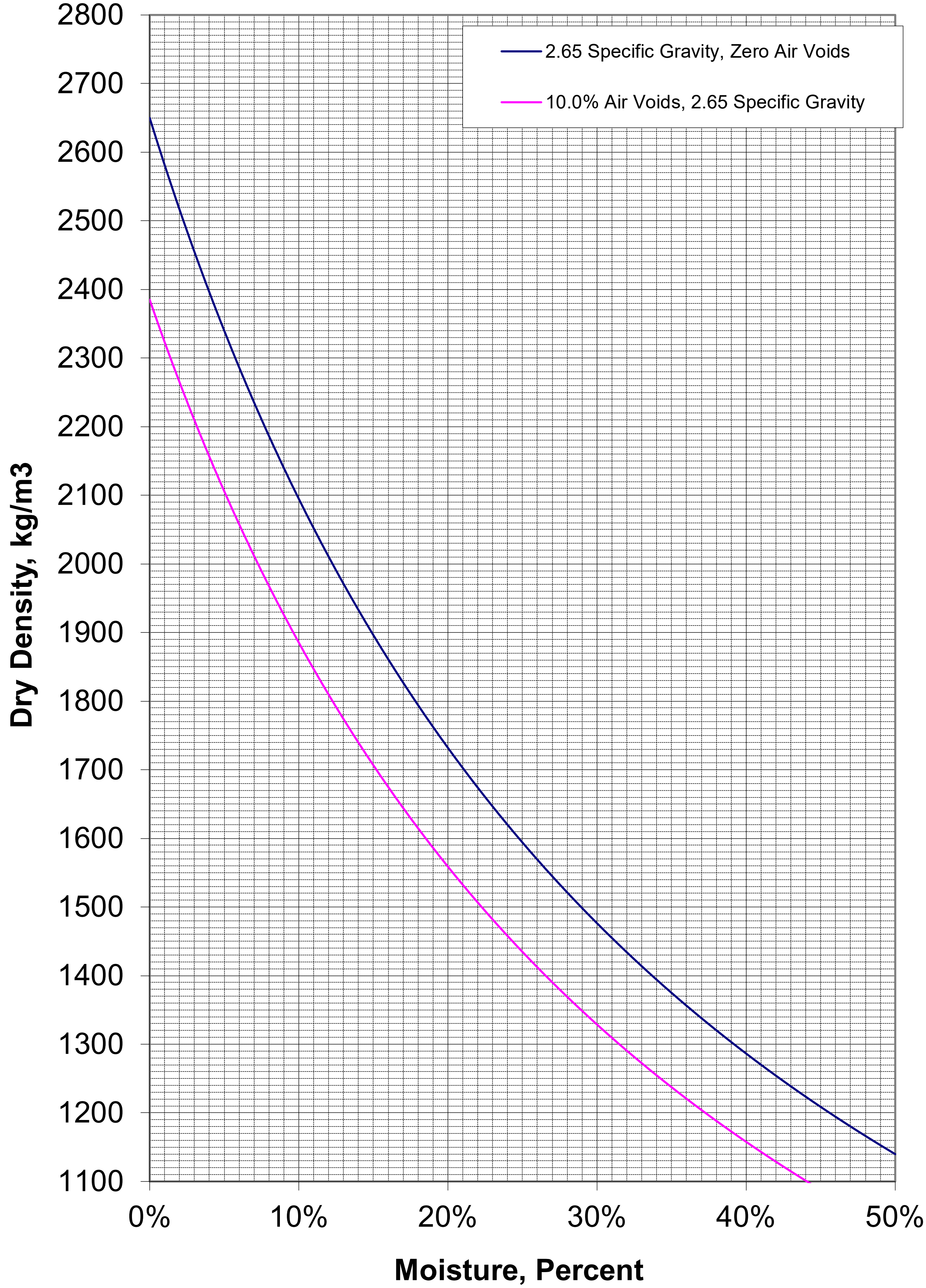

2.7 Specific Gravity, Zero Air Voids
10.0% Air Voids, 2.7 Specific Gravity
170
160
150
140
130
120
110
100
90
80
70
Dry Density, Lb/CuFt
0%
10%
20%
30%
40%
50%
Moisture, Percent

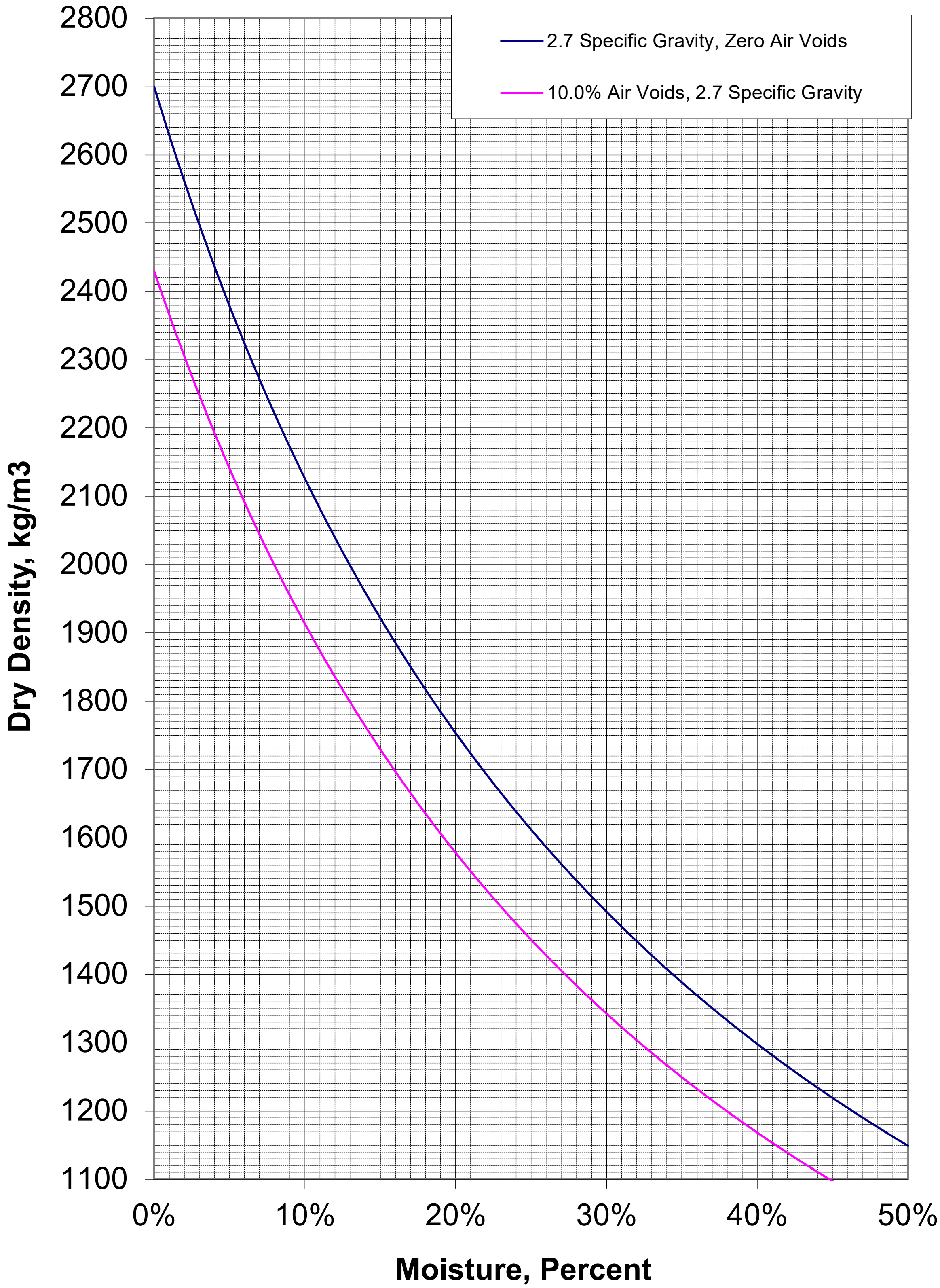

170
160
150
140
130
120
110
100
90
80
70
Dry Density, Lb/CuFt
2.75 Specific Gravity, Zero Air Voids
10.0% Air Voids, 2.75 Specific Gravity
0%
10%
20%
30%
40%
50%
Moisture, Percent

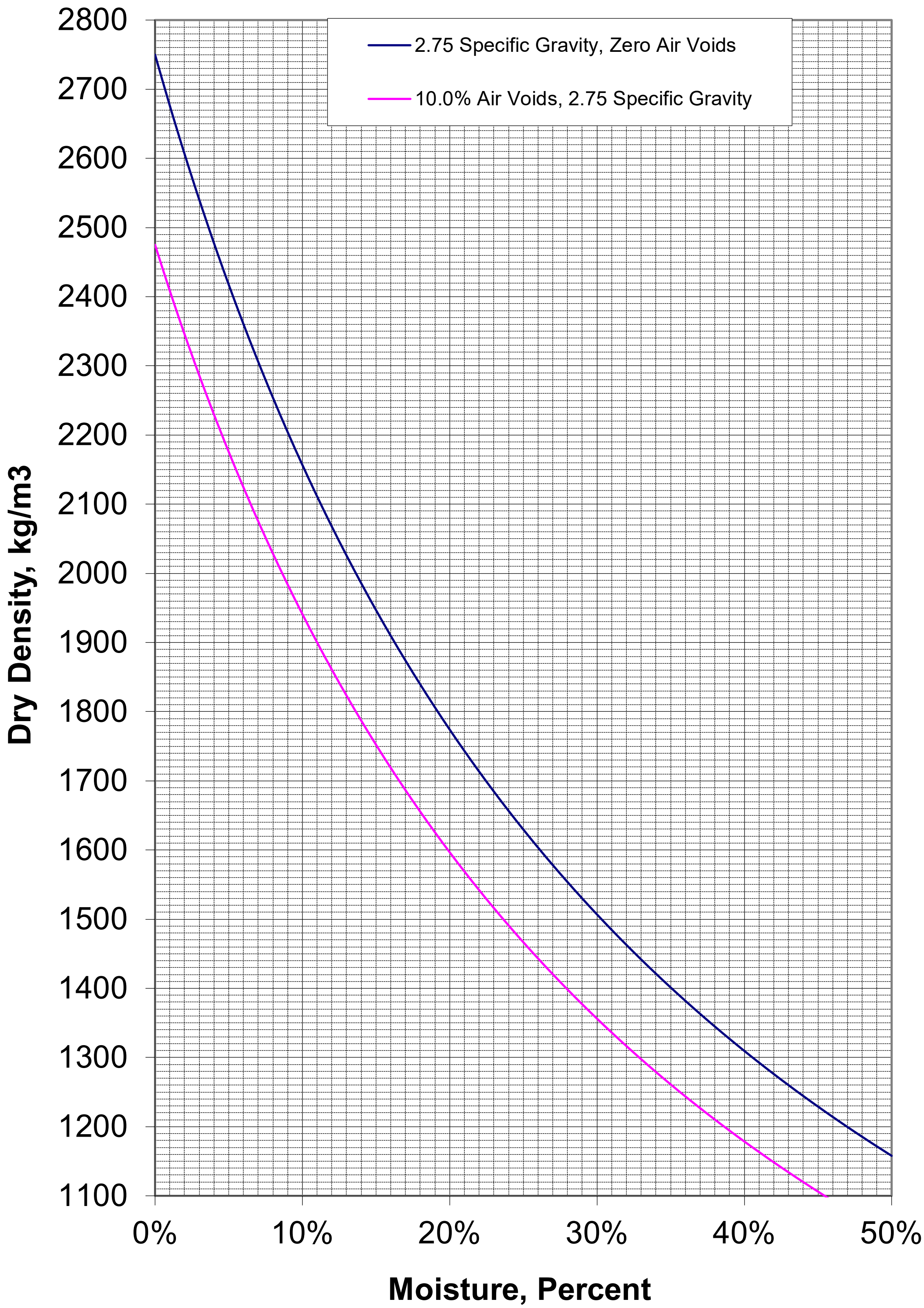


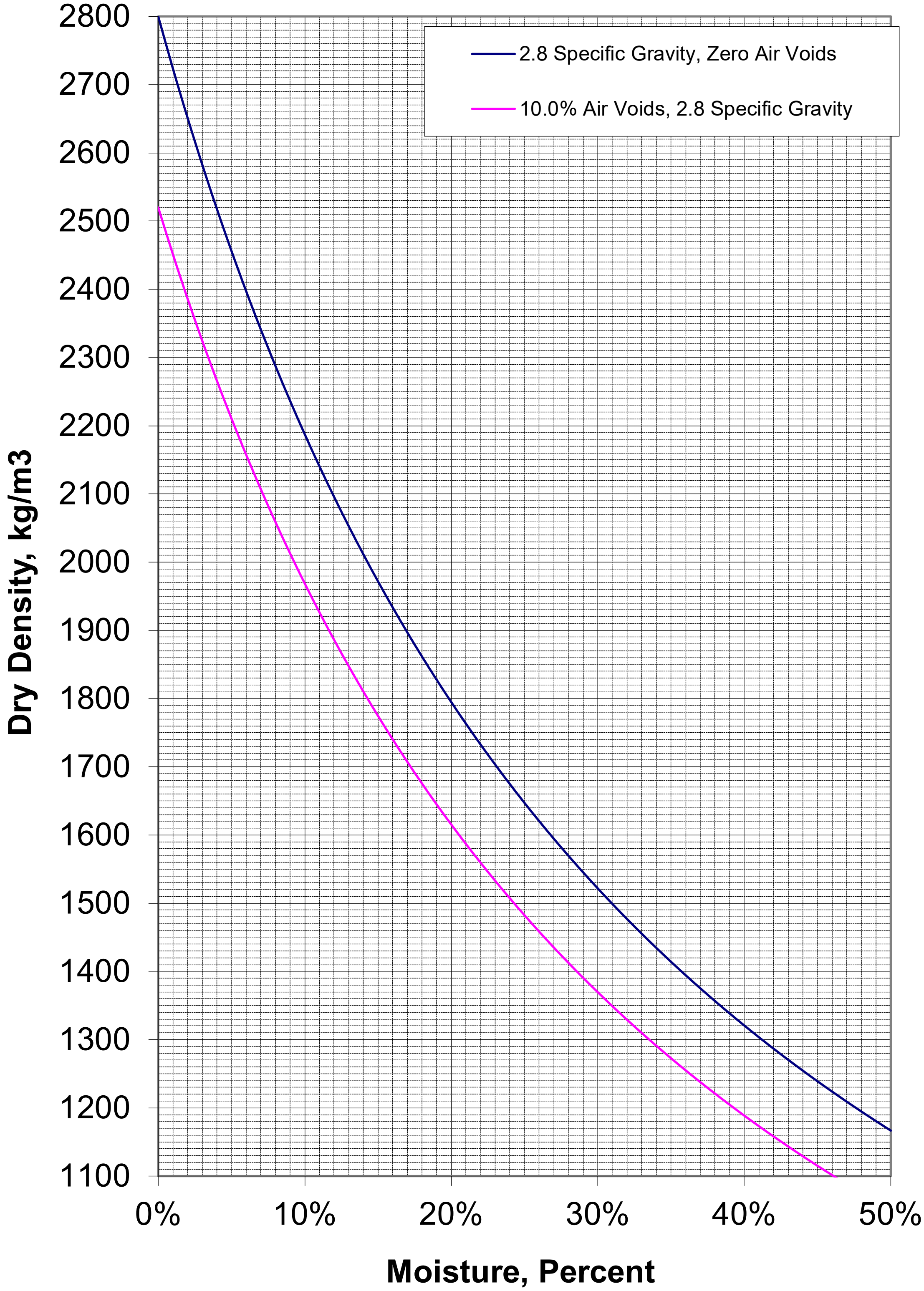
170
160
150
140
130
120
110
100
90
80
70
Dry Density, Lb/CuFt
2.8 Specific Gravity, Zero Air Voids
10.0% Air Voids, 2.8 Specific Gravity
0%
10%
20%
30%
40%
50%
Moisture, Percent


2.6 Specific Gravity, Zero Air Voids
10.0% Air Voids, 2.6 Specific Gravity
Dry Density, kg/m3
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
0%
10%
20%
30%
40%
50%
Moisture, Percent


2.65 Specific Gravity, Zero Air Voids
10.0% Air Voids, 2.65 Specific Gravity
Dry Density, kg/m3
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
0%
10%
20%
30%
40%
50%
Moisture, Percent


2.7 Specific Gravity, Zero Air Voids
10.0% Air Voids, 2.7 Specific Gravity
Dry Density, kg/m3
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
0%
10%
20%
30%
40%
50%
Moisture, Percent


2.75 Specific Gravity, Zero Air Voids
10.0% Air Voids, 2.75 Specific Gravity
Dry Density, kg/m3
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
0%
10%
20%
30%
40%
50%
Moisture, Percent


2.8 Specific Gravity, Zero Air Voids
10.0% Air Voids, 2.8 Specific Gravity
Dry Density, kg/m3
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
0%
10%
20%
30%
40%
50%
Moisture, Percent

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 ±25°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 ($CaCO_3$) 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 ($BaCl_2 \cdot 2H_2O$) 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 1000ºC 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 % SO4
Conductivity in m. mohs