

SECTION 860 Materials Testing and Acceptance - Aggregates

Standard spec references to aggregate testing and sampling methods contained in this chapter:

[Standard spec 209.2.3](#) granular backfill sampling and testing

[Standard spec 210.2.2](#) structure backfill sampling and testing

[Standard spec 301.2](#) base aggregate sampling and testing

[Standard spec 701.3](#) concrete aggregate testing

WisDOT's Test Modified (WTM) standards mobilized by the contract:

[WTM D5821](#) fracture testing

[WTM D4791](#) flat and elongated aggregate pieces

Revise the CMM provisions mobilized by the contract text box for section 860 to change references from CMM 860 to WisDOT's Test Modified (WTM) procedures [WTM D5821](#) and [WTM D4791](#).

860.1 General

There are two general categories for aggregate testing in the standard specification approval and acceptance. Approval testing is required before using aggregate sources in WisDOT projects. Aggregate acceptance testing is required throughout a project and is conducted either solely by the department, or by both the department (QV) and the contractor (QC) when under QMP provisions.

The following aggregate approval and acceptance guidance is intended to clarify the department's aggregate testing requirements outlined in the standard specifications and QMP provisions.

860.2 Aggregate Source Approval

Aggregate sources used in project construction must meet the contract specification minimum requirements for quality. Coarse aggregate source approval/certification testing is performed by both the contractor and the department on samples jointly obtained and split. The department also performs fine aggregate source certification testing on aggregate sources to be approved for use in concrete mixes.

There are four types of aggregate source approval:

1. New requests from suppliers planning to produce material. Sources that are not currently on the department's Approved Products List but plan to supply aggregates on future DOT projects.
2. Existing stockpile requests. Existing stockpiles in sources that are not currently producing aggregate materials.
3. Reapproval requests. Sources that are currently on the department's Approved Products List and are continuously producing and stockpiling aggregates for DOT projects.
4. Offsite approval. Aggregate that is processed and sampled in a different location from the quarry or pit.

Sampling scenario associated with the aggregate source approval types:

1. Scenario #1 - Prior to department sampling for new approval requests, suppliers should produce (crush) at least one day's worth of aggregate and stockpile at least 2500 tons.
2. Scenario #2 - Existing stockpiles greater than 2500 tons may be sampled by the department for aggregate source approval. Existing aggregate stockpiles of less than 2500 tons may be sampled and approved, but the source will not be placed on the approved list. Test results, for stockpiles of less than 2500 tons, will be placed on BTS 217 report and approved for the current construction year. The region independent assurance (IA) specialist must be notified before sampling existing stockpiles of less than 2500 tons.
3. Scenario #3 - There are no special considerations prior to department sampling for reapproval requests. Aggregate sources that have suspended processing operations and are requesting reapproval when resuming operations should be sampled like a new request in Scenario #1.
4. Scenario #4 - Aggregate suppliers may request sampling of material processed offsite (a different location from the pit or quarry) for source approval. Submit requests to central and regional office technical services staff member. Each request should include a detailed description of how the supplier plans to process material offsite. The request should include:
 - Supplier information
 - Original source information
 - Estimate of offsite processing quantity
 - Description of material processing method
 - Offsite location
 - Date range of offsite processing

- This type of request is expected to be rare and may be rejected. Suppliers should provide process control quality test results with the request. Aggregate stockpiles are traced to the source location by allowing a DOT technical services staff member to observe the transportation of shot rock or pit run from the source to the offsite location. At the processing location, suppliers should clearly label and

separate the offsite material from all other materials in that location. Photos, signage, email exchanges, and any tracking data may be used to document the process. Hauling of aggregate materials to projects should be from the original source location and not the offsite location. Materials staff will request resampling at the source location to verify aggregate quality properties. Offsite processing of materials is expected to be temporary.

In addition to routine source certification/recertification testing, BTS conducts additional testing on select approved sources (i.e. marginal source testing) to validate aggregate quality. If department source certification or marginal source test results do not meet specifications or are not within the allowable tolerances of the contractor's test results, as identified in [standard spec 106.3.4.2.2.3](#), the source is considered nonconforming and will not be approved for use.

BTS maintains lists of approved aggregate sources and updates the lists periodically. Sources that meet department specifications are approved for use and added to the approved source lists. The approved lists also show the aggregate quality test results.

860.2.1 Unique Source Identifier

Approved aggregate sources will be distinguished with a unique source identifier. The identifier will be tied to the geographic location of an aggregate source independent of the owner or operator. Unique Identifiers will be formatted as follows: SS-CC-XXX-YYY

Where, SS is the state FIIPS code and CC is the county number corresponding to the aggregate source location. XXX is an arbitrary number unique to each source within a county beginning with source 001. YYY indicates the source type; a three-letter description such as QRY for quarry, PIT for pit, or RCC for recycled concrete.

For example, the unique source identifier 55-01-001-QRY indicates that the source is located in Wisconsin (55), somewhere in Adams County (01), and is the first source to receive a unique number (001). For reference, table 860-1 contains a list of county codes. All unique identifiers are included on the approved aggregate source list.

TABLE 860-1 Wisconsin County Codes

Code	County	Code	County	Code	County
01	Adams	26	Iron	51	Racine
02	Ashland	27	Jackson	52	Richland
03	Barron	28	Jefferson	53	Rock
04	Bayfield	29	Juneau	54	Rusk
05	Brown	30	Kenosha	55	St. Croix
06	Buffalo	31	Kewaunee	56	Sauk
07	Burnett	32	La Crosse	57	Sawyer
08	Calumet	33	Lafayette	58	Shawano
09	Chippewa	34	Langlade	59	Sheboygan
10	Clark	35	Lincoln	60	Taylor
11	Columbia	36	Manitowoc	61	Trempealeau
12	Crawford	37	Marathon	62	Vernon
13	Dane	38	Marinette	63	Vilas
14	Dodge	39	Marquette	64	Walworth
15	Door	40	Milwaukee	65	Washburn
16	Douglas	41	Monroe	66	Washington
17	Dunn	42	Oconto	67	Waukesha
18	Eau Claire	43	Oneida	68	Waupaca
19	Florence	44	Outagamie	69	Waushara
20	Fond Du Lac	45	Ozaukee	70	Winnebago
21	Forest	46	Pepin	71	Wood
22	Grant	47	Pierce	73	Menominee
23	Green	48	Polk	00	Out-of-state
24	Green Lake	49	Portage	99	Obsolete
25	Iowa	50	Price		

860.2.2 Coarse Aggregate Source Certification Procedure

Coarse aggregate source certification testing is performed according to [standard spec 106.3.4.2.2](#) and results are submitted to WisDOT electronically via prefix 224 report using the department's MRS Soils and Aggregates software program. Provide electronic email notification to BTS and the regional materials coordinator when a 224 report is submitted. Only one aggregate source report will be accepted per email notification. Aggregate quality test results can be viewed on the department's approved list.

If submitting test results for an aggregate source without a unique source identifier, leave Aggregate Source field blank and write "New Aggregate Source" in remarks window. BTS will assign a unique source identifier for future usage.

Region staff are responsible for reporting aggregate source name changes to BTS. BTS will populate name changes on approved lists as notified. If submitting test results for an aggregate source that is not listed in the MRS software, notify the region's IA specialist. Unique source identifiers will not change with a source name change.

860.2.3 Marginal Source Testing

Marginal source testing is performed annually and is prioritized based on aggregate source variability, history and usage. The following summarizes prioritization criteria in order of importance:

1. **Usage**-marginal aggregate sources anticipated to be used on an upcoming project.
2. **History**-marginal aggregate sources that do not have a history of at least five source approvals.
3. **Variability**- marginal aggregate sources with a history of high variability.

860.2.4 Approved/Certified Aggregate Sources

The department's approved aggregate sources can be viewed from the [APL](#).

The 225 Aggregate Report shows certified coarse aggregate sources while the 162 Aggregate Report includes fine aggregate sources. The approved lists also show aggregate quality results from certification testing.

Sources identified as 'Not Certified' either failed to meet specifications or have an expired certification. Sources that are not certified cannot be used in WisDOT projects. Refer to the approved products list to view the most recent lists/test results.

860.2.5 Aggregate Quality Disputes

A contractor may request a second quality test if the first fails to meet approval criteria. However, request of a third sample/test requires a written submission that describes the corrective action(s) taken to produce conforming material. Corrective actions, including, but not limited to, modifications to crushing process, stockpiling and crushing location are acceptable.

The contractor may dispute the department's test results. Adequate justification is required to initiate a dispute resolution process. Testing proficiency or aggregate source variability are not acceptable justifications. Justifications, including, but not limited to, aggregate source history and aggregate geology.

860.2.6 Aggregate Quality Verification

Both the department and contractor should verify the quality of an aggregate source before incorporating into a project. Ensure that all sources have valid certifications and are approved for the appropriate use. Both parties should work together to help expedite any source approval/testing that is required.

860.2.7 Freeze-thaw Soundness Testing by WisDOT-Modified AASHTO T103

Revise 860.2.7 to remove some information. This information can be found in [WTM T103](#).

Follow AASHTO T103 Standard Method of Test for Soundness of Aggregates by Freezing and Thawing, procedure B, with modifications [outlined in WTM T103](#).

860.3 Aggregate Acceptance

Material acceptance is based on additional sampling and testing performed throughout construction. Test methods, frequencies, failure criteria, and documentation requirements are prescribed in the governing specifications. All materials, including preapproved products or sources, are subject to additional department quality assurance testing to verify quality and conformance with specifications. Subsequent sections provide guidance and test method requirements for acceptance testing under standard specification and QMP provisions.

860.4 Marginal Source Testing

Aggregates furnished for base courses, and aggregates or granular materials furnished for subbase courses, that contain moisture in excess of 7% when measured by the ton are required to have the moisture content reduced to 7% or less before being weighed, or have the moisture content in excess of 7% deducted from the measured weight. The moisture content of aggregates, including subbase materials, as determined by tests made on representative samples, will be based on and expressed as a percent of the dry weight of the aggregates. The moisture content so determined will include both the free and the absorbed water in the aggregates. The procedure for obtaining the pay weight is as follows:

1. Pay weight of aggregates having a moisture content of 7% or less will be measured wet weight.
2. Pay weight of aggregates having a moisture content in excess of 7% will be 107% of their dry weight, expressed as follows:

$$W_p = \frac{W_d \times 107}{100}$$

3. Dry weight of aggregate will be 100 times the quotient of the measured wet weight divided by the sum of 100 and the percent of total moisture, expressed as follows:

$$W_d = \frac{W_w}{100 + M} \times 100$$

4. For aggregates having moisture content in excess of 7%, the following formula may be used in computing pay weight:

$$W_p = \frac{107 W_w}{100 + M}$$

This formula was derived by substituting for W_d in step 2 the value of W_d given in Step 3 and simplifying.

The legend for the above formulas is:

W_p = Pay weight of aggregates

- Wd = Dry weight of aggregates
 Ww = Measured wet weight of aggregates
 M = Percent of total moisture in the aggregates, determined by moisture tests run on representative samples and based on the dry weight of the aggregate sample.

5. Corrections for moisture content in excess of 7% may be made on each load and shown on the load ticket, or the correction may be made periodically on the summation of the measured weight, using the average of the moisture content determined. Periodic corrections should be for a period of not more than one day's operation, where the moisture tests show a minimum of variations in moisture content. When moisture tests show appreciable variations in moisture content due to changed conditions at the pit, or to other specific causes, correction periods should be for each range of different moisture content. For this purpose, "appreciable variations in moisture content" may be considered to be variations of about 1% or more between the moisture contents.

860.5 Sampling Aggregates

Revise 860.5 to reference WTM R90.

Follow [WTM R90 Standard Practice for Sampling Aggregate Products](#).

860.5.1 Sample Size Requirements

860.5.1.1 General

Revise 860.5.1.1 to remove former Table 860-2 Size of Sampling information. This information can be found in [WTM R90](#). Renumber remaining table.

The minimum weight of the field sample depends on the nominal maximum particle size of the aggregate that sampled. The weight of the field sample will always be greater than that portion required for testing and must meet the requirements in [WTM R90](#).

Refer to [CMM 850](#), Materials Testing and Acceptance Guide, for specific sample sizes required for submittal to the central laboratory.

The sample should be reduced to the size needed for a specific test by using either a riffle splitter, quartering method or miniature stockpile method for damp fine aggregate only.

860.5.1.2 Definitions

Field sample A composite of all increments sampled.

Nominal maximum particle size The nominal maximum size as indicated by the appropriate specification or description. If the specification or description does not indicate a nominal maximum size (for example a sieve size indicating 90-100% passing), use the maximum size (that sieve or size indicating 100% passing).

TABLE 860-2 Nominal Maximum Sizes Based on the AASHTO Definition

Material	Nominal Maximum Size	Remarks
Dense Graded Base, 3-inch	3-inch (75 mm)	
Dense Graded Base, 1 1/4-inch	1 1/4-inch (32 mm)	
Dense Graded Base, 3/4-inch	3/4 -inch (19 mm)	
Open Graded Base	1-inch (25 mm)	
Breaker run	6-inch (150 mm)	When testing is required
Select Crushed	5-inch (125 mm)	When testing is required
Concrete Aggregate - Size #2	1 1/2-inch (37.5 mm)	
Concrete Aggregate - Size #1	3/4-inch (19 mm)	
Concrete Aggregate - fine	No. 4 (4.75 mm)	
Granular Backfill (GBF), Trench	Varies	By strict definition, the 3-inch component would define the size. Use the largest size material in the sample irrespective of the specification to establish the nominal size. Example: If 100 % passes the 3-inch but there is 1-inch material in the R4, use 1-inch as the nominal maximum size.
Granular Backfill, Bedding	1-inch, may vary	See note above for GBF-trench
Structural Backfill	Up to 3-inch, may vary	See note above for GBF-trench

860.5.2 Vacant

Remove the following subsections: Sampling from a Conveyor Belt, Sampling from a Conveyor Belt Discharge, Sampling from Stockpile, Sampling from Stockpile Alternatives 1 and 2, Sampling from Roadbed Windrow, Sampling After being Placed on Roadbed, Sampling from Concrete Plant Holding Bins, Sampling Asphalt Aggregates from Hot Bins, Sampling from a Truck, Sampling from a Truck Alternatives 1 and 2, and Sampling when Using a Clam Shovel (former subsection numbers 860.5.2, 860.5.3, 860.5.4, 860.5.4.1, 860.5.4.2, 860.5.5, 860.5.6, 860.5.7, 860.5.8, 860.5.9, 860.5.9.1, 860.5.9.2, and 860.5.10). This information can be found in [WTM R90](#).

860.5.3 Vacant

860.5.4 Vacant

860.5.5 Vacant

860.5.6 Vacant

860.5.7 Vacant

860.5.8 Vacant

860.5.9 Vacant

860.5.10 Vacant

860.6 Reducing Samples of Aggregate to Test Size

860.6.1 General

Revise information in 860.6.1 and refer to [WTM R76](#).

Just as important as obtaining a truly representative sample is the testing of these samples. The results of these tests have a significant bearing on the production process, the acceptance or rejection of products, and the assurance that the final product will have the necessary ingredients and characteristics to perform as intended. **Different sizes and types of aggregate will require different size samples for various tests. The field sample should be reduced to the size needed for a specific test. Do not attempt to arrive at an exact test sample weight. Portions of the original sample, which are eliminated by the reducing process, may be set aside for possible check testing.**

Follow [WTM R76](#) Standard Practice for Reducing Samples of Aggregates to Testing Size.

As in sampling, every effort should be made to follow these procedures as closely as possible to ensure that the test results are as reliable and accurate as the procedure is able to produce.

860.6.2 Vacant

Remove the following subsections: Methods for Reducing Field Sample Size, General, Use of the Riffle Splitter, Quartering Procedure, and Miniature Stockpile Method – Damp Fine Aggregate Only (former subsection numbers 860.6.2, 860.6.2.1, 860.6.2.2, 860.6.2.3, and 860.6.2.4). This information can be found in [WTM R76](#).

860.6.2.1 Vacant

860.6.2.2 Vacant

860.6.2.3 Vacant

860.6.2.4 Vacant

860.7 Aggregate Particle Shape

860.7.1 General

Particle shape is an important consideration in producing most products that use aggregate as a primary ingredient. Requirements for particle shape are specified for aggregates used for base, aggregates for HMA and concrete pavement, and other products used in transportation-related construction. Check the applicable specifications to determine if percent of fractured particles, percent of flat and elongated particles, or both must be determined for the material in question. The same test sample may be used to perform both tests.

860.7.1.1 Base Aggregate

In base aggregate, angular, nearly equidimensional particles having a rough surface texture are preferred over round, smooth particles. Angularity contributes to aggregate interlock, and a rough surface texture inhibits movement of one particle relative to another.

Flat and elongated aggregate particles have reduced strength when load is applied to the flat side of the particle. Flat and elongated particles are also prone to size segregation under handling and may breakdown during compaction. Where high stability is required, rounded aggregate should be avoided because of its tendency to shift under applied traffic loadings. WisDOT currently does not specify any limits for percent of flat and elongated particles for base aggregate.

860.7.1.2 Concrete

The particle shape and surface texture of an aggregate influence the properties of both fresh and hardened concrete. Rough-textured, angular crushed aggregate requires more water to produce workable concrete than smooth, rounded, naturally occurring aggregate. This extra water tends to reduce compressive strengths. However, the reduction in compressive strength is offset by an increase in the bond between the cement paste and aggregate, particularly in high-strength concretes and pavement concretes where high flexural strength is usually desired. WisDOT currently does not specify any requirements for percent of fractured particles for aggregates used in concrete.

Flat and elongated particles decrease mix workability and, if more water is used to maintain workability, the strength of the concrete is also reduced. Flat and elongated particles that exceed a ratio of 3:1 should be limited to 15% of the total coarse aggregate (R 3/8 inch material).

860.7.1.3 Hot Mix Asphalt (HMA)

In HMA a high percent of fractured particles plays an important part in the strength of the pavement, helps to reduce rutting, and produces a surface with a higher coefficient of friction for improved vehicle control and braking.

Flat and elongated particles used in HMA tend to increase mixture voids and affect compactibility. Flat and elongated particles may fracture during compaction and under traffic. Aggregates that fracture in the mix have uncoated surfaces that are more susceptible to the detrimental influence of infiltrating water. Flat and elongated particles that exceed a 5:1 ratio should be limited to 5% of the total coarse aggregate (R #4 material) for all mixture types except stone matrix asphalt (SMA) where the ratio is 3:1 and the limit is 20% of the total coarse aggregate (R #4 material).

Methods for determining coarse aggregate fracture are mobilized into the contract by [standard spec 106.3.4.2.2.1](#) and [standard spec 604.2](#).

860.7.2 Fractured Particles

Revise 870.7.2 to remove reference to ASTM and refer to [WTM D5821](#).

The purpose for specifying fractured face criteria is to maximize shear strength by increasing inter-particle friction in either bound or unbound aggregate mixtures. Another purpose is to provide increased friction and texture for aggregates used in pavement in surface courses. Follow [WTM D5821 Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate](#).

860.7.2.1 Vacant

Remove the following subsections: *General, Scope, Definitions, and Procedure* (former subsection numbers 860.7.2.1, 860.7.2.2, 860.7.2.3, and 860.7.2.4). This information can be found in [WTM D5821](#).

860.7.2.2 Vacant

860.7.2.3 Vacant

860.7.2.4 Vacant

Methods for measuring flat and elongated particles are mobilized into the contract by [standard spec 501.2.5](#).

860.7.3 Flat and Elongated Particles

Revise 860.7.3 to remove reference to ASTM and refer to [WTM D4791](#).

860.7.3.1 General

The purpose for specifying a limit on the percent of coarse aggregate particles that are flat and elongated is to minimize the effect that these particles may have on the construction process and finished product. [WTM D4791](#) describes three specifically different comparisons of the length, width, and thickness in determining if the particle is flat, elongated, or flat and elongated.

The department has previously used the term thin rather than flat in the specifications related to the ratio of the width of a particle compared to its thickness. Specifications previously indicating limits for thin or elongated particles have been revised and now contain limits for the percentage of flat and elongated particles (the ratio of the length dimension compared to the thickness dimension according to [WTM D4791](#) definitions). Follow [WTM D4791 Standard Method of Test for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate](#).

860.7.3.2 Vacant

Remove the following subsections: Scope, Definitions, and Procedure (former subsection numbers 860.7.3.2, 860.7.3.3, and 860.7.3.4). This information can be found in [WTM D4791](#).

860.7.3.3 Vacant

860.7.3.4 Vacant

860.8 Field Determination of Moisture Content of Fine and Coarse Aggregates

860.8.1 Apparatus

- Suitable pan for weighing samples.
- A scale or balance readable to 0.2% of the sample weight.
- A hot plate or field stove of sufficient size capable of maintaining a uniform temperature.

860.8.2 Procedure

The size of the sample must be at least 1 lb. (500 g) for fine aggregate and 5.5 lb (2500 g) for coarse aggregate or a mixture of fine and coarse aggregates.

1. After obtaining a representative sample of the material to be tested by standard size reduction procedure, place the sample in a suitable tared container and obtain the weight of the wet sample and container. Record this weight as:

$$W_w = \text{Weight of container plus wet material.}$$

2. Dry the material by heating at a moderate temperature (230° F or less), until it has given up all free and absorbed moisture and has reached a constant weight. Occasional stirring with a spoon may accelerate the drying, but care must be taken not to lose any of the sample clinging to the spoon. The sample is thoroughly dry when further heating causes, or would cause, less than 0.1 percent additional weight loss.
3. Remove the container from the hot plate or stove and weigh carefully. This weight is recorded as:

$$D_w = \text{Weight of container plus dry material.}$$

$$T = \text{Weight of container.}$$

4. The percent moisture is calculated as follows:

$$\frac{(W_w - D_w)}{(D_w - T)} \times 100$$

Example 1: Calculate Moisture Percentage

Weight of wet sample and container = 1,550 g

Weight of dry sample and container = 1,515 g

Weight of container = g

$$\text{Percent Moisture Content} = \frac{(1,550 - 1,515)}{(1,515 - 867)} \times 100 = 5.4\%$$

860.9 Field Test Procedures for Sieve Analysis of Aggregates

860.9.1 Washed Sieve Analysis

This test procedure is for determining the particle size distribution of fine aggregates, coarse aggregates, and mixtures of fine and coarse aggregates. It is intended for use in the sieve analysis of aggregates recovered from asphaltic mixtures or for the sieve analysis of mineral fillers.

For the purposes of these procedures, coarse aggregate is that having essentially all retained on the No.4 sieve, and fine aggregate is that having essentially all passing the No. 4 sieve. A graded base course material is an example of a mixture of fine and coarse aggregate.

860.9.1.1 Apparatus

The apparatus must consist of the following items:

860.9.1.1.1 Balances

The balance(s) or scale(s) must be sensitive to within 0.2% of the weight of the total sample to be tested.

860.9.1.1.2 Sieves (Washing)

A nest of two sieves must be used for washing the sample. The lower is a #200 sieve, with a #16 sieve above it.

860.9.1.1.3 Sieves (Gradation)

Sieves must be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. Suitable sieve sizes must be selected to furnish the information required by the specifications covering the material to be tested. The sieves must conform to Wire-Cloth Sieves for Testing Purposes, AASHTO Designation: M 92. The table 860-3 provides guidance on the maximum allowable weight on sieves. The amount of material retained on the overloaded sieve may be regulated by the introduction of a sieve having larger openings than in the critical sieve, or by sieving in increments.

The open screen area for the large Gilson screens is 14.75" x 22.75". The small Gilson screens have a screen area of 14" x 14". The average open screen area of WisDOT rocker boxes is 10.5" x 10.5".

The limit for loading on the 8-inch diameter and 12-inch diameter sieves for the minus No. 4 sieves is 227 (say 200 grams) and 511 (say 500 grams), respectively. The loads in table 860-3 are calculated from information taken from AASHTO T-27 ([ASTM C136](#)). Minus No. 4 sieve loads are calculated based on a maximum of 0.01 lb/in² (7 Kg/M²).

860.9.1.1.4 Washing Container

A bucket, pail, or vessel large enough to contain the sample when covered with water and to allow vigorous agitation without inadvertent loss of any part of the sample of water is required. The containers should be kept clean.

TABLE 860-3 Allowable Loadings on Sieves

Sieve size	12 " dia.	8 "dia.	Gilson large	Gilson small- porta screen	12"x12"	Rocker Box
2" (50 mm)	20# (9,125g)	8.9# (4,050g)	60# (27,061g)	35# (15,806g)	25# (11,613g)	20# (8,891g)
1 1/2" (37.5 mm)	15# (6,844g)	6.6# (3,038g)	45# (20,296g)	26# (11,855g)	19# (8,710g)	15# (6,668g)
1 1/4" (31.75 mm)	11.7# (5318g)	5.0# (2262g)	37.8# (17129g)	21.4# (9723g)	16.3# (7374g)	12.4# (5636g)
1" (25.0 mm)	10# (4,563g)	4.5# (2,025g)	30# (13,531g)	17# (7,903g)	13# (5,806g)	10# (4,446g)
3/4" (19.0 mm)	7.6# (3,468g)	3.4# (1,539g)	22# (10,283g)	13# (6,006g)	9.7# (4,413g)	7.5# (3,379g)
1/2" (12.5 mm)	5.0# (2,281g)	2.2# (1,013g)	15# (6,765g)	8.7# (3,952g)	6.4# (2,903g)	4.9# (2,223g)
3/8" (9.5 mm)	3.8# (1,734g)	1.7# (770g)	11# (5,142g)	6.6# (3,003g)	4.9# (2,206g)	3.7# (1,689g)
No. 4 (4.75 mm)	1.9# (867g)	0.8# (385g)	5.7# (2,570g)	3.3# (1,502g)	2.4# (1,103g)	1.9# (845g)

860.9.1.1.5 Drying Equipment

An oven, hot plate, stove, or other device for heating and drying the sample uniformly and as rapidly as possible without damaging the aggregate will be needed. Samples should be stirred frequently in order to prevent popping or baking of aggregate. The drying pan should be large enough to allow manipulation during drying of the aggregate without loss by spilling. The drying pan should be kept clean.

860.9.1.2 Sample Size

Field samples for sieve analysis must be reduced to testing size using a riffle splitter, quartering method, or miniature stockpile method for damp fine aggregate only. See table in [WTM R90](#) for required sizes of field samples. The field samples to be reduced must be thoroughly mixed, and the fine aggregate must be in a slightly moist condition. The test sample must be approximately the weight required as indicated in the following sections, and must be the end result of reduction from the larger field sample by either using a riffle splitter, quartering method, or miniature stockpile method for damp fine aggregate only. The selection of samples of exact predetermined weight must not be attempted.

860.9.1.2.1 Fine Aggregate

Samples of fine aggregate for sieve analysis must weigh, after drying, a minimum of 1 lb. (500 grams).

860.9.1.2.2 Coarse Aggregates and Mixtures of Coarse and Fine Aggregate

Samples of coarse aggregate or mixtures of coarse and fine aggregate for sieve analysis must weigh, after drying, not less than the amount indicated in table 860-4.

TABLE 860-4 Minimum Sample Weights for Aggregates

Nominal Maximum Size of Particles ^[1]	Minimum Weight of Sample ^[2] , g	Minimum Weight of Sample ^[2] , lb.
3/8" (9.5 mm)	1,000	2.2
1/2" (12.5 mm)	2,500	5.5
3/4" (19.0 mm)	5,000	11
1" (25.0 mm)	10,000	22
1 1/4" (31.75 mm)	10,000	22
1 1/2" (37.5 mm)	15,000	33
2" (50.0 mm)	20,000	44
> 2" (greater than 50 mm)	25,000	55

If for coarse concrete aggregates, a washed analysis is made only for determining the amount of material passing the No. 200 (75µm) sieve, the test sample may be reduced to the minimum sizes shown in table 860-5.

TABLE 860-5 Minimum Sample Weights for P200 Test

Nominal Maximum Size of Particles ^[1]	Minimum Weight of Sample ^[2] , g	Minimum Weight of Sample ^[2] , lb.
3/4" - 1" (19.0 -25mm)	2,500	5.5
1-1/2" (37.5 mm) or over	5,000	11

^[1] The nominal maximum particle size is defined as the nominal maximum size as indicated by the appropriate specification or description. If the specification or description does not indicate a nominal maximum size (for example a sieve size indicating 90-100% passing), use the maximum size (that sieve indicating 100% passing).

^[2] For samples weighing 11 lb. (5,000g) or more, it is recommended that sieves or coarse aggregate fractions be mounted in 12-inch or larger frames or the sieving may be done in increments using the standard 8-inch diameter sieves.

860.9.2 Procedure for Fine or Coarse Aggregates for Concrete Masonry

1. The test sample must be thoroughly dried.
2. After drying, cooling, and weighing, the sample must be placed in the container and sufficient water added to cover it. It is desirable to use as much water as possible in order to reduce the number of decantations needed. When clay balls or clay coatings on the aggregate particles are noted, the sample must be allowed to soak at least 10 minutes before to agitating and decanting. When aggregates have a particularly heavy or tight coating, it may be desirable to add a very small quantity of organic wetting agent (such as a household detergent) to the initial wash water.
3. The contents of the container must be agitated vigorously, and the wash water poured promptly over the nested sieves arranged with the coarser sieve on top. For dirty aggregates, it may be necessary to wait 10 to 15 seconds before decanting the wash water in order to avoid blocking the openings of the No. 200 sieve. When the No. 200 sieve becomes blocked, it may be reopened by back-washing the material retained on the No. 200 sieve into the drying pan. Agitation should be sufficiently vigorous to completely separate all of the passing the No. 200 material from other particles and to bring all the passing the No. 200 fraction into suspension in order that it will be removed by decantation of the wash water. Twisting of the pail handle will usually not result in vigorous enough action.

Using a large spoon to stir and agitate the aggregate in the wash water has been found most acceptable. Care must be taken to avoid, as much as possible, the decantation of the coarse particles of the sample. The operation must be repeated until the wash water is substantially clear.

4. All material retained on the nested sieves must be returned to the washed sample. The washed aggregate must again be thoroughly dried.

When performing this test to determine the percentage of material passing the #200 sieve (AASHTO T11) follow the calculation procedure described below.

Calculations for the percent of material that passed the #200 sieve during washing should be made as follows:

$$\left(\frac{(\text{Original Dry Weight} - \text{Washed Dry Weight})}{\text{Original Dry Weight}} \right) \times 100 = \text{Percent Passing The \#200 Sieve}$$

When performing this test to determine sieve gradation requirements, cool the sample to prevent damage to the sieves, and place the washed and dried sample over a nest of sieves as required by the

specifications with any additional sieves added to prevent overloading of the individual sieves. Follow the guidelines provided in the Materials Testing Guide to limit the quantity of material on a given sieve so that all particles have opportunity to reach sieve openings a number of times during the sieving operation. The sieving operation must be conducted by means of a lateral and vertical motion of the sieve, accompanied by jarring action so as to keep the sample moving continuously over the surface of the sieve. In no case should fragments in the sample be manipulated through the sieve by hand. Sieving must be continued until not more than 1% of the weight of the material retained on a given sieve passes that sieve during one minute of hand sieving.

On that portion of the sample retained on the No. 4 and larger sieves, the procedure described above for determining thoroughness of sieving must be carried out with a single layer of material. When mechanical sieving is used, the thoroughness of sieving must be tested by using the hand method of sieving described above.

5. Calculations for the gradation of the washed sample should be made as follows:

$$\text{Percent Retained} = \frac{\text{Weight (2)}}{\text{Weight (1)}} \times 100$$

$$\text{Percent Passing} = 100 - \% \text{ Retained}$$

Weight (1) is initial weight of the dried unwashed sample, and Weight (2) is dry weight, after sieving, of the washed sample cumulatively retained on each sieve.

The electronic Materials Tracking System (MTS) provides the prefix 162, fine and coarse aggregates for concrete worksheet that should be utilized for calculating and reporting tests. Note that the final gradation results are calculated to the nearest 0.1% for all sieves. However, when results are reported, percentages are rounded off to the nearest whole percent except for the percent passing the No. 200 sieve, which is reported to the nearest 0.1% and administered in accordance with the specification requirements.

All tabulations of these gradation data should clearly indicate whether washed or unwashed testing was used.

860.9.3 Procedure for Mixtures of Fine and Coarse Aggregates for Base Course

1. The unwashed test sample must be thoroughly dried. Materials containing portions of reclaimed or recycled materials, when the materials would be altered by heat in the drying process, should be spread and air or oven dried at a temperature of 100 degrees F or less.
2. After cooling, the sample must then be separated on a No. 4 sieve, the two portions weighed, and the relative proportions determined.
3. The portion passing the No. 4 sieve must be reduced by use of the riffle splitter or quartering procedures to a sample weighting approximately 1 lb. (500g).
4. The material retained on the No. 4 sieve and the test sample of the material passing the No. 4 sieve must then be washed, dried, (recycle and reclaim content - air or oven dry 100 degrees F or less), cooled, and sieved separately in accordance with the procedure previously discussed.
For 3-inch dense graded base course material only the material passing the No. 4 sieve needs to be washed.
5. The electronic Materials Tracking System (MTS) provides the prefix 217, aggregates testing worksheet that should be used for calculating and reporting tests. When using non-electronic methods calculations of gradation for washed analysis should be made as illustrated in the following and in figure 860-1.

[DT1348](#), Sieve analysis for Mixture of Fine and Coarse Aggregates. is provided to help make these calculations orderly and accurately. Note that the final gradation results are calculated to the nearest 0.1% of all sieves. However, when results are reported, percentages are rounded off to the nearest whole percent, except for the percent passing the No. 200 sieve, which is reported to the nearest 0.1% and administered in accordance with the specification requirements.

All tabulations of these gradation data should clearly indicate whether washed or unwashed testing was used.

Example 2: Unwashed Sieve Analysis

Weight of total unwashed sample = 5,064g										
Weight of R-4.75 mm (No. 4) fraction of total sample = 2,951g										
R-4.75 mm (No. 4) fraction (proportion of total sample) = $\frac{2,951}{5,064} = 0.583(A)$										
Weight of P-4.75 mm (No. 4) fraction of total sample = 2,113g										
P-4.75 mm (No. 4) fraction (proportion of total sample) = $\frac{2,113}{5,064} = 0.417(B)$										
Weight of reduced size unwashed P-No.4 sample = 521g										
SIEVE ANALYSIS OF WASHED R-No. 4 FRACTION										
(Total weight of unwashed fraction = 2,951)										
Sieve	(g)	Weight % Ret.	% Pass. (C)							
1" (25.0 mm)	0	0	100.0							
3.8" (9.5 mm)	1,318	44.7	55.3							
#4 (4.75 mm)	2,776	94.1	5.9							
#10 (2.00 mm)	2,871	97.3	2.7							
#40 (425 µm)	2,873	97.4	2.6							
#200 (75 µm)	2,887	97.8	2.2							
SIEVE ANALYSIS OF WASHED P- No. 4 FRACTION										
(Total weight of reduced size sample = 521 g.)										
Sieve	(g)	Weight % Ret.	% Pass. (D)							
#4 (4.75 mm)	0	0	100.0							
#10 (2.00 mm)	113	21.7	78.3							
#40 (425 µm)	386	74.1	25.9							
#200 (75 µm)	443	85.0	15.0							
The gradation of the total sample is obtained by combining gradations (C) and (D) in the proportions that the R-No. 4 and P-No. 4 fractions occurred in the original total sample, as follows:										
1. Multiply each value (C) by (A).										
2. Multiply each value (D) by (B).										
3. Add the two values together for each sieve.										
Sieve									Values Reported	
#1 (25 mm)	(0.583 x 100)	+	(0.417 x 100)	=	58.3	+	41.7	=	100.0	100
3/8" (9.5 mm)	(0.583 x 55.3)	+	(0.417 x 100)	=	32.2	+	41.7	=	73.9	74
#4 (4.75 mm)	(0.583 x 5.9)	+	(0.417 x 100)	=	3.4	+	41.7	=	45.1	45
#10 (2.00 mm)	(0.583 x 2.7)	+	(0.417 x 78.3)	=	1.6	+	32.7	=	34.3	34
#40 (425 µm)	(0.583 x 2.6)	+	(0.417 x 25.9)	=	1.5	+	10.8	=	12.3	12
#200 (75 µm)	(0.583 x 2.2)	+	(0.417 x 15.0)	=	1.3	+	6.3	=	7.6	7.6

Figure 860-1 provides an example of [DT1348](#) for washed sieve analysis.

FIGURE 860-1 Washed Gradation of a size No. 1 Gravel Base course Aggregate, (A portion of DT1348)

MOISTURE CONTENT							Weight of Total Sample (dry, unwashed) <u>5064 g</u>					
Weight of Sample (moist) <u>5170 g</u>			Weight of Sample (dry) <u>5064</u>				Weight of R4.75 mm (No. 4) dry, unwashed <u>2951</u> = 0. <u>583</u> (A)					
Moisture Loss <u>106</u>			% Moisture <u>2.1</u>				Weight of P4.75 mm (No. 4) dry, unwashed <u>2113</u> = 0. <u>417</u> (B)					
R-4.75 mm (R-4) MATERIAL Washed: <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No				P-4.75 mm (P-4) MATERIAL Washed: <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No			TOTAL MATERIALS (% Passing)					
				Wt. = <u>521</u> (Min. 500 g)								
Sieve	Weight Retained	% Retained	% Pass (C)	Weight Retained	% Retained	% Pass (D)	4.75 mm (R-4) (A)(C)	4.75 mm (P-4) (B)(D)	Dry Sieved	Corr. Factor	Corr. Or Washed Results	Spec.
37.5mm (1-1/2")												
25 mm (1")	0	0	100	0	0	100	58.3	41.7			100	100
19 mm (3/4")	452	15.3	84.7	0	0	100	49.3	41.7			91.0	—
9.5 mm (3/8")	1318	44.7	55.3	0	0	100	32.2	41.7			73.9	40-75
4.75 mm (No. 4)	2776	94.1	5.9	0	0	100	3.4	41.7			45.1	25-60
2 mm (No. 10)	2871	97.3	2.7	113	21.7	78.3	1.6	32.7			39.3	15-45
425 µm (No. 40)	2873	97.4	2.6	386	74.1	25.9	1.5	10.8			12.3	—
75 µm (No. 200)	2887	97.8	2.2	443	85.0	15.0	1.3	6.3			7.6	3-12
In pan	16			7								

860.9.4 Procedure for Granular and Structural Backfill and Subbase

Revise 860.9.4 to remove reference to former table and refer to WTM R90 for field sample information.

1. The sample size must meet the minimum requirements of table in [WTM R90](#) (field sample) and table 860-4 (laboratory sample) based on the nominal maximum size of aggregate in the R4 component of the sample. The unwashed test sample must be thoroughly dried.
2. After cooling, the sample must then be separated on a No. 4 sieve, the two portions weighed, and the relative proportions determined.
3. The material retained on the No. 4 sieve is sieved and the percent passing for each sieve calculated based on the total dry unwashed sample weight.
4. The portion passing the No. 4 sieve must be reduced by use of the riffle splitter or quartering procedures to a sample weighting approximately 1 lb. (500g).
5. The test sample of the material passing the No. 4 sieve must then be washed and dried.
6. The electronic Materials Tracking System (MTS/MIT) provides the prefix 217, aggregates testing worksheet that should be used for calculating and reporting tests. The following example illustrates the calculations for backfill testing.

Calculation of the R4 sieve components is based on the total sample and is done unwashed. The P4 washed sieve analysis is based on the reduced dry unwashed sample and stands alone. R4 and P4 sieve results are individually compared to the specifications as cited in Standard Specification section 209.

When reporting granular backfill results indicate use as either trench backfill or bedding backfill. This defines the general requirements of the material. The term "trench" backfill is also applicable to materials used for backfilling excavations for frost heave or other unstable materials, such as marsh backfill etc, when specified.

Example 3: Backfill Sieve Analysis

Weight of total unwashed sample = 26,890g (A)			
Weight of R-4.75 mm (No. 4) fraction of total sample = 4,567g			
R-4.75 mm (No. 4) fraction (proportion of total sample) = $4567g / 26890g = 0.17g$			
Weight of P-4.75 mm (No. 4) fraction of total sample = 2, 113g			
P-4.75 mm (No. 4) fraction (proportion of total sample) = $22323g / 26890g = 0.83g$			
Weight of reduced size unwashed P-No.4 sample = 600g			
SIEVE ANALYSIS OF R-No. 4 FRACTION (Total weight fraction = 26890 [A])			
Sieve	(g) [B]	Weight % Ret. (B/A*100)	% Pass
6" (150 mm)	0	0	100.0
3" (75.0 mm)	3000	11.2	88.8
1" (25.0 mm)	3900	14.5	85.5
3/4"(19 mm)	4325	16.1	83.9
3/8" (9.5 mm)	4421	16.4	83.6
#4 (4.75 mm)	4567	17.0	83.0
SIEVE ANALYSIS OF WASHED P- No. 4 FRACTION (Total weight of reduced size sample = 600 g. [C])			
Sieve	(g) [D]	Weight % Ret.[D/C*100]	% Pass
#4 (4.75 mm)	0	0	100.0
#40 (425 μm)	155	25.8	74.2
#100 (150 μm)	530	88.3	11.7
#200 (75 μm)	561	93.5	6.5

Example 4: Materials Tracking System (MTS/MIT) prefix 217 entry screens for Backfill testing

As shown below, the type of use selection is required and sets the options for the R4 specifications.

Type of Material:
 Granular Backfill Structural Backfill

Gradation:
 Grade 1 Grade 2

Special Provision: Yes No

Type of Use: Trench Backfill Bedding

Field Determination of Percent of Fractured Particles:
 Number of Fractured Particles:
 Number of Questionable/Borderline Fractured Particles:
 Number of Unfractured Particles:
 % Fractured:
 Specification Requirement: %

Moisture Content:
 Weight of Sample (Moist) (Grams):
 Weight of Sample (Dry) (Grams):

Type of Material:
 Granular Backfill Structural Backfill Dense Graded Base Open Graded Base Br

Gradation:
 Grade 1 Grade 2 Grade 3

Weight of Sample (Dry) (Grams): 5238 5238

Weight of R-No 4 (Dry Unwashed) (Grams): = 28.8% R-4 Factor

Weight of P-No 4 (Dry Unwashed) (Grams): 3731 = 71.2% P-4 Factor

Sieve Size Metric (English)	Total Dry Sample	Percent Retained:	Percent Passing:	Specs	P-4 Material			
					wt:	Percent Retained:	Percent Passing:	Specs
Cumulative Weight (Grams)				STAI	Cumulative Weight (Grams)			STAI
150.0 (6")	<input type="text"/>			100 Min				
125.0 (5")	<input type="text"/>							
75.0 (3")	<input type="text"/>			85 - 100				
50.0 (2")	<input type="text"/>							
37.5 (1 1/2")	<input type="text"/>							
31.5 (1 1/4")	<input type="text"/>							
25.0 (1")	<input type="text"/>							
19.0 (3/4")	<input type="text" value="0"/>	0.0%	100.0%					
12.5 (1/2")	<input type="text" value="4"/>	0.1%	99.9%					
9.5 (3/8")	<input type="text" value="7"/>	0.1%	99.9%					
4.75 (#4)	<input type="text" value="1507"/>	28.8%	71.2%	25 - 100	<input type="text" value="0"/>	0.0%	100.0%	100 Min
2.36 (#8)					<input type="text" value="234"/>	39.2%	60.8%	
2.00 (#10)					<input type="text" value="277"/>	46.4%	53.6%	
1.18 (#16)					<input type="text" value="364"/>	61.0%	39.0%	
0.600 (#30)					<input type="text" value="430"/>	72.0%	28.0%	
0.425 (#40)					<input type="text" value="452"/>	75.8%	24.2%	
0.300 (#50)					<input type="text" value="468"/>	78.4%	21.6%	
0.150 (#100)					<input type="text" value="491"/>	82.3%	17.7%	0 - 30
75 µm (#200)					<input type="text" value="514"/>	86.1%	13.9%	0 - 15
In Pan					<input type="text" value="521"/>			

860.9.5 Procedure for MSE Wall Backfill Material (Standardized Special Provision)

Revise 860.9.5 to remove reference to former table and refer to WTM R90 for field sample information.

This procedure is used when certain of the fine aggregate sieves need to comply with the specification based on the total sample and the percent passing the No. 200 sieve is based only on the percent passing the No. 4 sieve.

1. The sample size must meet the minimum requirements of table in [WTM R90](#) (field sample) and table 860-4 (laboratory sample) based on the nominal maximum size of aggregate in the R4 component of the sample. The unwashed test sample must be thoroughly dried.
2. After cooling, the sample must then be separated on a No. 4 sieve, the two portions weighed, and the relative proportions determined.

- The R4 material component is dry sieved and the percent passing for each sieve calculated based on the dry unwashed sample weight of the R4. This includes sieving of any materials that remain in the pan after sieving. Record the cumulative percent passing for all sieves as weighed except for the #200 sieve. The total of the R4 dry unwashed weight is recorded as the #200 weight. This way there is 0% contribution calculated from the R4 component.
- The portion passing the No. 4 sieve must be reduced by use of the riffle splitter or quartering procedures to a sample weighting approximately 1 lb. (500g).
- The test sample of the material passing the No. 4 sieve must be weighed, washed, dried, cooled and sieved.
- The electronic Materials Tracking System (MTS/MIT) provides the prefix 217, aggregates testing worksheet that should be used for calculating and reporting tests. Select material type Dense Graded Base- 3-Inch. A specification for the MSE Wall Backfill Material is available for selection.

Example 5: Materials Tracking System (MTS/MIT) prefix 217 entry screens for MSE Wall Backfill Material

217 Main
Gradation
217D - 2004 Version

Type of Material:
 Granular Backfill
 Structural Backfill
 Dense Graded Base
 Open Graded Base
 Breaker Run Stone

Gradation:
 3 inch
 1 1/4 inch
 3/4 inch

Weight of Sample (Dry) (Grams): 15300
Weight of R-No 4 (Dry Unwashed) (Grams): 3200 = 20.9% R-4 Factor
Weight of P-No 4 (Dry Unwashed) (Grams): 12100 = 79.1% P-4 Factor

Sieve Size Metric (English)	R-4 Material	Percent Retained	Percent Passing	Specs	P-4 Material	Percent Retained	Percent Passing	Specs	R-4:	P-4:	Results:
	Cumulative Weight (Grams)				vWt: 600 Cumulative Weight (Grams)						
150.0 (6")									0.0%	0.0%	0.0%
125.0 (5")									0.0%	0.0%	0.0%
75.0 (3")	0	0.0%	100.0%		0	0.0%	100.0%	100 Min	20.9%	79.1%	100.0%
50.0 (2")									0.0%	0.0%	0.0%
37.5 (1 1/2")	1500	46.9%	53.1%		0	0.0%	100.0%		11.1%	79.1%	90.2%
31.5 (1 1/4")									0.0%	0.0%	0.0%
25.0 (1")	2000	62.5%	37.5%		0	0.0%	100.0%		7.8%	79.1%	86.9%
19.0 (3/4")	2100	65.6%	34.4%		0	0.0%	100.0%		7.2%	79.1%	86.3%
12.5 (1/2")									0.0%	0.0%	0.0%
9.5 (3/8")									0.0%	0.0%	0.0%
4.75 (#4)	3100	96.9%	3.1%		0	0.0%	100.0%	45 - 100	0.7%	79.1%	79.7%
2.36 (#8)									0.0%	0.0%	0.0%
2.00 (#10)	3120	97.5%	2.5%		200	33.3%	66.7%		0.5%	52.7%	53.2%
1.18 (#16)									0.0%	0.0%	0.0%
0.600 (#30)									0.0%	0.0%	0.0%
0.425 (#40)	3150	98.4%	1.6%		300	50.0%	50.0%	10 - 50	0.3%	39.5%	39.9%
0.300 (#50)									0.0%	0.0%	0.0%
0.150 (#100)	3200	100.0%	0.0%		400	66.7%	33.3%		0.0%	26.4%	26.4%
75 µm (#200)	3200	100.0%	0.0%		545	90.8%	9.2%	0 - 8	0.0%	7.2%	7.2%
In Pan	0										

860.9.6 Unwashed Sieve Analysis

Any gradation specification relates to the total gradation that generally implies the need for a washed sieve analysis. However, in some cases, the materials are of such nature and so devoid of coatings or lumps of P/No. 200 material that the gradation specification could be administered without the need for complete washed sieve analysis of every sample.

The procedures for unwashed sieve analysis are identical to those for washed analysis except for those references to washing operations.

The validity of the design to use unwashed analysis can be established only by testing and by acceptance of certain judgment criteria.

860.10 Aggregate Acceptance Tests

All results of acceptance tests made on aggregates for use in base course, asphaltic surfacing, portland cement concrete, granular subbase, structural backfill, and granular backfill are to be reported. Report the results electronically on the MTS using prefixes 217, 162, or 257.

Aggregate acceptance tests are to be prepared for all contracts let to bid or entered into with municipalities on a force account or agreed unit price basis. Testing and acceptance must conform to the Materials Testing and Acceptance Guide. Reporting should be done in accordance with the requirements listed in [CMM 845](#). When completing the form, it should be noted that the percent passing the 200 sieves is reported to the nearest tenth of a percent and administered to the nearest whole percent. Aggregate sieve analysis test reports are listed or referenced on the Test Report Record printed from materials tracking.

MTS prefix 217 for base course, subbase, granular backfill, should be used whenever possible. Use prefix 162 for PCC aggregate and 257 for aggregates in asphaltic mixtures.

FIGURE 860-2 Test Report Record

TEST REPORT RECORD									
PROJECT: 6999-08-78 (1ST AVE SOUTH, CITY OF WISCONSIN RAPIDS)									
#	Test Number	Test Type	Description	Material	Manufacturer	Satisfactory	Tested	Verified	Verified By
1	0-217-218-2003	Verification	Aggregates			Yes	09/30/2003	09/30/2003	Wayne Kleisl
2	4-130-272-2003	Verification	Concrete cylinders	CYLINDERS 1A, 1B		Yes	10/29/2003	11/04/2003	JEFF BAYARD
3	4-130-278-2003	Verification	Concrete cylinders	CYLINDERS 2 A,B		Yes	11/05/2003	11/05/2003	JEFF BAYARD
4	4-155-7-2003	Verification	Miscellaneous Materials	E1 12.5MM (R) 25A-118-03		Yes	11/18/2003	11/18/2003	JEFF BAYARD
5	4-162-24-2003	Verification	Fine & coarse aggregate for concrete	#1 CONCRETE AGG		Yes	09/11/2003	09/11/2003	JEFF BAYARD
6	4-162-27-2003	Verification	Fine & coarse aggregate for concrete	CONC. AGG. FINES, #1 STONE		Yes	10/01/2003	10/02/2003	JEFF BAYARD
7	4-162-31-2003	Verification	Fine & coarse aggregate for concrete	#1 CONCRETE AGG		No	09/18/2003	10/22/2003	JEFF BAYARD
8	4-217-44-2003	Verification	Aggregates	INSITUE GRANULAR BACKFILL #2		Yes	09/12/2003	09/17/2003	JEFF BAYARD
9	4-217-48-2003	Verification	Aggregates	CABC #2 STONE		Yes	10/01/2003	10/02/2003	JEFF BAYARD
10	4-217-52-2003	Verification	Aggregates	CABC #2 STONE		Yes	10/03/2003	10/03/2003	JEFF BAYARD
11	4-217-61-2003	Verification	Aggregates	GRANULAR BACKFILL #1		No	09/18/2003	10/22/2003	JEFF BAYARD
12	4-9-155-10-2003	Verification	Miscellaneous Materials	#1 CONCRETE AGG TYPE A	MILESTONE MATERIALS	No	09/18/2003	12/04/2003	Mike Bohm
13	4-9-155-11-2003	Verification	Miscellaneous Materials	GRANULAR BACKFILL TYPE B	FANNING PIT	No	09/18/2003	12/04/2003	Mike Bohm
14	4-9-155-18-2003	Verification	Miscellaneous Materials	OMP ASPHALTIC MIXTURE	AMERICAN ASPHALT	Yes	11/19/2003	12/01/2003	Mike Bohm
15	4-9-155-19-2003	Verification	Miscellaneous Materials	VOID		Yes	12/02/2003	12/03/2003	Mike Bohm
16	4-9-155-20-2003	Verification	Miscellaneous Materials	ASPHALT DENSITY SUMMARY		Yes	12/03/2003	12/03/2003	Mike Bohm
17	4-9-900-4-2003	Reference Report	Reference Report	VARIOUS AGGREGATE QUALITY TESTS		N/A	11/06/2003	01/29/2004	Mike Bohm
18	4-9-900-9-2003	Reference Report	Reference Report	ASPHALT ITEMS		N/A	11/06/2003	01/29/2004	Mike Bohm
19	4-9-900-10-2003	Reference Report	Reference Report	PAVEMENT MARKING EPOXY		N/A	11/06/2003	01/29/2004	Mike Bohm
20	4-9-900-11-2003	Reference Report	Reference Report	STABILIZED EARTH MODULAR BLOCK WALL ELECTRICAL ITEMS		N/A	11/06/2003	01/29/2004	Mike Bohm
21	4-9-900-12-2003	Reference Report	Reference Report	ELECTRICAL ITEMS		N/A	11/06/2003	01/23/2004	Mike Bohm
22	4-9-900-1-2004	Reference Report	Reference Report	WATER FOR CONCRETE		N/A	01/23/2004	01/23/2004	Mike Bohm

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860.11 Field Determination of Density for Aggregate Courses

When the plans or special provisions specifically require special compaction for granular subbase course or crushed aggregate base course, sufficient check tests of in-place density should be made to satisfy the frequency requirements discussed in the following sections. The density can be checked by either the sand cone method or the nuclear method.

860.12 Field Density Testing by the Sand Cone Method Part 1

860.12.1 Scope

The sand cone density procedures outlined here are intended as a guide for the individual inexperienced with the field density test. As experience is gained with field testing procedures and the inspector becomes more acquainted with the methods and techniques available, the speed and accuracy should improve.

For practical use and for simplicity, this guidance is divided into two parts. Part 1 is a general discussion of the sand cone density test and equipment, methods of calibrating the density and equipment, and the errors that may be caused by using inappropriate equipment and improper techniques. Part 2 outlines in detail the sand cone density test and procedures to be followed in calibrating the density sand and cone.

A field density flow chart that outlines the procedures to be followed by the inspector to prepare for and to perform the field density test is shown in figure 860-3.

A nomograph for correcting the standard laboratory density (if laboratory and field samples differ in gravel content) is also included. This nomograph will enable the inspector to determine a corrected standard maximum density for comparison with the field density. The nomograph is shown in figure 860-4.

FIGURE 860-3 Field Density Flow Chart

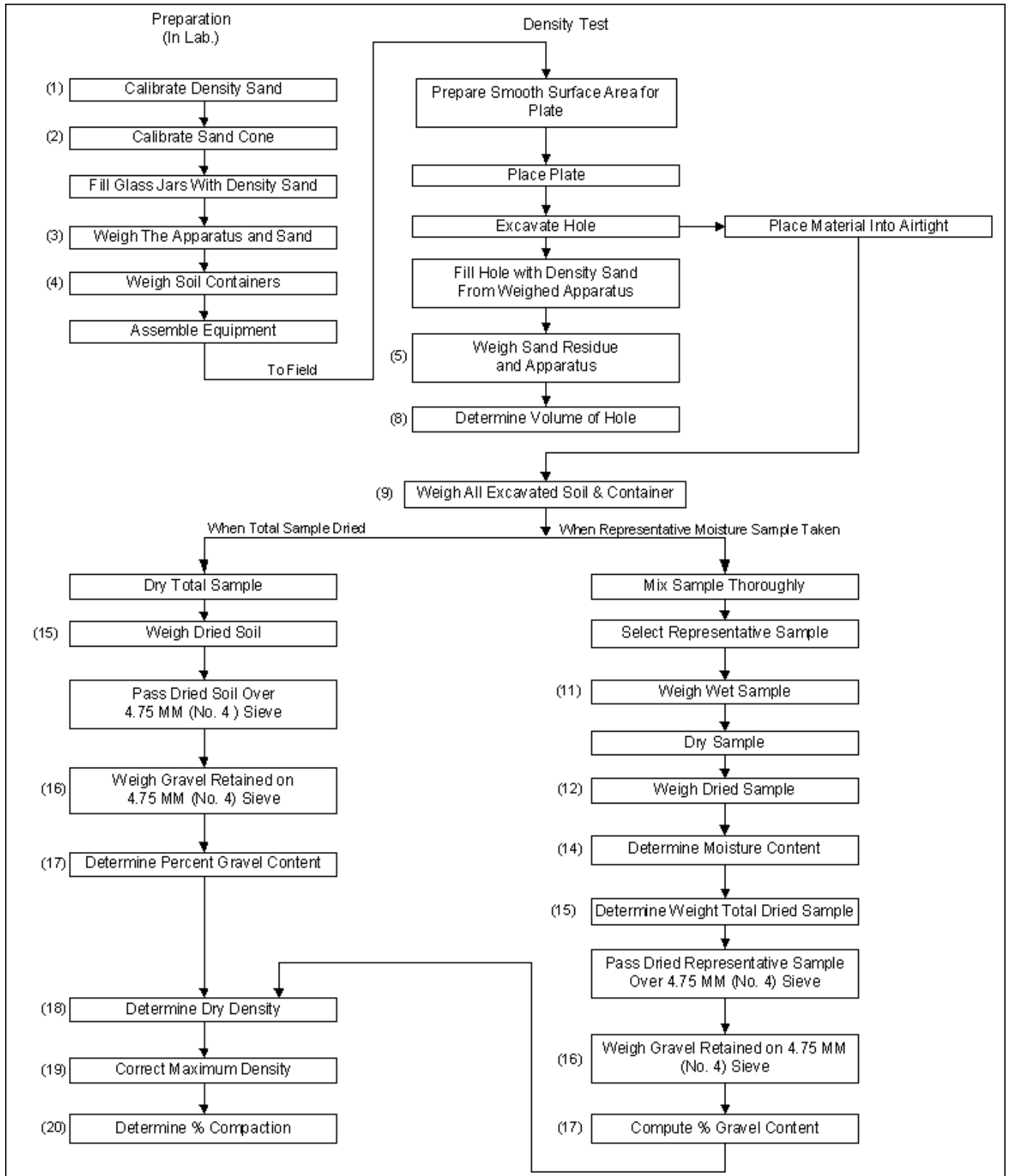
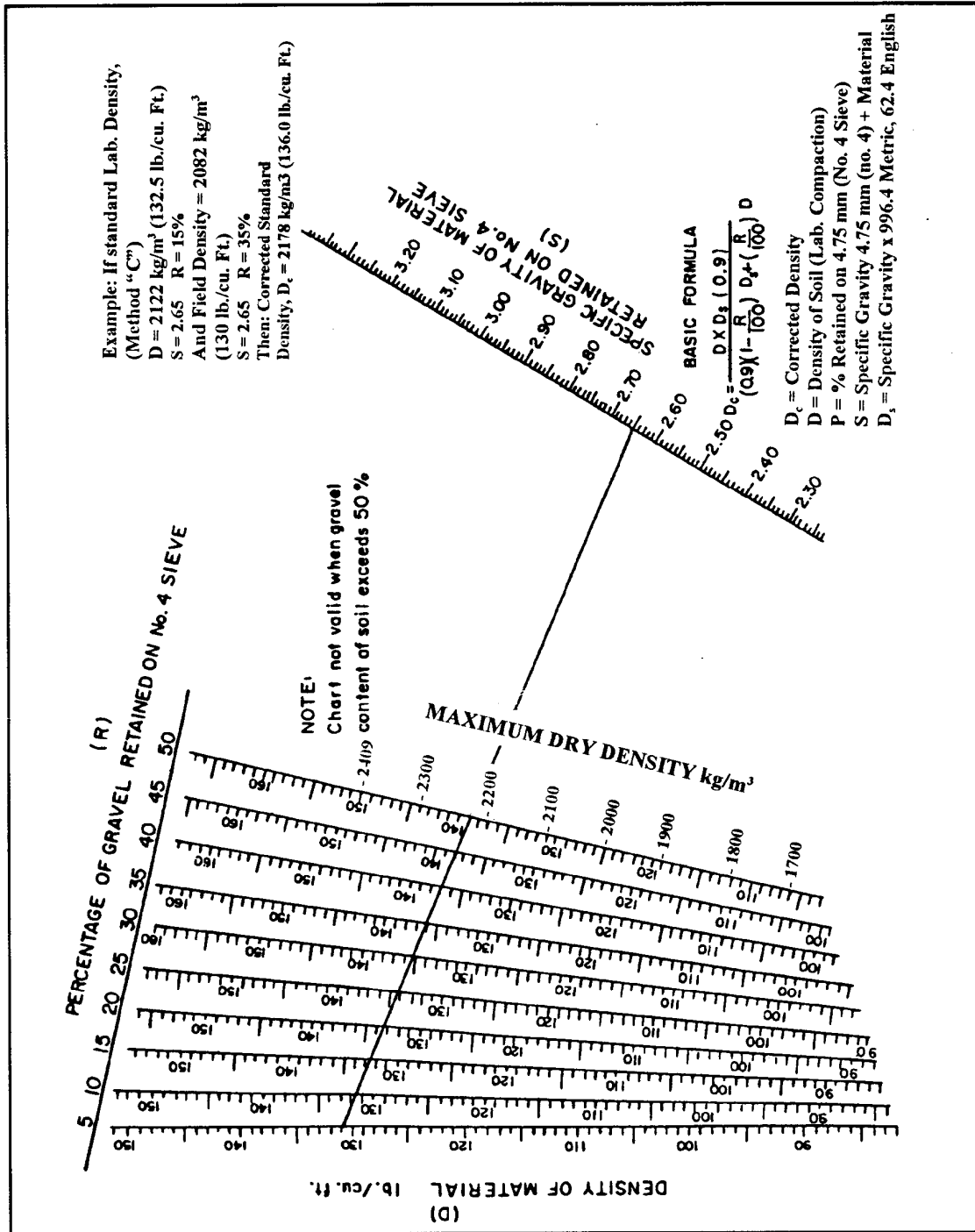


FIGURE 860-4 Nomograph for Determining Corrected Maximum Density for Soil with R No. 4 Sieve Material



860.12.2 Overview of Method

860.12.2.1 Equipment

Essentially, the sand cone apparatus consists of a 60-degree metal double-cone assembly fitted to a standard screw top glass jar and a 12-inch square metal plate. The assembly consists of a bottom cone with a 6-1/2 inch diameter base, a 1/2-inch valve and a top cone that is threaded for the screw top jar. The bottom cone fits into a recess in the metal plate that is placed over the area to be tested for density.

860.12.2.2 Density Sand

In accordance with ASTM, any sand with rounded particles passing the No. 10 sieve and retained on the No. 200 sieve may be used, providing the sand is clean, dry, and free flowing. To be acceptable, the sand should not have a variation in bulk density greater than 1%. It is possible to use locally prepared sand if it

is washed thoroughly, oven-dried, and graded over the required sieves. This is usually time-consuming and prohibitive for general use, especially when many tests are performed. It is usually cheaper to buy commercial sand. Portage silica sand, processed by the Manley Sand Company, Portage, Wisconsin, has served very well as calibration sand. It is uniformly graded with particles passing the No. 20 sieve and predominantly retained on the No. 50 sieve. Other sources of calibration sand are the Eau Claire Sand and Gravel Company and any local supplier of plaster sand.

After density sand is oven-dried, it should be calibrated before it is used. The sand should be kept in a covered container where it will remain relatively moisture free. During humid weather, the sand will absorb some moisture from the air, thus lowering its loose density. Therefore, frequent spot-checks are necessary to determine what changes, if any, occur. Although density sand may be free flowing, it may still contain enough absorbed moisture to alter its loose density. This small amount of absorbed moisture may cause the measured field soil density to be as much as 2-lbs/cubic foot lighter than the actual density. For this reason, supply containers holding density sand should be kept covered at all times. The spot-check should be made on every bag when about half of the sand has been used.

For economy, some field inspectors have been retrieving the density sand from the hole and using it on subsequent tests. This practice should be discouraged because the sand becomes contaminated with soil particles. The added time required to retrieve, wash, and process the sand is rarely worth the effort.

860.12.2.3 Calibration of Density Sand

Before any field density test is performed, the bulk or loose density of the sand to be used in the field test must be known. The bulk density is determined by filling a container of known volume with the density sand. The net weight of the sand divided by the volume of the container is the bulk density of the sand, expressed in pounds per cubic foot.

Various types of containers can be used to determine the bulk density of the dry sand. Types of containers and their use are explained in three methods. Containers should dimensionally approximate the largest test hole to be excavated.

The first method describes using such containers as the C.B.R. mold, 1/10-cubic foot mortar bucket and others in which the volume is known or can be determined without using water.

The second method outlines a procedure using the gallon glass or plastic jar that accompanies the sand cone. Any glass jar with slightly curved surface can be used, providing it is of proportions that will eliminate shoulder void. The volume of these containers is usually determined by water at a temperature between 35 F and 60 F. The density of water in that temperature range is close to 62.4 pounds per cubic foot.

The third method that is frequently used by field personnel involves using the sand cone apparatus to calibrate the density sand. In this method, a rubber gasket is required to prevent water from seeping around the threaded connection of the cone and jar. The gasket must be in place for both the water and sand weighings, and the cone threads must be turned on the jar threads to the same place. A check mark on each will help facilitate this determination. The method is acceptable, providing the glass jar does not have squared or sharp shoulders. Some gallon glass jars have a sharp curved portion just below the neck where bulking action of the sand occurs and air pockets or voids are formed. These voids are visible on close observation. The condition introduces an error in the weight of the sand filling the jar and causes a sand density determination, which can vary as much as 1.5 lbs per cubic foot.

During all calibrations and tests, care should be taken to avoid jarring or vibrating the apparatus while the density sand is flowing and the valve is open.

860.12.2.4 Calibration of Cone

Before the volume of the test hole can be computed, the weight of the sand filling the sand cone and plate (between the ground surface and the valve of the apparatus) must be subtracted from the total weight of the sand used in the test. Because of dissimilarity in construction of sand cones and plates, the volumes of the different cones and plates may vary. For this reason, a sand cone and plate are kept together as a set and should not be interchanged.

860.12.2.5 Calibration Spot-Check

To reduce possibility of error due to an incorrect unit weight of the sand, a spot-check of the density should be made for each bag of density sand when the bag is approximately half full. This spot-check can be made by running a sand cone calibration as described under the calibration procedures.

Once the weight of sand filling the cone has been determined during the original calibration of the density sand, it is a simple matter to check that weight again.

When the weight of sand filling the cone remains the same, and the volume of the cone is constant, the density of the sand remains unchanged. If, during the spot-check, the weight of the sand filling the cone

varies from the original calibration by 13.6 g (0.03 lbs) one can assume that the density of the sand has changed. The sand should then be recalibrated by one of the methods explained under the calibration procedures. When there is a variation of 13.6 g (0.03 pounds) in the weight of the sand filling a test hole of parabolic shape 6-inches in maximum diameter and 6-inches deep, the soil density will vary by approximately one pound.

Spot-checking of sand density is an integral part of an organized testing program. Without constant spot-checks the validity of the whole testing program can be questioned.

860.12.2.6 Trials

Whenever a calibration is performed to determine sand density, weight of sand filling the cone, or volume of container, three determinations or trials should be made unless the first two trials give the same reading. When three trials are made, the average of the three readings is taken as the final result.

860.12.2.7 Preparation

When filling the glass jars with calibrated sand in preparation for the field density test, it is suggested that all glass jars be filled with calibrated sand to a constant weight, say 16 lbs. This is to avoid errors in recording weights of jars plus sand if many jars are used on the project at one time.

The jar plus the sand may be weighed with or without the cone or jar cover attached. Either can be done, but it is recommended that the same procedure be followed throughout the job. When many tests are performed in the laboratory, it may be preferable to weigh the jar plus sand without the sand cone.

860.12.2.8 Field Density

Three very important steps in the field density test are preparation of the surface test area, excavation of the hole, and moisture determination. When preparing the surface area, an attempt should be made to prepare a surface without voids or protruding stones. Power equipment such as a motor grader, dozer, or front-end loader should not be used to level and smooth the surface test area. To reduce the surface roughness, some fine material may be scraped from the surrounding area or passed through the No. 4 sieve and sprinkled to just fill the surface voids. Then the surface is smoothed and compacted with a trowel. This procedure of filling the surface voids will greatly reduce the error due to surface roughness. When it is desired to completely eliminate the error due to surface roughness, a method is suggested in [ASTM D1556](#).

It is occasionally helpful to secure the density plate in hard soil areas by driving a large spike adjacent to each plate edge. This prevents plate movement when the digging becomes difficult. The density plate is used for several reasons:

- The circular opening in the plate serves as a guide and template for digging the hole.
- The plate helps support the apparatus, especially in soft, loose soils.
- The plate helps reduce the loss when transferring soil from the test hole to the container.

860.12.2.9 Excavating the Density Hole

The test hole should be excavated in such a manner that the material surrounding the hole is neither compacted nor loosened. This is important because a discrepancy in the volume of the hole will directly affect the computed density. In a fine-grained soil there is a tendency to press down with the spoon, compacting the soil and enlarging the hole. This increases the volume of the hole and results in lower-than-actual density values.

Conversely, in a coarse-grained (gravelly or sandy) soil, the soil surrounding the hole is loosened when projecting rocks are extruded. This results in higher-than-actual density values. In either case, considerable care must be exercised when digging the hole. Sharp cutting edges on cutting tools or digging spoons are a necessity for excavation in silty or clayey soils.

When a nuclear device is used to check the density obtained by the sand cone method, all stones, regardless of size, should be removed and included with the soil from the test hole. Otherwise, the density determined by the nuclear device will generally be higher than that determined by the sand cone apparatus.

860.12.2.10 Moisture and Gravel Content Determination

The procedures outlined above for Field Density, are suggested because they give quick and reliable results. There are other reliable ways to determine moisture and gravel contents, although they may be more time consuming.

In the case of moisture content of a clayey soil, it is important to break the clay soil into clay lumps, pulverizing the lumps as the soil dries. As the clay soil dries, moisture is lost from the surface and a hard crust forms, trapping some moisture internally. Unless the lump is further broken apart to allow the internal moisture to escape, the clay will not completely dry as quickly, and an erroneous moisture

content may result. For this reason, the clay soil should be constantly manipulated and the lumps broken down while drying, unless the soil is dried overnight in an oven to a constant weight.

The "Speedy" moisture device may be used to determine moisture content of fine grained soils accurately and quickly. Inspectors are cautioned against using the Speedy with coarse grained soil (high gravel content), since a very small moisture sample is used, and it may not be representative of the total sample.

In highly organic material, care should be taken to avoid burning the soil. At high temperatures the organic matter may be burned off, resulting in higher than actual moisture content determination.

860.13 Field Density Testing by the Sand Cone Method Part 2

860.13.1 Equipment

The equipment necessary for the field density test should include the following: (The first eight items may be included in a kit for field use.)

- 6-inch sand cone and 1-gallon glass jar. 4-inch cones and 1/2-gallon jars are not acceptable.)
- 1-gallon container with tight fitting lid (to hold excavated soil)
- 12" x 12" metal density plate with four large spikes for hold-downs
- Large screwdriver and geologist's hammer (wood handle) to loosen materials
- Large spoon with sharpened edges (for excavating material)
- Small trowel (to prepare test hole surface)
- Small paint brush (to sweep and collect loose material)
- Shovel, square-end, D-handle (to level test area)

The following equipment may be kept in a field laboratory:

- 20 kg solution balance or field scale, 35 lb. capacity. If a solution balance is used it will be necessary to convert kilogram or gram weights to pounds if reported in lbs./cubic foot.
- Gram scale, 2,000 g capacity
- Gasoline, electric or gas stove
- Drying pan approximately 9" x 12"
- Pie pan
- No. 4 sieve (to determine percent gravel and for specific gravity sample)
- Sand scope (for filling glass jars)
- Supply of dry density sand 100 lb bags
- Field density data forms
- Gasoline can with flexible pouring spout (for gasoline stove)
- The following are optional
- Cardboard manila tags (for tagging gallon soil containers)
- Wax marking pencils (to mark apparatus and other equipment)
- Clipboard (to hold forms)

The term "apparatus" as used in these procedures refers to the glass jar with the sand cone attached.

860.13.2 Calibration Procedures

860.13.2.1 Calibration of Density Sand

1. Using containers with volume known or computed by actual measurement: C.B.R. mold - 6" diameter, 4.59" depth; volume 1/13.33 cubic foot. Mortar bucket - volume 1/10 cubic foot.
 - A. Weigh the container.
 - B. Fill the apparatus (glass jar with cone) with dry, clean density sand.
 - C. Close the valve.
 - D. Invert the apparatus and place it over the container so that the inside of the cone rests on the rim edge of the container. If the container is larger in area than the sand cone, place the metal plate that accompanies the apparatus over the container and set the sand cone apparatus on the plate.
 - E. Holding the apparatus in place; open the valve and allow sand to flow into container. Avoid jarring or vibrating the container.
 - F. When the sand stops flowing, close the valve and remove apparatus and plate carefully.
 - G. Using a straightedge, strike off the surface of the sand level with the rim of the container. Avoid jarring or vibrating container when striking off.
 - H. Tap the sides of the container to settle sand and thus avoid possible spilling or losing of sand from the container when transferring to scales.
 - I. Brush excess sand off the outside of any protruding parts of the container.

- J. Weigh the container and sand.
 - K. Determine net weight of sand: J minus A.
 - L. Calculate unit weight of sand: Unit weight of sand in pounds per cubic foot = net weight of sand divided by volume of container.
2. Using 1-gallon glass jar and glass plate or other containers with slightly curved or tapered sides: volume determined using cold water 35 F - 60 F
- A. For weight of sand filling container:
 - 1) Weigh glass jar.
 - 2) Invert a filled density apparatus (glass jar with cone and sand), and place onto the glass jar.
 - 3) Open valve and allow the sand to flow into the glass jar (avoid jarring or vibration).
 - 4) When the sand stops flowing, close the valve.
 - 5) Remove the density apparatus carefully.
 - 6) Using the straightedge, carefully strike off the surface of the sand level with the top rim of the jar (avoid jarring or vibrating jar with straightedge during this operation).
 - 7) Weigh the glass jar with the sand.
 - 8) Determine net weight of sand: Step 7 minus Step 1.
 - B. For volume of jar:
 - 1) Weigh glass jar with glass plate.
 - 2) Fill the glass jar with cold water to the top rim of the jar neck.
 - 3) Place the glass plate on the jar (to eliminate excess water caused by surface tension).
 - 4) Dry the surface of the jar and glass plate.
 - 5) Weigh the jar with water and glass plate.
 - 6) Determine net weight of water: Step 5 minus Step 1.
 - 7) Volume of jar = net weight water divided by in pounds divided by 62.4 pcf. Sand unit weight = net weight of sand divided by volume of jar.
3. Using sand cone apparatus: 1-gallon glass jar with rubber gasket and sand cone attached.
- A. Find weight of the sand filling the apparatus:
 - 1) Weigh empty glass jar with cone and rubber gasket.
 - 2) Pour density sand into inverted apparatus through open valve until jar and valve are full. During this operation, try to keep the cone full of sand. Avoid jarring or vibrating the apparatus while sand is flowing until the valve is closed.
 - 3) Close the valve.
 - 4) Remove the excess sand in the cone.
 - 5) Weigh the jar with the cone and sand.
 - 6) Determine the net weight of the sand: Step 5 minus Step 1.
 - B. Find volume of the apparatus:
 - 1) Weigh empty jar with rubber gasket and sand cone.
 - 2) Pour cold water into inverted density apparatus through open valve until water appears in the cone.
 - 3) Close valve, remove the excess water, and dry the cone and outside surface of apparatus.
 - 4) Weight the apparatus with the water.
 - 5) Determine net weight of water: Step 4 minus Step 1 in pounds.
 - 6) Volume of apparatus (including valve) = net weight of water divided by (62.4 pcf).
 - 7) Unit weight of sand = net weight of sand in pounds divided by volume of apparatus.

860.13.2.2 Calibration of Cone and Plate

1. Fill the glass jar with density sand and attach sand cone.
2. Weigh the glass jar with the density sand and attached cone.
3. Set the density plate on a smooth level surface.
4. Invert the apparatus and seat the sand cone in the hole of the plate.
5. Open the valve and allow sand to flow into the cone until it stops (avoid jarring or vibrating apparatus while sand is flowing).
6. Close the valve.
7. Re-weigh the apparatus (jar and cone) and remaining sand.
8. Determine net weight of sand used to fill the cone and plate. Step 2 minus Step 7.

9. Record this weight as the weight of sand filling cone.

860.13.2.3 Spot-Check Calibration

The spot-check calibration should be performed for each new bag of density sand.

1. Follow the procedures outlined Calibration of Cone and Plate.
2. If the weight of the sand filling the cone is 13.6 g (0.03 lbs), more or less, than the original cone calibration, recalibrate the density sand.

860.13.3 Field Density Procedure

860.13.3.1 Preparation Preliminary to Test

1. Spot-check sand density using calibrated sand cone.
2. Recalibrate density sand, if necessary.
3. Fill all necessary glass jars with the calibrated sand to a constant weight.
4. Record the weight of each filled glass jar (always weigh filled jar with or without cone attached. Be consistent in procedure to avoid errors when several jars are used at one time).
5. Weigh and record the weight of all soil containers.
6. Assemble necessary equipment required in the field (take along extra filled jars in case hole dug is unusually large).

860.13.4 Performing the Field Density Test

1. Remove all loose and dry soil from the surface of the site to be tested. Go below depth disturbed by machinery.
2. Trim to a smooth, level surface an area large enough for the density plate to bed firmly. (If the surface is gravelly and irregular, sprinkle just enough fine material, scraped from the surrounding area or passing the No. 4 sieve, over the area to fill the surface voids; then smooth and compact with a trowel. Do not place a bedding layer for the plate thicker than 1/4").
3. Set the density plate firmly in place.
4. Loosen the soil with a screwdriver or geologist's pick and carefully remove the soil with a spoon.
5. Dig the test hole carefully, in such a manner that the material surrounding the hole is neither compacted nor loosened.
6. Place all soil from the hole into the airtight container.
7. Using a brush, gently sweep all loose particles from the sides of the hole and around the top edge of the plate hole into the hole. Remove and place all particles into the soil container.
8. Seal the container to prevent moisture loss from sample.
9. Invert the apparatus with the valve closed and set it onto the plate (make sure the lip of the cone edge is properly seated in the groove of the plate before opening valve).
10. Open the valve and allow the sand to flow into the hole and cone until it stops (there should be no vibration from earth-moving equipment in the immediate area until the valve is closed).
11. Close the valve and remove the apparatus with the remaining sand.
12. Weigh the apparatus with the remaining sand and record the weight to the nearest 5 g (0.01 lb). (When outside, shield the scale from the wind. Maintain a level scale.)
The glass jar with the remaining sand should be weighed either with or without the cone attached.
13. To find the weight of the sand filling the hole and the cone, subtract the remaining weight of apparatus and sand from the original weight of apparatus and sand.
14. The weight of sand filling the hole is found by subtracting the weight of sand filling the cone from the weight of sand filling the hole and the cone: Step 13 minus cone calibration.
15. The volume of the soil sample (hole) is found by dividing the weight of sand filling the hole by the weight per cubic foot of the density sand: Step 14 divided by sand density.
16. Weigh the soil sample and container. When outside, shield the scale from the wind. Maintain a level scale.
17. Record the weight to the nearest 5 g (0.01 lb).
18. Find weight of wet soil: Step 16 minus weight of soil container.
19. Determine dry weight and gravel content of total soil sample:
 - A. When time allows, the total wet soil sample may be dried for greater accuracy:
 - 1) Dry the entire sample to a constant weight. Manipulate and stir the soil; pulverize any clay lumps for more complete and rapid drying.
 - 2) Weigh the total dry sample to the nearest 5 g (0.01 lb) and record.
 - 3) For gravel content, pass total sample over No. 4 sieve. Make sure gravel retained contains no clay lumps.
 - 4) Weigh the gravel fraction retained on the No. 4 sieve to the nearest 5 g (0.01 lb) and record.

- 5) Find percent gravel content: Weight of gravel retained multiplied by 100 and the result divided by dry weight of total sample. Step 4 multiplied by 100 and divided by Step 2.
- B. When time does not allow drying the total soil sample, or if the material does not contain an appreciable amount of gravel, a representative sample may be taken as follows:
- 1) Thoroughly mix the total wet soil sample.
 - 2) Select a representative sample for moisture and gravel content according to the following:

Suggested Minimum Size of Moisture Content Samples		
Maximum Particle Size	Moisture Content Sample, lb.	Moisture Content Sample, g
No. 4 Sieve	0.22	100
1/2" Sieve	0.55	250
1" Sieve	1.1	500
2" Sieve	2.2	1,000

- 3) Weigh the moisture content sample and record the weight to the nearest 0.1 g.
- 4) Dry the moisture content sample to a constant weight. For sandy soils, manipulate and stir. Pulverize any clay lumps for more complete and rapid drying. For clay soils, begin stirring and manipulating immediately upon heating to prevent the formation of a hard crust and to allow internal moisture to escape.
- 5) Weigh the dry sample and again record weight to nearest 0.1 g.
- 6) Find weight of moisture loss: Weight wet sample minus weight dry sample. Step 3 minus Step 5.
- 7) Determine percent moisture content: Weight of moisture loss multiplied by 100 and the result divided by dry weight of sample. Step 6 times 100 divided by Step 5.
- 8) For dry weight of total sample: Total dry weight = total wet weight divided by (1.0 + % moisture/100.)
- 9) For gravel content: Pass dried moisture content sample over the No. 4 sieve (make sure material retained on No. 4 sieve contains no hardened clay lumps).
- 10) Weigh gravel portion retained on No. 4 sieve to nearest 0.1 g and record.
- 11) Find the percent gravel content: Weight of the gravel retained multiplied by 100 and the result divided by the dry weight of the moisture content sample: Step 10 times 100 divided by Step 3.

In the case of fine-grained soils which contain no gravel, the "Speedy" moisture device may be used for a quick determination of the moisture content.

20. Specific gravity of gravel: If not previously known, the specific gravity of the gravel may be determined by the method described in AASHTO Designation: T85.
21. Find dry density of field soil sample:

$$\text{English : Dry density, pcf} = \frac{\text{Dry weight total sample, lbs.}}{\text{Volume of hole, cf.}}$$

22. Correct standard maximum density if gravel content of field sample differs from laboratory compaction sample by 5% or more.
23. Percent compaction

$$\text{Percent Compaction} = \frac{\text{Field density}}{\text{Corrected standard density}} (100)$$

860.13.5 Calculations

860.13.5.1 Calculations (Metric)

1. Volume of density apparatus (jar with sand cone attached):

$$\text{Volume, m}^3 = \frac{\text{Weight of water filling jar, kg}}{996.4 \text{ kg/ m}^3}$$

2. Unit weight of sand.

$$\text{Density, kg/ m}^3 = \frac{\text{Weight of sand filling container, kg}}{\text{Volume of container, m}^3}$$

3. Volume of test hole.

$$\text{Volume, } m^3 = \frac{\text{Weight of sand filling hole, kg}}{\text{Unit weight of sand, kg/ } m^3}$$

4. Moisture content:

$$\text{Moisture, \%} = \frac{\text{Wetweight} - \text{dry weight}}{\text{Dry weight}} (100)$$

5. Dry weight of soil sample from hole

$$\text{Dry weight (kg)} = \frac{\frac{\text{Wet weight sample, kg}}{1 + \% \text{ moisture}}}{100}$$

6. Dry density of soil sample from hole.

$$\text{Dry density, kg/ } m^3 = \frac{\text{Dry weight, kg}}{\text{Volume of test hole, } m^3}$$

7. Percent of standard laboratory density

$$\% = \frac{\text{Field density}}{\text{Corrected standard density}} (100)$$

860.13.5.2 Calculations (English)

1. Volume of density apparatus (jar with sand cone attached)

$$\text{Volume, cf.} = \frac{\text{Weight of water filling jar, lbs.}}{62.4 \text{ lbs./cf.}}$$

2. Unit weight of sand:

$$\text{Density, lbs./cf.} = \frac{\text{Weight of sand filling container, lbs.}}{\text{Volume of container, cf.}}$$

3. Volume of test hole

$$\text{Volume, cf.} = \frac{\text{Weight of sand filling hole, lbs.}}{\text{Unit weight of sand, lbs./cf.}}$$

4. Moisture content

$$\text{Moisture, \%} = \frac{\text{Wetweight} - \text{dry weight}}{\text{Dry weight}} (100)$$

5. Dry weight of soil sample from hole:

$$\text{Dry weight (lbs.)} = \frac{\frac{\text{Wet weight sample, lbs.}}{1 + \% \text{ moisture}}}{100}$$

6. Dry density of soil sample from hole:

$$\text{Dry density, lbs./cf.} = \frac{\text{Dry weight, lbs.}}{\text{Volume of test hole, cf.}}$$

7. Percent of standard laboratory density:

$$\% = \frac{\text{Field density}}{\text{Corrected standard density}} (100)$$

860.13.6 Laboratory Standard Density Correction for Variation in Gravel Content

These instructions pertain to using the nomograph as a guide for grading inspectors and others concerned with field compaction.

By referring to the nomograph with the specific gravity of the aggregate and a laboratory compaction density of the material, the inspector can establish the standard maximum density for a field sample containing a certain gravel content. The field density can then be compared with the standard density and the percent of compaction determined.

Example 5: Using Nomograph to Determine Maximum Density

Given:

1. Field density = 13.0 pcf
with gravel content = 35%
and specific gravity = 2.65
2. Laboratory compaction = (Method C)
Maximum density = 132.5 pcf
Gravel content = 15%
Specific gravity = 2.65

Find:

Standard maximum density for the field sample containing 35% gravel.

Procedure:

1. Find on the nomograph the laboratory density value of 132.5 pcf at the 15% line and the specific gravity of 2.65 at the specific gravity line.
2. Using a straightedge, draw a straight line through the two points, 132.5 at the 15% line and 2.65 specific gravity, and extend it to the 5% line at the extreme left. The standard maximum density for a specific soil type with a certain gravel content will be found along the drawn line. This line indicates how the maximum density varies with a variation in the gravel content.
3. Move along the drawn line to the 35% retained column and read 136 pcf as the standard density for the field sample containing 35% gravel.
4. To find the percent of compaction, divide the field density value 130.0 pcf by 136.0 pcf, and multiply by 100. This will give 95.7% compaction.