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

CMM provisions mobilized by the contract:

- **860.7.3** ........................................................... flat and elongated aggregate pieces
- **860.7.2** ............................................................ fracture testing

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.

Before sampling for source approval testing, at least one day of aggregate production (crushing) is required. 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 IA specialist must be notified before sampling existing stockpiles of less than 2500 tons.

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>
<thead>
<tr>
<th>TABLE 860-1 Wisconsin County Codes</th>
</tr>
</thead>
</table>

April 2020  Construction and Materials Manual
<table>
<thead>
<tr>
<th>Code</th>
<th>County</th>
<th>Code</th>
<th>County</th>
<th>Code</th>
<th>County</th>
</tr>
</thead>
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<tr>
<td>01</td>
<td>Adams</td>
<td>26</td>
<td>Iron</td>
<td>51</td>
<td>Racine</td>
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<td>02</td>
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<td>27</td>
<td>Jackson</td>
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<td>Barron</td>
<td>28</td>
<td>Jefferson</td>
<td>53</td>
<td>Rock</td>
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<td>29</td>
<td>Juneau</td>
<td>54</td>
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<td>05</td>
<td>Brown</td>
<td>30</td>
<td>Kenosha</td>
<td>55</td>
<td>St. Croix</td>
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<td>06</td>
<td>Buffalo</td>
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<td>Kewaunee</td>
<td>56</td>
<td>Sauk</td>
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<td>Burnett</td>
<td>32</td>
<td>La Crosse</td>
<td>57</td>
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<td>08</td>
<td>Calumet</td>
<td>33</td>
<td>Lafayette</td>
<td>58</td>
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<td>Chippewa</td>
<td>34</td>
<td>Langlade</td>
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<td>Lincoln</td>
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<td>Manitowoc</td>
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<tr>
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<td>Crawford</td>
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<td>Marathon</td>
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<td>Vernon</td>
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<td>Dane</td>
<td>38</td>
<td>Marinette</td>
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<td>Vilas</td>
</tr>
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<td>Dodge</td>
<td>39</td>
<td>Marquette</td>
<td>64</td>
<td>Walworth</td>
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<td>15</td>
<td>Door</td>
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<td>Milwaukee</td>
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<td>Washburn</td>
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<td>16</td>
<td>Douglas</td>
<td>41</td>
<td>Monroe</td>
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<td>Oconto</td>
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<td>Outagamie</td>
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<td>Waushara</td>
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<td>Pepin</td>
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<td>Grant</td>
<td>47</td>
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<td>Menominee</td>
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<td>23</td>
<td>Green</td>
<td>48</td>
<td>Polk</td>
<td>00</td>
<td>Out-of-state</td>
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<tr>
<td>24</td>
<td>Green Lake</td>
<td>49</td>
<td>Portage</td>
<td>99</td>
<td>Obsolete</td>
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<tr>
<td>25</td>
<td>Iowa</td>
<td>50</td>
<td>Price</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 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 & 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**
Follow AASHTO T103 Standard Method of Test for Soundness of Aggregates by Freezing and Thawing, procedure B, with the following modifications:

3.1.6 Temperature measuring equipment shall consist of thermometers, resistance thermometers, or thermocouples, capable of measuring the temperature at various points within the testing chamber and at the centers of each sample container. The thermometers, resistance thermometers, or thermocouples shall have an approximate range from -26 to 50 C (-15 to 120 F), readable and accurate to 1.0 C. Data storage devices shall be capable of sampling temperature measurements every ten minutes for the duration of the test.

4.2 Coarse aggregate for the test shall consist of plus 4.75 mm (No.4) sieve size material. For WisDOT source approval, sample stockpiles with 100 percent passing the 1-1/2 inch sieve.

6 Use procedure B with methyl alcohol.

6.1.2 Each sample fraction container shall be placed in the freeze apparatus. Samples shall be covered and placed a minimum of 6 inches above the base of the apparatus and shall have a minimum of 1 inch clear space around the entire sample (shelf not included). The sample shall be cooled until the temperature at the center of the sample reaches -23 +/- 3 C (-9 +/- 5 F). A minimum of one temperature probe per freezer shall be placed in the center of a sample while freezing and thawing. A minimum of one fan shall circulate air within the freezer during each freezing cycle. A thermometer or thermocouple shall be suspended in the center of the freezer (in air). The air temperature in the freezer shall not decrease below -28 C (-18 F). Air surrounding the specimen while thawing shall not increase above 30 C (85 F). The temperature at the center of the sample shall be held constant at the low temperature for a minimum of 2 hours before the start of the thaw cycle. Upon completion of a freeze cycle, the temperature at the center of the sample shall be raised to 21 +/- 3 C (70 +/- 5 F) and shall be held at the constant thawed temperature for a minimum of 30 min. The air temperature surrounding the specimen during thawing shall not exceed 24 C (75 F).

6.2.1 In this procedure, the samples shall be placed in a vacuum chamber and saturated by subjecting them to an air pressure of not over 3.4 kPa (25.4 mm of mercury) and breaking the vacuum with a sufficient amount of 0.5 percent (by mass) solution of methyl alcohol in water to completely cover the samples. The samples shall be left in the solution for 15 minutes.

7.1 Alternate freezing and thawing shall be repeated until the required number of cycles is obtained. One test cycle consists of one freeze cycle and one thaw cycle. Repeat the procedure of alternate freezing and thawing for 16 cycles. One complete cycle shall not exceed 24 hours. If the test is interrupted, the sample shall remain covered in a thawed state until testing is resumed. The sample shall remain partially immersed during the test.

Delete paragraph 2.

**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
- \( W_d \) = Dry weight of aggregates
- \( W_w \) = 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
860.5.1 Sample Size Requirements
860.5.1.1 General
The minimum weight of the field sample depends on the nominal maximum particle size of the aggregate that is to be sampled. The weight of the field sample will always be greater than that portion required for testing and must meet the requirements of table 860-2.

<table>
<thead>
<tr>
<th>TABLE 860-2 Size of Samples</th>
</tr>
</thead>
</table>
### Nominal Maximum Sizes Based on the AASHTO Definition

<table>
<thead>
<tr>
<th>Nominal Maximum Size of Particles Passing Sieve</th>
<th>Minimum Weight of Field Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine Aggregate</td>
<td>kg</td>
</tr>
<tr>
<td>No. 10 (2.0 mm)</td>
<td>5</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>5</td>
</tr>
<tr>
<td>Coarse Aggregate</td>
<td>kg</td>
</tr>
<tr>
<td>3/8 in. (9.5 mm)</td>
<td>5</td>
</tr>
<tr>
<td>1/2 in. (12.5 mm)</td>
<td>10</td>
</tr>
<tr>
<td>3/4 in. (19.0 mm)</td>
<td>15</td>
</tr>
<tr>
<td>1 in. (25.0 mm)</td>
<td>25</td>
</tr>
<tr>
<td>1 1/4 in. (31.75 mm)</td>
<td>25</td>
</tr>
<tr>
<td>1 1/2 in. (37.5 mm)</td>
<td>30</td>
</tr>
<tr>
<td>2 in. (50 mm)</td>
<td>40</td>
</tr>
<tr>
<td>2 1/2 in (62.5 mm)</td>
<td>45</td>
</tr>
<tr>
<td>Larger than 2 1/2 in</td>
<td>115</td>
</tr>
</tbody>
</table>

Refer to 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).
### Sampling from a Conveyor Belt

860.5.2 Sampling from a Conveyor Belt

After normal flow has been established, randomly obtain at least three approximately equal increments from the unit being sampled and combine to form a field sample of the required size. Stop the conveyor belt while the sample increments are being obtained. Separate the increments at their ends and collect all the material, including the fines, and place in a container. If the angle of the conveyor belt is such that the aggregates roll, place templates, with forms fitting the configuration of the conveyor belt, through the increments at their ends before collecting the material.

860.5.3 Sampling from a Conveyor Belt Discharge

Randomly select units to be sampled from production after normal flow has been established. Obtain at least three approximately equal increments from the unit being sampled and combine to form a field sample. Take each increment from the entire cross-section of the material as it is being discharged.

### Sampling from Stockpiles

860.5.4.1 Alternate 1

Obtain increment samples from each quarter point of the working face of the stockpile. The working face is the face of the pile from which the aggregate is being removed. Obtain each quarter point sample by cutting deep into the face of the pile with an end loader or other similar power equipment. Dump each quarter point sample in a separate pile, level the pile and take at least three shovels full to form one increment. The total sample will consist of three increments, one increment from each quarter point sample.

860.5.4.2 Alternate 2

Obtain increments with a square nosed shovel from quarter points of the pile perimeter at both 1/3 and 2/3 levels of slope length from bottom to top. Increments must be obtained by holding a protective barrier above the sampling location to prevent aggregate slide, and discarding 10 - 12 inches of surface aggregate. Total sample = 8 increments.

### Sampling from Roadbed Windrows

A windrow to be considered for sampling should be uniform in cross-section and well mixed. A slightly moist condition of the aggregate is desirable both for mixing and sampling purposes. When the contract is in English units, a 100-foot unit should be selected to represent the area to be evaluated. If the above units cannot be selected, then another length may be selected and so noted in the project records. Obtain at least

### Table: Nominal Maximum Sizes and Remarks

<table>
<thead>
<tr>
<th>Material</th>
<th>Nominal Maximum Size</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense Graded Base, 3-inch</td>
<td>3-inch (75 mm)</td>
<td></td>
</tr>
<tr>
<td>Dense Graded Base, 1 1/4-inch</td>
<td>1 1/4-inch (32 mm)</td>
<td></td>
</tr>
<tr>
<td>Dense Graded Base, 3/4-inch</td>
<td>3/4-inch (19 mm)</td>
<td></td>
</tr>
<tr>
<td>Open Graded Base</td>
<td>1-inch (25 mm)</td>
<td></td>
</tr>
<tr>
<td>Breaker run</td>
<td>6-inch (150 mm)</td>
<td>When testing is required</td>
</tr>
<tr>
<td>Select Crushed</td>
<td>5-inch (125 mm)</td>
<td>When testing is required</td>
</tr>
<tr>
<td>Concrete Aggregate - Size #2</td>
<td>1 1/2-inch (37.5 mm)</td>
<td></td>
</tr>
<tr>
<td>Concrete Aggregate - Size #1</td>
<td>3/4-inch (19 mm)</td>
<td></td>
</tr>
<tr>
<td>Concrete Aggregate - fine</td>
<td>No. 4 (4.75 mm)</td>
<td></td>
</tr>
<tr>
<td>Granular Backfill (GBF), Trench</td>
<td>Varies</td>
<td>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.</td>
</tr>
<tr>
<td>Granular Backfill, Bedding</td>
<td>1-inch, may vary</td>
<td>See note above for GBF-trench</td>
</tr>
<tr>
<td>Structural Backfill</td>
<td>Up to 3-inch, may vary</td>
<td>See note above for GBF-trench</td>
</tr>
</tbody>
</table>
three random samples of approximately equal size within the unit selected. Before obtaining the sample increments, the outside surface of the windrow should be removed at each selected location.

860.5.6 Sampling After Being Placed on Roadbed
A visual inspection for uniformity of the area to be sampled should be made after the material has been mixed and laid out. Lack of uniformity should be corrected before proceeding with the sampling. Obtain at least three approximately equal increments, selected at random, from the unit being sampled. A 100-foot unit should be selected to represent the area to be evaluated. If the above units cannot be selected, then another length may be selected and so noted in the project records. Take increments for the depth of the material under consideration, being careful not to contaminate the sample with any underlying material. A square nose shovel must be used to obtain each sample increment. Care should be taken not to cause degradation of the aggregate during the sampling process. Care should also be taken to keep the sides as vertical as possible during the excavation.

860.5.7 Sampling from Concrete Plant Holding Bins
With a minimum of one full truckload above the grate or floor and no material being drawn from the feeding bin, if applicable, the material should be blended using an end loader or other similar power equipment. The bottom material should be lifted to the top several times. The material must be leveled to create a sampling surface. Obtain at least five shovels full at the center and the quarter points of the diagonals.

860.5.8 Sampling Asphalt Aggregates from Hot Bins
When the roadway site is remote from the plant site and when truck box sampling is undesirable, the engineer may elect to require plant adjustments and determination of contractor compliance with the specifications to be based on hot bin samples, unless correlation tests indicate significant differences between hot bin and extracted gradations.

Some plants are designed so that the entire flow of aggregate from any bin may be diverted into a sampling container. Other plants are designed to permit a sampling pan to be placed in the flow of aggregates as the flow drops from the hot bin into the weigh hopper. In the latter case, only a partial cross-section of the flow may be included in the sample.

In instances where representative samples cannot be obtained by the above methods, a dry batch of aggregate can be dumped from each bin through the pug mill into a container and a representative sample secured from the container. This sample should be a composite of a number of sampling increments uniformly spaced around and throughout the depth of the dry batch.

Samples of combined aggregates may be obtained by proportioning the aggregate into the pug mill; dry mixing; discharging into the truck box, end loader bucket, or other container of sufficient capacity; and securing a sample as described above.

860.5.9 Sampling from a Truck
860.5.9.1 Alternate 1
With the box elevated, open the gate about 6 - 10 inches. With a suitable sample box:
- Obtain the first increment from the discharge near one side of the gate and representing first part of discharge.
- Obtain the second increment from the discharge near the middle of the gate and representing approximately the middle of the total discharge.
- Obtain the third increment from the discharge near the other side of the gate and representing the last part of the total load.

860.5.9.2 Alternate 2
With the entire load discharged on the ground from a moving truck to form an elongated pile, level the top and obtain at least three increments from distributed points.

860.5.10 Sampling when Using a Clam Shovel
When aggregate is transferred from a stockpile to the proportioning bins with a clam shovel or bucket, dump a selected clam full on the ground, level the top and obtain at least three increments from distributed points.

860.6 Reducing Samples of Aggregate to Test Size
860.6.1 General
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.
This section contains an overview of AASHTO T248 - Reducing Samples of Aggregate to Testing Size. Refer to AASHTO T248 for complete instructions for these procedures. 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 Methods for Reducing Field Sample Size**

**860.6.2.1 General**

Different sizes and types of aggregate will require different size samples for the various tests. The field sample should be reduced to the size needed for a specific test by either using a riffle splitter, quartering method or miniature stockpile method for damp fine aggregate only. 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.

**860.6.2.2 Use of the Riffle Splitter**

When reducing the size of the field sample with the aid of a riffle splitter, the material must be fed evenly, at a uniform rate, and flow smoothly without restriction or loss of material through the splitter chutes. To accomplish these objectives, the splitter is supplied with a hopper and two straight edged pans or three straight edged pans, which may, at any one time, be used to feed the sample into the splitter or receive the material during the splitting operation. The splitter must have an even number of equal width chutes, but not less than a total of eight for coarse aggregate or 12 for fine aggregate, which discharge alternately to each side of the splitter. Splitter chute opening requirements are given in table 860-4 below.

<table>
<thead>
<tr>
<th>TABLE 860-4  Splitter Chute Opening Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Aggregate</td>
</tr>
<tr>
<td>Coarse aggregates and mixed aggregate</td>
</tr>
<tr>
<td>Dry fine aggregate that entire sample will pass the 3/8 in. sieve</td>
</tr>
</tbody>
</table>

Place the field sample in the hopper or one of the flat edged pans and uniformly distribute it from edge to edge from the hopper or straight-edged pan, which has a width equal to or slightly smaller than the overall width of the assembly of chutes. When introduced into the chutes, approximately equal amounts should flow through each chute. The rate at which the material is introduced should be such as to allow free flowing through the chutes to the receptacles below without clogging the chutes. Set aside the material not to be split further and continue the above process until the test sample size specified is reached.

The riffle splitter should not be used for fine aggregates that are wetter than saturated surface dry (SSD). Fine aggregates that are in a free moisture condition (damp) should be split using the quartering method or miniature stockpile method.

**860.6.2.3 Quartering Procedure**

Distribute the aggregate as uniformly as possible over a wide flat area on a tight-weave canvas, clean metal surface, or other clean smooth surface. Continue to distribute the material in layers until the entire sample is used to make a flat pile that is reasonably uniform in thickness and in distribution of aggregate sizes. Mix the pile thoroughly by turning over the entire lot three times with a flat-end shovel or trowel and redistribute into the flattened pile of uniform thickness and diameter. Divide the pile cleanly into equal quarters with a shovel, trowel, or other appropriate tool. Completely remove two opposite quarters and set aside. Repeat the foregoing procedure with the remaining portion until the test sample size specified is reached.

**860.6.2.4 Miniature Stockpile Method - Damp Fine Aggregate Only**

The sample must be distributed and mixed in the same manner as in the quartering procedure. The sample may be left in a conical pile or flattened to a uniform thickness by pressing the apex with a shovel or trowel. Obtain the required sample portion by selecting at least five increments of material at random locations from the miniature stockpile with a sampling thief, small scoop, or spoon.
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 & 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 equi-dimensional 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 & elongated aggregate particles have reduced strength when load is applied to the flat side of the particle. Flat & 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 & 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 & elongated particles decrease mix workability and, if more water is used to maintain workability, the strength of the concrete is also reduced. Flat & 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 & elongated particles used in HMA tend to increase mixture voids and affect compactibility. Flat & 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 & 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 106.3.4.2.1 and standard spec 604.2.

860.7.2 Fractured Particles by WisDOT-Modified ASTM D5821

See ASTM D5821.

860.7.2.1 General

The purpose for specifying fractured face criteria is to maximize sheer 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.

860.7.2.2 Scope

This test method determines the percentage of a coarse aggregate sample that consists of fractured particles meeting the specified requirements. The percent of fracture particles is the count of fractured particles expressed as a percentage of the total count of particles in the sample.

860.7.2.3 Definitions

A fracture face is an angular, rough, or broken surface of an aggregate particle created by a mechanical crusher, or by nature. A face will be considered fractured only if it has a projected area at least as large as one quarter of the maximum projected area (maximum cross-sectional area) of the particle and the face has sharp and well defined edges. This excludes small nicks.
A fractured particle is an aggregate particle with at least the minimum number of fractured faces specified.

860.7.2.4 Procedure
1. Sample the aggregate and determine sample size according to the "Sampling Aggregates" section of this procedure. Reduce the sample to the lab sample according to the "Reducing Samples of Aggregate to test Size" section of this procedure.
2. Remove the material passing the No. 4 sieve. Aggregate particles retained on the No. 4 sieve from a washed sieve analysis can be used.
3. Further reduce the No. 4 retained material sample according to the "Reducing Samples of Aggregate to test Size" section of this procedure until 400 or more individual aggregate particles remain.
4. Spread the dried test sample on a clean flat surface large enough to permit careful inspection of each particle. To verify that a particle meets the fracture criteria, hold the aggregate particle so that the face is viewed directly. If the face constitutes at least one quarter of the maximum cross-sectional area of the rock particle, consider it a fractured face.
5. Separate the sampled particles into categories based on whether a particle:
   - Has the required number of fractured faces.
   - Does not meet the specified fracture criteria.
   - Has a questionable or borderline face.
6. Following the division of all sampled particles into the categories, determine the count of particles in the fractured category, the count of particles in the questionable category, and the count of particles not meeting the specified fracture criteria.
7. Calculate and report the percentage of particles, by count, found to have the specified numbers of fractured faces to the nearest 1% in accordance with the following:

\[
P = \left( \frac{F + \left( \frac{Q}{2} \right)}{(F + Q + N)} \right) \times 100 \quad \text{and} \quad TS = F + Q + N
\]

Where:
- \( P \) = Percentage of particles with the specified number of fractured faces
- \( F \) = Count of particles with at least the specified number of fractured faces
- \( Q \) = Count of particles in the questionable or borderline category
- \( N \) = Count of particles in the uncrushed category not meeting the fractured particle criteria
- \( TS \) = Total sample particle count

If more than one number of fractured faces is specified (for example, 70% with one or more fractured faces and 40% with two or more fractured faces), repeat the procedure to identify the particles that have two fractured faces or questionable two-faced fractures, and perform the calculation for each requirement.
8. Report the specific fracture criteria against that which the sample was evaluated.
9. Report the total count of the coarse aggregate sample tested.

Methods for measuring flat and elongated particles are mobilized into the contract by standard spec 501.2.5.

860.7.3 Flat & Elongated Particles

860.7.3.1 General
The purpose for specifying a limit on the percent of coarse aggregate particles that are flat & elongated is to minimize the effect that these particles may have on the construction process and finished product. ASTM D4791 describes three specifically different comparisons of the length, width, and thickness in determining if the particle is flat, elongated, or flat & 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 & elongated particles (the ratio of the length dimension compared to the thickness dimension according to ASTM D4791 definitions).

860.7.3.2 Scope
This test method determines the percentage of a coarse aggregate sample that consists of particles considered to be flat & elongated as defined in ASTM D4791. The percentage of flat & elongated is to be based on the
weight of flat & elongated particles compared to the total weight of test sample. This test may be performed with the same sample used in determining fractured particles when both tests are required.

860.7.3.3 Definitions
- Flat or elongated particles of aggregate are particles that have a ratio of width to thickness or length to width greater than the specified value.
- Flat & elongated particles of aggregate are particles having a ratio of length to thickness greater than the specified value.
- Length is the maximum dimension of the particle.
- Width is the maximum dimension of the particle in the plane perpendicular to the length.
- Thickness is the maximum dimension of the particle in the plane perpendicular to the length and width.

860.7.3.4 Procedure
The following test procedure describes the method to be used in determining the percent of flat & elongated particles in a sample of coarse aggregate for which limits are defined in the specifications for that material. For HMA aggregate when the sample to be tested is the same sample used in determining the percentage of fractured particles in coarse aggregate previously described, begin the following procedure at step number 4. Currently only aggregates used in HMA mixtures have specification requirements for fractured particles and limits for flat & elongated particles.

1. Sample the aggregate and determine sample size according to the "Sampling Aggregates" section of this procedure. Reduce the sample to the lab sample according to the "Reducing Samples of Aggregate to test Size" section of this procedure.
2. Remove the material passing the No. 4 sieve for CABC and HMA aggregate or material passing the 3/8" sieve for PCC aggregate. Aggregate particles retained on the No. 4 sieve for CABC and HMA aggregate or 3/8" sieve for PCC aggregate from a washed sieve analysis can be used.
3. Further reduce the No. 4 retained material sample according to the "Reducing Samples of Aggregate to test Size" section of this procedure until 400 or more individual aggregate particles remain.
4. Spread the dried test sample on a clean flat surface large enough to permit careful inspection of each particle. Obtain the total dry weight of the test sample and record that weight.
5. Using a proportional caliber suitable for this test method to determine which particles in the test sample are flat & elongated as specified for the material being tested and which particles are not flat & elongated (ASTM D4791, see figures 1, 2, or 3 for examples of proportional calibers suitable for this test and follow the instructions for the type of proportional caliper that is used).
6. Following the division of all sampled particles into the categories of flat & elongated and not flat & elongated, determine the weight of particles in each category. Verify that the total of both these weights matches the total weight of the test sample determined in step 4 to ensure that no loss of particles have occurred during the testing process.
7. Calculate and report the percentage of particles, by weight, found to exceed the specified ratio for flat & elongated particles to the nearest 1% in accordance with the following:

\[
P = \left( \frac{FE}{FE + NFE} \right) \times 100 \quad \text{and} \quad TS = FE + NFE
\]

Where:
- \(P\) = percentage of particles considered to be flat & elongated
- \(FE\) = Weight of flat & elongated particles
- \(NFE\) = Weight of particles not flat & elongated
- \(TS\) = Weight of total test sample.
8. Report the specific ratio of length to thickness criteria against which the sample was evaluated and the specified limit for flat & elongated particles for the type of material tested.
9. Report the total weight of the coarse aggregate sample tested.

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 (230º 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 = 867 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 that follows provides guidance on the maximum allowable weight on sieves (sieve overloading). 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 860-5 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 permit vigorous agitation without inadvertent loss of any part of the sample of water is required. The containers should be kept clean.

### TABLE 860-5 Allowable Loadings on Sieves

<table>
<thead>
<tr>
<th>Sieve size</th>
<th>12 &quot; dia.</th>
<th>8 &quot; dia.</th>
<th>Gilson large</th>
<th>Gilson small</th>
<th>12&quot;x12&quot;</th>
<th>Rocker Box</th>
</tr>
</thead>
<tbody>
<tr>
<td>2&quot; (50 mm)</td>
<td>20# (9,125g)</td>
<td>8.9# (4,050g)</td>
<td>60# (27,061g)</td>
<td>35# (15,806g)</td>
<td>25# (11,613g)</td>
<td>20# (8,891g)</td>
</tr>
<tr>
<td>1 1/2&quot; (37.5 mm)</td>
<td>15# (6,844g)</td>
<td>6.6# (3,038g)</td>
<td>45# (20,296g)</td>
<td>26# (11,855g)</td>
<td>19# (8,710g)</td>
<td>15# (6,668g)</td>
</tr>
<tr>
<td>1 1/4&quot; (31.75 mm)</td>
<td>11.7# (5318g)</td>
<td>5.0# (2,262g)</td>
<td>37.8# (17,129g)</td>
<td>21.4# (9,723g)</td>
<td>16.3# (7,374g)</td>
<td>12.4# (5,636g)</td>
</tr>
<tr>
<td>1&quot; (25.0 mm)</td>
<td>10# (4,563g)</td>
<td>4.5# (2,025g)</td>
<td>30# (13,531g)</td>
<td>17# (7,903g)</td>
<td>13# (5,806g)</td>
<td>10# (4,446g)</td>
</tr>
<tr>
<td>3/4&quot; (19.0 mm)</td>
<td>7.6# (3,468g)</td>
<td>3.4# (1,539g)</td>
<td>22# (10,283g)</td>
<td>13# (6,006g)</td>
<td>9.7# (4,413g)</td>
<td>7.5# (3,379g)</td>
</tr>
<tr>
<td>1/2&quot; (12.5 mm)</td>
<td>5.0# (2,281g)</td>
<td>2.2# (1,013g)</td>
<td>15# (6,765g)</td>
<td>8.7# (3,952g)</td>
<td>6.4# (2,903g)</td>
<td>4.9# (2,223g)</td>
</tr>
<tr>
<td>3/8&quot; (9.5 mm)</td>
<td>3.8# (1,734g)</td>
<td>1.7# (770g)</td>
<td>11# (5,142g)</td>
<td>6.6# (3,003g)</td>
<td>4.9# (2,206g)</td>
<td>3.7# (1,689g)</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>1.9# (867g)</td>
<td>0.8# (385g)</td>
<td>5.7# (2,570g)</td>
<td>3.3# (1,502g)</td>
<td>2.4# (1,103g)</td>
<td>1.9# (845g)</td>
</tr>
</tbody>
</table>

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 permit 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 by the use of a riffle splitter, quartering method, or miniature stockpile method for damp fine aggregate only. See table 860-1 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 the use of 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 860-6.

### TABLE 860-6 Minimum Sample Weights for Aggregates
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 860-7.

### TABLE 860-7 Minimum Sample Weights for P200 Test

<table>
<thead>
<tr>
<th>Nominal Maximum Size of Particles</th>
<th>Minimum Weight of Sample, g</th>
<th>Minimum Weight of Sample, lb.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot; - 1&quot; (19.0 -25mm)</td>
<td>2,500</td>
<td>5.5</td>
</tr>
<tr>
<td>1-1/2&quot; (37.5 mm) or over</td>
<td>5,000</td>
<td>11</td>
</tr>
</tbody>
</table>

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.

   The use of a large spoon to stir and agitate the aggregate in the wash water has been found most satisfactory. 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:
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 set forth 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 to be rounded off to the nearest whole percent except for the percent passing the No. 200 sieve, which is to be 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. Download department form DT1348, Sieve analysis for Mixture of Fine and Coarse Aggregates.

DT1348 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 to be 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)

<table>
<thead>
<tr>
<th>Sieve</th>
<th>(g)</th>
<th>Weight % Ret.</th>
<th>% Pass. (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&quot; (25.0 mm)</td>
<td>0</td>
<td>0</td>
<td>100.0</td>
</tr>
<tr>
<td>3.8&quot; (9.5 mm)</td>
<td>1,318</td>
<td>44.7</td>
<td>55.3</td>
</tr>
<tr>
<td>#4 (4.75 mm)</td>
<td>2,776</td>
<td>94.1</td>
<td>5.9</td>
</tr>
<tr>
<td>#10 (2.00 mm)</td>
<td>2,871</td>
<td>97.3</td>
<td>2.7</td>
</tr>
<tr>
<td>#40 (425 µm)</td>
<td>2,873</td>
<td>97.4</td>
<td>2.6</td>
</tr>
<tr>
<td>#200 (75 µm)</td>
<td>2,887</td>
<td>97.8</td>
<td>2.2</td>
</tr>
</tbody>
</table>

### SIEVE ANALYSIS OF WASHED P- No. 4 FRACTION
(Total weight of reduced size sample = 521 g.)

<table>
<thead>
<tr>
<th>Sieve</th>
<th>(g)</th>
<th>Weight % Ret.</th>
<th>% Pass. (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#4 (4.75 mm)</td>
<td>0</td>
<td>0</td>
<td>100.0</td>
</tr>
<tr>
<td>#10 (2.00 mm)</td>
<td>113</td>
<td>21.7</td>
<td>78.3</td>
</tr>
<tr>
<td>#40 (425 µm)</td>
<td>386</td>
<td>74.1</td>
<td>25.9</td>
</tr>
<tr>
<td>#200 (75 µm)</td>
<td>443</td>
<td>85.0</td>
<td>15.0</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Sieve</th>
<th>(g)</th>
<th>Weight % Ret.</th>
<th>% Pass. (D)</th>
<th>Values Reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 (25 mm)</td>
<td>(0.583 x 100) + (0.417 x 100) = 58.3 + 41.7 = 100.0</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/8&quot; (9.5 mm)</td>
<td>(0.583 x 55.3) + (0.417 x 100) = 32.2 + 41.7 = 73.9</td>
<td>74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#4 (4.75 mm)</td>
<td>(0.583 x 5.9) + (0.417 x 100) = 3.4 + 41.7 = 45.1</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#10 (2.00 mm)</td>
<td>(0.583 x 2.7) + (0.417 x 78.3) = 1.6 + 32.7 = 34.3</td>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#40 (425 µm)</td>
<td>(0.583 x 2.6) + (0.417 x 25.9) = 1.5 + 10.8 = 12.3</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#200 (75 µm)</td>
<td>(0.583 x 2.2) + (0.417 x 15.0) = 1.3 + 6.3 = 7.6</td>
<td>7.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
860.9.4 Procedure for Granular and Structural Backfill and Subbase

1. The sample size must meet the minimum requirements of table 860-2 (field sample) and table 860-6 (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

<table>
<thead>
<tr>
<th>Weight of total unwashed sample</th>
<th>26,890g (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of R-4.75 mm (No. 4) fraction of total sample</td>
<td>4,567g</td>
</tr>
<tr>
<td>R-4.75 mm (No. 4) fraction (proportion of total sample)</td>
<td>4567g / 26890g = 0.17g</td>
</tr>
<tr>
<td>Weight of P-4.75 mm (No. 4) fraction of total sample</td>
<td>2,113g</td>
</tr>
<tr>
<td>P-4.75 mm (No. 4) fraction (proportion of total sample)</td>
<td>22323g / 26890g = 0.83g</td>
</tr>
<tr>
<td>Weight of reduced size unwashed P-No.4 sample</td>
<td>600g</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sieve</th>
<th>(g) [B]</th>
<th>Weight % Ret. (B/A*100)</th>
<th>% Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>6” (150 mm)</td>
<td>0</td>
<td>0</td>
<td>100.0</td>
</tr>
<tr>
<td>3” (75.0 mm)</td>
<td>3000</td>
<td>11.2</td>
<td>88.8</td>
</tr>
<tr>
<td>1” (25.0 mm)</td>
<td>3900</td>
<td>14.5</td>
<td>85.5</td>
</tr>
<tr>
<td>3/4” (19 mm)</td>
<td>4325</td>
<td>16.1</td>
<td>83.9</td>
</tr>
<tr>
<td>3/8” (9.5 mm)</td>
<td>4421</td>
<td>16.4</td>
<td>83.6</td>
</tr>
<tr>
<td>#4 (4.75 mm)</td>
<td>4567</td>
<td>17.0</td>
<td>83.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weight of total unwashed sample</th>
<th>26,890g (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of R-4.75 mm (No. 4) fraction of total sample</td>
<td>4,567g</td>
</tr>
<tr>
<td>R-4.75 mm (No. 4) fraction (proportion of total sample)</td>
<td>4567g / 26890g = 0.17g</td>
</tr>
<tr>
<td>Weight of P-4.75 mm (No. 4) fraction of total sample</td>
<td>2,113g</td>
</tr>
<tr>
<td>P-4.75 mm (No. 4) fraction (proportion of total sample)</td>
<td>22323g / 26890g = 0.83g</td>
</tr>
<tr>
<td>Weight of reduced size unwashed P-No.4 sample</td>
<td>600g</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sieve</th>
<th>(g) [B]</th>
<th>Weight % Ret. (B/A*100)</th>
<th>% Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>6” (150 mm)</td>
<td>0</td>
<td>0</td>
<td>100.0</td>
</tr>
<tr>
<td>3” (75.0 mm)</td>
<td>3000</td>
<td>11.2</td>
<td>88.8</td>
</tr>
<tr>
<td>1” (25.0 mm)</td>
<td>3900</td>
<td>14.5</td>
<td>85.5</td>
</tr>
<tr>
<td>3/4” (19 mm)</td>
<td>4325</td>
<td>16.1</td>
<td>83.9</td>
</tr>
<tr>
<td>3/8” (9.5 mm)</td>
<td>4421</td>
<td>16.4</td>
<td>83.6</td>
</tr>
<tr>
<td>#4 (4.75 mm)</td>
<td>4567</td>
<td>17.0</td>
<td>83.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sieve</th>
<th>(g) [D]</th>
<th>Weight % Ret.[D/C*100]</th>
<th>% Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>#4 (4.75 mm)</td>
<td>0</td>
<td>0</td>
<td>100.0</td>
</tr>
<tr>
<td>#40 (425 µm)</td>
<td>155</td>
<td>25.8</td>
<td>74.2</td>
</tr>
<tr>
<td>#100 (150 µm)</td>
<td>530</td>
<td>88.3</td>
<td>11.7</td>
</tr>
<tr>
<td>#200 (75 µm)</td>
<td>561</td>
<td>93.5</td>
<td>6.5</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Type of Material:</th>
<th>Granular Backfill</th>
<th>Structural Backfill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradation:</td>
<td>Grade 1</td>
<td>Grade 2</td>
</tr>
<tr>
<td>Special Provision:</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Type of Use:</td>
<td>Trench Backfill</td>
<td>Beeding</td>
</tr>
</tbody>
</table>

Field Determination of Percent of Fractured Particles:
- Number of Fractured Particles:
- Number of Unfractured Particles:
- % Fractured:
- Specification Requirement: % %

Moisture Content:
- Weight of Sample (Moist) (Grams) = 5624
- Weight of Sample (Dry) (Grams) = 5238

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

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 860-1 (field sample) and table 860-6 (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 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.

4. The portion passing the No. 4 sieve must be reduced by use of the riffle splitter or quartering procedures to a sample weighing approximately 1 lb. (500g).

5. The test sample of the material passing the No. 4 sieve must be weighed, washed, dried, cooled and sieved.

6. 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

<table>
<thead>
<tr>
<th>217 Men</th>
<th>Gradation</th>
<th>217D - 2004 Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Material:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural Backfill</td>
<td>Dense Graded Base</td>
<td>Open Graded Base</td>
</tr>
<tr>
<td>Gradation:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 inch</td>
<td>1 34 inch</td>
<td>5 8 inch</td>
</tr>
<tr>
<td>Weight of Sample (Dry) (Gram):</td>
<td>5530</td>
<td></td>
</tr>
<tr>
<td>Weight of R4 - No 4 Unwrapped (Grams):</td>
<td>2000</td>
<td>20.0% R4 Factor</td>
</tr>
<tr>
<td>Weight of R4 - No 4 Unwrapped (Grams):</td>
<td>12000</td>
<td>78.1% R4 Factor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Material</th>
<th>Percent Passing</th>
<th>Percent Passing %</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.0 (P)</td>
<td>0</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>12.5 (P)</td>
<td>0</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>10.0 (P)</td>
<td>0</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>7.0 (P)</td>
<td>0</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>5.0 (P)</td>
<td>0</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>3.3 (T)</td>
<td>0</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>2.0 (T)</td>
<td>0</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>1.18 (T)</td>
<td>0</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>0.80 (P00)</td>
<td>0</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>0.635 (P00)</td>
<td>0.0%</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>0.50 (P00)</td>
<td>0.0%</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>0.150 (P00)</td>
<td>0.0%</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Pan</td>
<td>0.0%</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

860.9.6 Unwashed Sieve Analysis

860.9.6.1 General

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.

860.9.6.2 Aggregates for Portland Cement Concrete

If for either the fine or coarse concrete aggregate the test results of several washed sieve analyses indicate that the percent passing the No. 200 sieve of the total sample is in the lower half of the specification range and that the results are not marginal on any sieve, testing may be done by unwashed sieve analysis. When use is continuous, the reliability of the dry sieving procedure and test results should be checked by testing about every tenth sample by performing an unwashed and subsequent washed sieve analysis on the same field sample, and comparing the test results of the washed and unwashed sieve analyses. When use is not continuous and is for incidental construction, the frequency of the comparison checks must be such that the project records will be properly documented with comparison checks between washed and unwashed sieve analyses made on the aggregates being incorporated into the work.
If at any time the test results or either washed or unwashed sieve analyses are marginal or the material passing the No. 200 sieve is in the upper half of the specification range, it will be necessary to perform washed sieve analyses until tests again meet the criteria for testing by dry sieve analysis. Figure 860-1 provides an example of Form DT1348 for washed sieve analysis.

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

<table>
<thead>
<tr>
<th>MOISTURE CONTENT</th>
<th>Weight of Total Sample (dry, unwashed)</th>
<th>Weight of R4.75 mm (No. 4) dry, unwashed</th>
<th>Weight of P4.75 mm (No. 4) dry, unwashed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of Sample (moist)</td>
<td>5700.0 g</td>
<td>2451 g</td>
<td>213 g</td>
</tr>
<tr>
<td>Weight of Sample (dry)</td>
<td>5264 g</td>
<td>0.583</td>
<td>0.417</td>
</tr>
<tr>
<td>% Moisture</td>
<td>2.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>R-4.75 mm (R-4) MATERIAL</th>
<th>P-4.75 mm (P-4) MATERIAL</th>
<th>TOTAL MATERIALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washed: □ Yes □ No</td>
<td>Washed: □ Yes □ No</td>
<td>( % Passing )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sieve</th>
<th>Weight Retained</th>
<th>% Retained</th>
<th>% Pass (C)</th>
<th>Weight Retained</th>
<th>% Retained</th>
<th>% Pass (D)</th>
<th>4.75 mm (R-4) (A)(C)</th>
<th>4.75 mm (P-4) (B)(D)</th>
<th>Dry Sieved</th>
<th>Corr. Factor</th>
<th>Corr. Dr. Washed Results</th>
<th>Spec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5mm (1.18&quot;)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 mm (1&quot;)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 mm (3/4&quot;)</td>
<td>452</td>
<td>15.3</td>
<td>84.7</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>100</td>
<td>49.3</td>
<td>41.7</td>
<td>910</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.5 mm (3/8&quot;)</td>
<td>131.6</td>
<td>44.7</td>
<td>55.3</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>100</td>
<td>32.2</td>
<td>41.7</td>
<td>789</td>
<td>40-75</td>
<td></td>
</tr>
<tr>
<td>4.75 mm (No. 4)</td>
<td>2776</td>
<td>94.1</td>
<td>5.9</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>100</td>
<td>3.4</td>
<td>41.7</td>
<td>45.1</td>
<td>25-60</td>
<td></td>
</tr>
<tr>
<td>2 mm (No. 10)</td>
<td>2871</td>
<td>97.3</td>
<td>2.7</td>
<td>113</td>
<td>21.7</td>
<td>78.3</td>
<td>1.6</td>
<td>32.7</td>
<td>39.3</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>425 µm (No. 40)</td>
<td>2873</td>
<td>97.4</td>
<td>2.6</td>
<td>386</td>
<td>74.1</td>
<td>25.9</td>
<td>1.5</td>
<td>10.8</td>
<td>12.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75 µm (No. 200)</td>
<td>2887</td>
<td>97.8</td>
<td>2.2</td>
<td>443</td>
<td>85.0</td>
<td>15.0</td>
<td>1.3</td>
<td>6.3</td>
<td>7.6</td>
<td>8-12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In Pan</td>
<td>16</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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 is to be in accordance with the Materials Testing and Acceptance Guide. Reporting should be done in accordance with the requirements listed in 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.
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 the use of unsatisfactory 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.
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 the use of 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 the use of 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 the use of 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 satisfactory, 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 satisfactory.
- 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.


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 permits, 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 permit 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 table:

      | 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 percent gravel content: Weight of 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

   \[
   \text{Percent Compaction} = \frac{\text{Field density}}{\text{Corrected standard density}} \times 100
   \]

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:

   \[
   \text{Moisture, } \% = \frac{\text{Wetweight - dry weight}}{\text{Dry weight}} \times 100
   \]

5. Dry weight of soil sample from hole

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

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

   \[
   \% = \frac{\text{Field density}}{\text{Corrected standard density}} \times 100
   \]
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

   \[
   \text{Moisture, \%} = \frac{\text{Wetweight - dry weight}}{\text{Dry weight}} \times 100
   \]

5. Dry weight of soil sample from hole:

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

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:

   \[
   \% = \frac{\text{Field density}}{\text{Corrected standard density}} \times 100
   \]

860.13.6 Laboratory Standard Density Correction for Variation in Gravel Content

These instructions pertain to the use of 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.