Inspection & Sampling Procedures for Fine & Coarse Aggregates

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1 Testing Equipment

Laboratory

General
Sampling
Sample Reduction
Sieve Analysis
Decantation
Deleterious and Chert

Test Equipment Verification

Laboratory Set-Up

1 CHAPTER ONE:
TESTING EQUIPMENT

The following equipment and supplies are deemed necessary to properly perform the various required tests for aggregate inspection. The technician will have on hand, or have access to sufficient quantities of these supplies or equipment before attempting to conduct tests.

LABORATORY

General

Equipment required for various general procedures:

1) Electronic balance, Class G2, general purpose balance in accordance with AASHTO M 231. The balance shall be readable to 0.1 g and accurate to 0.2 g or 0.1% of the test load, whichever is greater, throughout the range of use.

2) Laboratory oven capable of maintaining a temperature of 230 ± 9 °F,. (gas burners or electric hot plates may be used).

3) Metal pans for drying and storage

4) Utensils for washing and drying samples, such as trowels, spatulas, etc.

5) Appropriate data sheets, log books, etc.

Sampling

Equipment required for **AASHTO T 2** or **ITM 207**:

1) Square-nose shovel

2) Sample tube for sand

3) Containers, such as 20 gallon buckets, plastic fiber bag, etc. Galvanized bushel tubs work well.

4) Labels of sufficient size to allow for proper identification of samples.

5) Templates for belt sampling.

Sample Reduction

Equipment required for **AASHTO T 248**:

1) Mechanical splitters

2) Buckets

Sieve Analysis

Equipment required for **AASHTO T 27**

1) Sieves - for coarse aggregates 15 in. x 23 in. or 14 in. x 14 in. screens are recommended with sieve designations 2 in., 1 1/2 in., 1 in., 3/4 in., 1/2 in., 3/8 in., No. 4, No.8 and pan. For fine aggregates 8 in. round sieves are standard with sieve designations 3/8 in., No. 4, No. 8, No. 16, No. 30, No. 50, No. 100, No. 200, and pan.

2) Mechanical sieve shaker -- appropriate model to accommodate sieves.

3) Sieve brushes -- Wire and bristle brushes (a wire brush will damage a No. 50 or smaller sieve).

Decantation

Equipment required for **AASHTO T 11**:

1) Sieves - No. 16 and No. 200. The No. 200 sieve can be protected from punctures and tears by covering with a No. 16 sieve.

2) Container - size sufficient to contain the sample covered with water and permit vigorous agitation.

3) Wetting Agent - such as liquid detergent, etc. Some fine materials, especially limestone dust, require a wetting agent to break the surface tension of the particles. A drop or 2 of dish washing liquid is usually sufficient.

4) Decant Machine - may be used provided the results are consistent with those obtained using manual operations.

Deleterious and Chert

1) Scratch hardness tester.

2) Hydrochloric acid and glass plate.

TEST EQUIPMENT VERIFICATION

The test equipment shall be properly verified, and maintained within the limits described in the applicable test method. The Certified Aggregate Producer Program requires equipment to be verified prior to beginning testing in the Coordinated Testing Phase and also at a minimum frequency as follows:

EQUIPMENT	REQUIREMENT	MINIMUM FREQUENCY	PROCEDURES
Balances	Verification	12 mo.	ITM 910
Mechanical Shakers	Check sieving thoroughness	12 mo.	ITM 906
Sieves	Check physical thoroughness	12 mo.	ITM 902

LABORATORY SET-UP

Proper organization of the laboratory is necessary in order to maximize efficiency and minimize problems and erroneous results. Special consideration should be given to the “flow” of the work to be done and the laboratory organized in the direction of this flow. For example, one might arrange the equipment from left to right when running sieve analyses as follows:

1) Riffle splitter -- for reduction of incoming samples.

2) Oven -- for drying samples after reduction.

3) Cooling rack and fan -- for cooling samples when dry (note: make sure that the fan does not blow towards the balance in the weighing area and does not disperse sample fines).

4) Coarse aggregate shaker.

5) Fine aggregate shaker.

6) Weighing area -- balance should be in an area free from vibration, dust, and air flow.

Every laboratory situation is different. The lab should be set up to meet the flow requirements of the most routine test performed. The need for back-tracking should be minimized, especially if more than one technician is working at a time. A little extra time and thought to the set up of the lab will significantly increase productivity and decrease turn-around time.

2 Sampling

Sampling Techniques

Safety

Sample References

Size of Original Samples

Sample Type

Method of Sampling

Production Sampling

Stockpile Sampling

Sampling Directly from Trucks, Rail Cars, or Barges

2 CHAPTER TWO: SAMPLING

SAMPLING TECHNIQUES

Sampling is perhaps the most important step in assuring that good quality aggregates are being used. Since a sample is just a small portion of the total material, the importance that the sample be representative of the material being delivered can not be overemphasized. Any test performed on the sample, regardless of how carefully and accurately performed, is worthless unless the sample is truly representative of the material offered for use on the project.

SAFETY

The sampling of materials can expose the technician to machinery, moving belts, large stockpiles, and other potential dangers. Proper safety practices are always the first concern. When not sure of safety the technician should stop and seek the supervisor's instructions.

SAMPLE REFERENCES

A representative sample can be obtained by following the standard procedures detailed in the latest edition of **AASHTO T2** and **ITM 207**, "Method of Sampling Stockpile Aggregate."

SIZE OF ORIGINAL SAMPLES

The key to any sample program is to obtain a representative sample. A standard sampling method must be followed to obtain uniform samples.

The following is a list of recommended minimum sizes of composite samples to be used as a guide when collecting samples.

MATERIAL	SAMPLE SIZE
No. 2 coarse aggregate	220 lb
No. 5 coarse aggregate	110 lb
No. 8 coarse aggregate	55 lb
No. 9 coarse aggregate	35 lb
No. 11 & No. 12 coarse aggregate	25 lb
No. 43 coarse aggregate	110 lb
No. 53 coarse aggregate	135 lb
No. 73 coarse aggregate	80 lb
2 in. Structure Backfill	245 lb
1 1/2 in. Structure Backfill	190 lb
1 in. Structure Backfill	135 lb
1/2 in. Structure Backfill	60 lb
All sands No. 4 & No. 30 B Borrow	25 lb

The weight of the sample depends on the maximum particle size of the material being inspected. As a rule, a larger top size material the larger the sample. A 25 lb sample of No. 2 coarse aggregate would not be as representative of the material as a 25 lb sample of natural sand.

TWO IMPORTANT DEFINITIONS TO REMEMBER

Top Size or Maximum Particle Size--The sieve on which 100 percent of the material will pass.

Nominal Maximum Particle Size--Smallest sieve opening through which the entire amount of the aggregate is permitted to pass.

SAMPLE TYPES

The technician should realize there are different types of samples. The most common sample is a stockpile sample.

Some samples need to be taken by the Producer in the processing operation to assure that the final product will be within control limits. These samples are referred to as production samples. The gradation at this point may not be the same as the stockpile sample at some facilities.

Occasionally, an investigative sample should be obtained by the Producer when looking for a very specific feature, such as a certain sieve, oversized material, etc. These tests may consist of many shortcuts and should only be used as a quick comfort level check.

Every source can have other types of samples which are unique to their operation.

METHODS OF SAMPLING

Due to the various sampling locations and the availability of equipment, there are several methods of taking aggregate samples. Uniformity of obtaining the sample cannot be emphasized enough, since it eliminates one variable in test results. The technician must remember that safety comes first.

PRODUCTION SAMPLING

Bin Sample

Sampling the top of the bin is extremely dangerous as well as a difficult, if not impossible, method to obtain a representative sample. For this reason, this method of sampling is undesirable.

Discharge Sampling of Bins or Belts

Bin samples can be taken at the discharge chute. In these cases a number of small samples should be taken at short intervals and combined to make the total sample. Each of these samples must include the entire cross section of the flow of material from the chute or belt. Continuity of operation normally will not allow the technician to control the rate of flow from the discharge chute to allow these samples to be taken easier. A mechanical deversion or slide chute system is the quickest, safest, and most accurate system for taking a belt sample; unfortunately very few mechanical systems exist.

Belt Sampling

Belt sampling consists of taking samples of materials directly from conveyor belts. The proper procedure is to:

1) Make sure that the belt is carrying a normal load of material that is not segregated;

2) Have the plant operator stop the belt, and use proper lock out procedures;

3) Take a complete cross section of the material, being careful to include all the material on the belt and only the material in the section. A template is recommended, especially on steeply inclined belts. Remove most of the sample with a scoop or shovel and the remainder with a brush; and

4) Take as many complete cross sections as necessary to obtain a sample that meets the minimum sample size.

STOCKPILE SAMPLING

Coarse Aggregate Stockpiles

Coarse aggregates are recommended to be sampled using **ITM 207**. A summary of the procedure includes the following:

1) Locate the area of the stockpile from which hauling will begin.

2) Using a front-end loader, dig into the stockpile and set aside a small pile of 10 to 15 t of material. This should be done in the same manner as if a truck is being loaded for shipment (Figs. 2.1 and 2.2). When forming the small pile, the loader bucket should be as low as possible, and the operator should roll the material from the bucket rather than dumping the material. Reducing the distance the material is allowed to free-fall will reduce the amount of segregation that may occur in the small pile (Fig. 2.3). Each additional bucket load of material should be taken and dumped in the same manner as set out above, and should be placed uniformly over the preceding one. (Fig. 2.4).

3) Thoroughly mix the small pile. Using the loader bucket, go to the end of the oblong pile and roll the material over. Keeping the loader bucket as low as possible, push the bucket into the material until the front of the bucket passes the midpoint of the original pile. The loader bucket should then be slowly raised and rolled forward thus producing a smooth mixing of the material. (Figs. 2.5, 2.6 and 2.7). Go to the opposite end of the pile, and repeat this mixing procedure. If the pile does not appear to be reasonably uniform, additional mixing should be done.

4) The pile is now ready for sampling. Do <u>not</u> strike off the top (Fig. 2.8). The sample will be taken at the center of the volume which is approximately one-third of the height of the pile. The sample shall consist of not less than 6 full shovels of material taken at equal increments around the pile (Figs. 2.9, 2.10 and 2.11). The shovel shall be inserted full-depth horizontally into the material and raised vertically. Care should be taken to retain as much of the material as possible on the blade of the shovel (Fig. 2.12).

Fine Aggregate Stockpiles

Fine aggregate samples normally are obtained in the same method as coarse aggregate samples, except a fire shovel or sampling tube is used to collect the material.

SAMPLING DIRECTLY FROM TRUCKS, RAIL CARS, OR BARGES

Direct sampling from the trucks, rail cars, or barges is not recommended. There are a number of factors that may influence the gradation of the material, such as segregation or particle breakdown during loading, transporting, and unloading. Therefore, material being shipped by cars or barges should be sampled at the point of delivery.

Figure 2.1

Figure 2.2

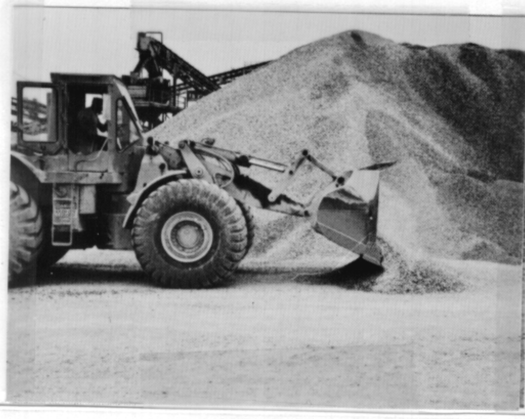


Figure 2.3

Figure 2.4

Figure 2.5

Figure 2.6

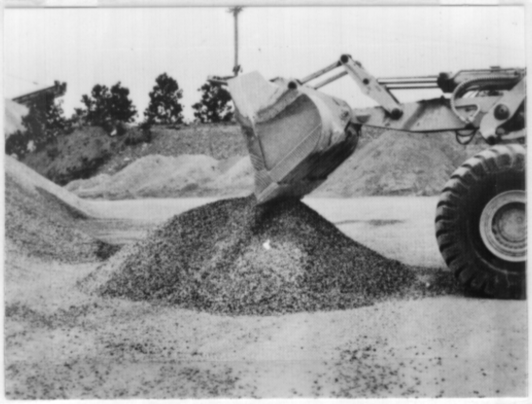


Figure 2.7

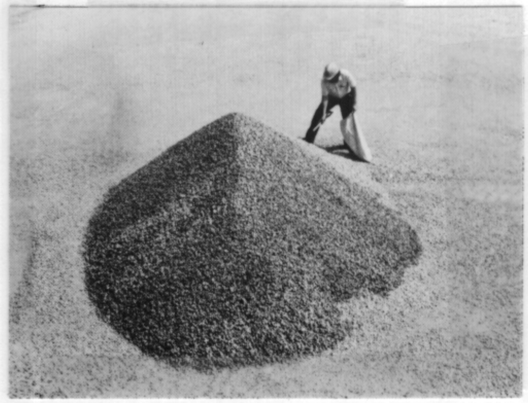


Figure 2.8

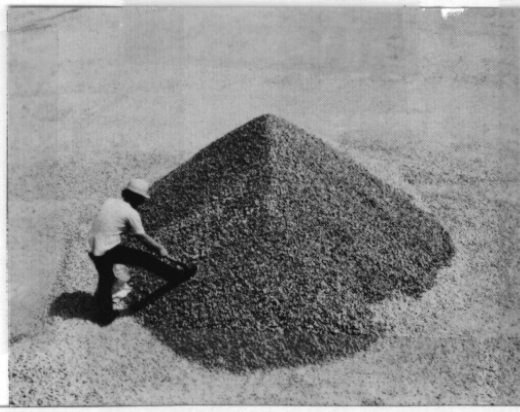


Figure 2.9

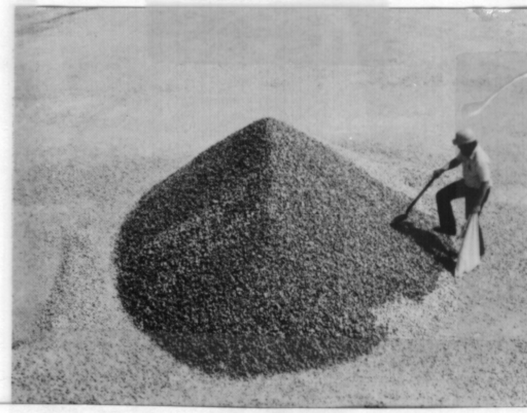


Figure 2.10

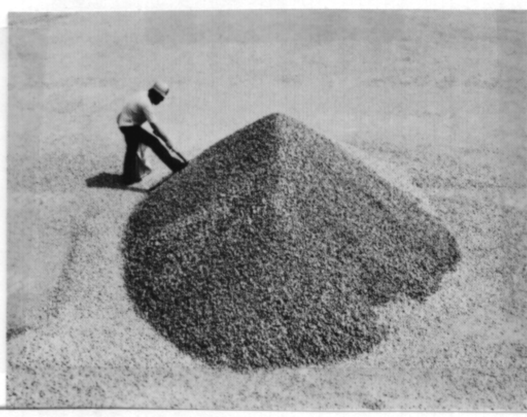


Figure 2.11

Figure 2.12

3 Sample Reduction

Reducing A Sample To Test Size

Mechanical Splitter

Sand Splitter

Miniature Stockpile

Quartering

Size of Test Sample (After Splitting)

3 CHAPTER THREE:
SAMPLE REDUCTION

REDUCING A SAMPLE TO TEST SIZE

The total sample must be reduced to a sample size that can be quickly tested. Time will not allow the technician to run the total sample. The key to sample reduction is to ensure that the sample remains representative of the material in the stockpile. This practice is commonly referred to as splitting a sample. Four different methods are used to reduce a sample to the proper test size.

1) **Mechanical Splitter** is the most accepted method of reducing to test size all coarse aggregate material smaller than gradation size No. 1, except highly moistened Compacted Aggregate.

2) **Sand Splitter** is the accepted method of reducing fine aggregate or the minus No. 4 material from compacted aggregate samples that is drier than the saturated-surface-dry condition. As a quick check to determine this, if the material retains its shape when molded in the hand, it is considered wetter than saturated-surface-dry.

3) **Miniature Stockpile** is the method used for fine aggregate that has free moisture on the particle surfaces.

4) **Quartering** is the method that is used for highly moistened Compacted Aggregate or when a mechanical splitter is not available.

Mechanical Splitter

The Mechanical Splitter "splits" the sample into halves as the material passes through the spaces between the bars in the splitter. The same number of each particle size will go into each half of the sample, thus keeping the reduced sample representative of the total collected sample.

In using the Mechanical Splitter, adjust the splitter bars to approximately 50% larger than the maximum particle size of the material to be split. A No. 5 aggregate has a maximum particle size of 1 1/2 in. Therefore, the recommended bar opening would be approximately 2.25 in. INDOT allows the bar opening to be 3 in. or 6 bars (each bar is approximately 1/2 in.) for all coarse aggregate No. 5 or smaller. The splitter must be level to ensure that each half of the split is approximately the same size; within approximately 10 percent of each other by weight.

The splitting procedure is as follows:

1) Properly place the pans under the splitter in such a way that all of the particles diverting in both directions will be caught;

2) Pour the sample evenly into the hopper;

3) Open the hopper fully and allow the material to free fall through the splitter (If wet particles stick inside the splitter, gently tap the splitter with a rubber hammer to loosen them);

4) Place both halves of the sample back into the hopper and repeat the splitting operation to ensure that the sample has not been segregated during sampling; and

5) After the second splitting, the two receiving pans will contain approximately the same amount of material. Only one pan is placed back into the hopper and the splitting procedure repeated until a sample of the desired size is obtained. Skillful manipulation of the splitter will allow a sample of nearly any size to be made that is still representative of the material in the stockpile.

Sand Splitter

The sand splitter is a small version of the Mechanical Splitter except that the openings are fixed and there are no hopper doors.

The splitting procedure is as follows:

1) Place the pans under the splitter to catch all of the particles;

2) Slowly pour the dry sample into the splitter from the side (never from the end or corner);

3) Recombine the samples and split the sample a second time to eliminate any segregation; and

4) Reduce the sample to proper size by additional splitting of the material in one of the pans.

Miniature Stockpile

This method is used for reducing all samples of fine aggregates when the material is in a damp or moist condition. If the sample to be split is dry, then the material must be moistened before using this method.

The splitting procedure is as follows:

1) Place the original sample on a clean, dry plate or other hard, smooth, non-absorptive surface;

2) Using a trowel or other suitable tool, turn the entire sample over three times;

3) Shape the material into a conical pile; and

4) With a spoon or small trowel, randomly take at least five small portions of material around the pile and one-third way up the cone until the required test sample is obtained.

Quartering

Quartering is a non-mechanical method of reducing a sample. This is the best method of reducing highly moistened Compacted Aggregate or when a mechanical splitter is not available.

The quartering procedure is as follows:

1) Place the sample on a hard, clean, level surface where there will be neither loss of material nor the accidental addition of foreign material;

2) Using a large trowel, shovel, or other suitable tool, turn the entire sample over at least 3 times and form the entire sample into a conical pile by depositing individual lifts on top of the preceding lift;

3) Flatten the pile until the diameter is approximately equal to four to eight times the thickness of the pile;

4) With a large trowel or other suitable tool, divide the sample in half by vertically passing the tool through the center of the pile. In a similar manner divide each of these halves into two parts, thus “quartering” the sample; and

5) Combine diagonally opposite quarters into two samples. All fine materials shall be included by brushing the surface clean. Store one of these two halves. If the remaining material still weighs too much, repeat the entire quartering process until the proper test sample size is obtained.

SIZE OF TEST SAMPLE (AFTER SPLITTING)

The original sample must be reduced to test sample size which falls within the minimum and maximum weight in the following table.

WEIGHT OF TEST SAMPLE

AGGREGATE SIZE	MINIMUM	MAXIMUM
No. 2	11300 g	---
No. 5	6000 g	8000 g
No. 8	6000 g	8000 g
No. 9	4000 g	6000 g
No. 11	2000 g	---
No. 12	1000 g	---
No. 43	6000 g	8000 g
No. 53	6000 g	8000 g
No. 73	6000 g	8000 g
No. 91	6000 g	8000 g
B Borrow	4000 g	6000 g
Structure Backfill, 2 in.	11,300 g	---
Structure Backfill, 1 1/2 in. & 1 in.	6000 g	8000 g
Structure Backfill, 1/2 in.	4000 g	6000 g
Structure Backfill: No. 4 & No. 30	300 g	---
Fine aggregate	300 g	---

4 Testing

Gradation

Sieving

Decantation

Sieve Analysis Test

Fineness Modulus

Sieve Analysis for Dense Graded Materials

Deleterious Materials

Deleterious Materials in Coarse Materials

Deleterious Materials in Natural Sands

Crushed Particles

Flat and Elongated Particles

Clay Content

Fine Aggregate Angularity

Plastic Limit

Surface Moisture Tests

4 CHAPTER FOUR:
TESTING

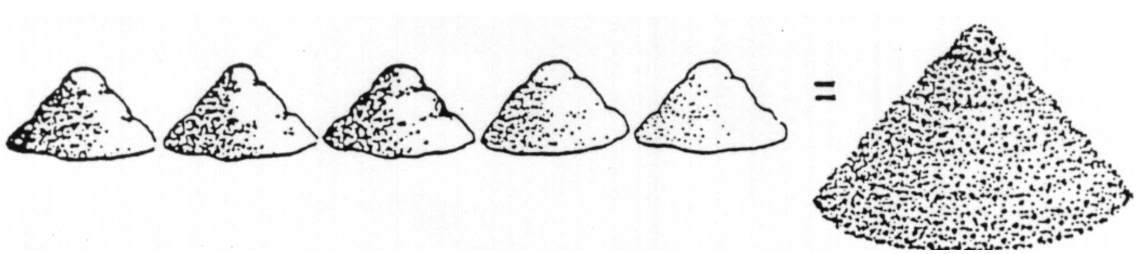
After obtaining and splitting the sample, the obvious next step is to conduct the test. Uniform and consistent testing is required to remove variables in the total operation

GRADATION

Gradation is the range and relative distribution of particle sizes in the aggregate material

Range refers to the size limits of an aggregate set and to the number of sizes in that set. For example, the sizes in a set may extend from 1 1/2 in. aggregates to 3/8 in. aggregates and include sizes of 1 in., 3/4 in. and 1/2 in. Another set may extend from 2 1/2 in. aggregates to 1/2 in. aggregates with intermediate sizes of 1 1/2 in., 1 in., and 3/4 in.

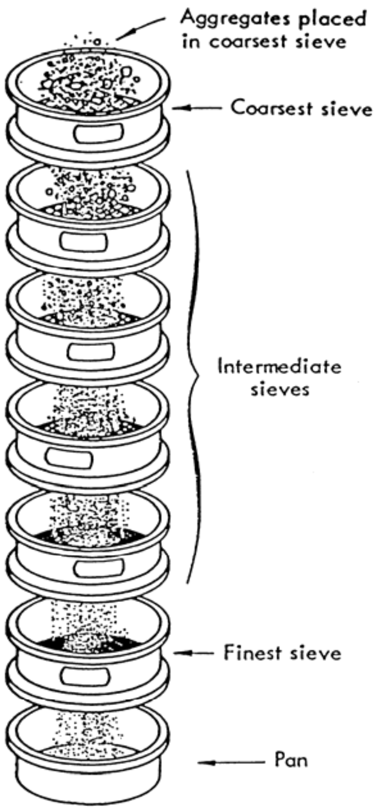
The relative distribution refers to the percentage of each particle size in the total material. For example, in a given set of aggregates, 16 percent of the total material could be 1 1/2 in. aggregates, 23 percent could be 1 in. aggregates, 14 percent could be 19 mm aggregates and so on.



Sets of graded aggregates are referred to by size number with each having a specified range and relative distribution.

The sizes of fine and coarse aggregates used by INDOT and the gradation requirements for each size are found in Section **904**.

Sieving



Gradation is determined by sieving. A sample of the aggregate material being tested is weighed and then passed through a series of sieves as shown on the left.

Sieve sizes correspond to the size of the openings in the mesh. Range is determined by the number and sizes of sieves used. Relative distribution is calculated by weighing the aggregates retained on each sieve.

The coarser sieves are classified according to the size of the openings, in linear inches. Thus, the 1 in. sieve has openings 1 in. square.

Aggregates coarser than the 1 in. sieve are called plus 1 in. material. Aggregates finer than 1 in. sieve are called minus 1 in. material. (Plus (retained) means coarser than; minus means finer than.) To be retained on any sieve, the aggregate must be coarser in every direction than the sieve size.

Decantation

The decantation test determines the amount of material finer than the No. 200 sieve. The test is conducted on both fine and coarse aggregate and is usually done in conjunction with the sieve analysis test. The test is performed according to **AASHTO T 11**, with exceptions noted in Section 904.06.

NOTE: If the total amount passing the No. 200 sieve is required to be determined by the specifications, the amount is determined by a combination of wet and dry sieving, and is represented by the total amount passing the No. 200 sieve following both decantation and dry sieve analysis.

The procedure for decantation is:

1) After the sample has been reduced to the proper size, the sample is thoroughly dried and allowed to cool to room temperature. The weight is recorded on the gradation analysis sheet.

2) The dried material is then placed in a container large enough to hold the sample with adequate wash water and room for agitating the sample.

3) The sample is covered with water.

4) The sample is agitated with a spoon or trowel to separate all particles and to suspend the minus No. 200 material.

5) The wash water is immediately poured or allowed to overflow through a No. 200 sieve. A protector sieve (No. 16) is nested above the No. 200 sieve for protection from the larger particles. Only the wash water (not the sample) is poured on the sieve.

6) The washing and sieving of the wash water is continued until the water runs clear.

7) After the wash water has cleared, the excess water is drained from the sample through the No. 200 sieve. Any residue material is removed from the protector sieve and the No. 200 sieve and placed with the test sample.

8) The washed sample is dried, allowed to cool to room temperature, and weighed. The weight is recorded in the Decant Section of the gradation analysis sheet.

9) The percentage of material finer than a No. 200 sieve is calculated by using the formula:

$$\% \text{ Decant} = \frac{\text{Original Dry Weight - Dry Weight after Decant}}{\text{Original Dry Weight}} \text{ X } 100$$

$$\% \text{ Decant} = \frac{5942.1 - 5885.2}{5942.1} \text{ X } 100 = 0.96\% \approx 1.0\%$$

Decant	Original	Final	Grams Loss	% Loss	% Req.
	5942.1	5885.2	56.9	1.0	

SIEVE ANALYSIS TEST

Sieve analysis is used primarily to determine the particle-size distribution or gradation of materials. The results are used to determine compliance with the applicable specification requirements. The test is conducted on both the fine and coarse aggregates and is usually done in conjunction with the decantation test.

The sieve analysis for mineral filler is conducted in accordance with **AASHTO T 37**. Because of the very fine particle-size of mineral filler, this test requires washing the material over the required sieves. The sieve analysis for all other fine aggregates and all coarse aggregates is conducted in accordance with **AASHTO T 27**. Exceptions to **AASHTO T 37** and **AASHTO T 27** are listed in Section **904.06**.

The procedure for the sieve analysis in accordance with **AASHTO T 27** is as follows:

1) The dried (decanted) sample is placed in the top sieve of properly nested sieves. The sieves are nested in sequence with the smallest sieve placed on the pan and stacked by increasing size.

2) The shaking time must be sufficient to ensure that the sample is divided into fractional sizes. The actual shaking time is required to be determined in accordance with **ITM 906**. The standard for establishing the proper shaking time is found in **AASHTO T 27**. The minimum shaking times are as follows.

Coarse Aggregate, Size 9 or larger	5 Minutes
Coarse Aggregate, Smaller than Size 9	10 Minutes
Fine Aggregates	15 Minutes

3) At the conclusion of sieving, the material retained on each sieve is carefully transferred to a pan and weighed. The weight of the material retained on each sieve is recorded on the Gradation Analysis sheet. The weight cannot exceed the allowable amount on each sieve as indicated in Table 1.

NOTE: The larger sieves (above the No. 16) are cleaned with a small trowel or piece of flat metal. The sieves between the No. 16 and No. 50 are cleaned with a wire brush. Sieves smaller than the No. 50 cleaned with a soft bristle brush. Care must be taken not to damage the sieves.

TABLE 1 APPROXIMATED SIEVE OVERLOAD				
SCREEN SIZE	**STANDARD 15 in. x 23 in.**	**STANDARD 14 in. x 14 in.**	**12 in. DIAMETER**	**8 in. DIAMETER**
3 in.	40.5 kg	23.0 kg	12.6 kg	-------------
2 in.	27.0 kg	15.3 kg	8.4 kg	3.6 kg
1-1/2 in.	20.2 kg	11.5 kg	6.3 kg	2.7 kg
1 in.	13.5 kg	7.7 kg	4.2 kg	1.8 kg
3/4 in.	10.2 kg	5.8 kg	3.2 kg	1.4 kg
1/2 in.	6.7 kg	3.8 kg	2.1 kg	890 g
3/8 in.	5.1 kg	2.9 kg	1.6 kg	670 g
No. 4	2.6 kg	1.5 kg	800 g	330 g
8 in. diameter sieves, No. 8 to No. 200 shall not exceed 200g / sieve				
12 in. diameter sieves, No. 8 to No. 200 shall not exceed 469g / sieve				

TOTAL WEIGHT: 5942.1g				
SIEVE SIZE	WEIGHT RETAINED	WEIGHT PASSING	PERCENT PASSING	PERCENT REQUIRED
1½ in.	g	g	%	%
1 in.	0 g	5942.1 g	%	%
¾ in.	690.6 g	g	%	%
½ in.	2462.7 g	g	%	%
⅜ in.	1368.1 g	g	%	%
No. 4	997.0 g	g	%	%
No. 8	264.5 g	g	%	%
No. 16	g	g	%	%
No. 30	g	g	%	%
No. 50	g	g	%	%
No. 100	g	g	%	%
No. 200	g	g	%	%
PAN	88.1 g	g	%	%
DECANT ORIGINAL	FINAL	GRAMS LOSS	PERCENT LOSS	PERCENT REQUIRED
5942.1 g	5885.2 g	56.9 g	1.0 %	%

4) The weight passing each sieve is calculated next by subtracting the weight retained on the largest sieve from the total sample weight. The weight retained on the next largest sieve is subtracted from the weight of material still remaining from the first subtraction. The process is continued for all sieves.

1 in.	5942.1 – 690.6	= 5251.5
3/4 in.	5251.5 – 2462.7	= 2788.8
3/8 in.	2788.8 – 1368.1	= 1420.7
No. 4	1420.7 – 997.0	= 423.7
No. 8	423.7 – 264.5	= 159.2
Pan material		= 88.1

TOTAL WEIGHT: 5942.1g				
SIEVE SIZE	WEIGHT RETAINED	WEIGHT PASSING	PERCENT PASSING	PERCENT REQUIRED
1½ in.	g	g	%	%
1 in.	0 g	5942.1 g	%	%
¾ in.	690.6 g	5251.5 g	%	%
½ in.	2462.7 g	2788.8 g	%	%
⅜ in.	1368.1 g	1420.7 g	%	%
No. 4	997.0 g	423.7 g	%	%
No. 8	264.5 g	159.2 g	%	%
No. 16	g	g	%	%
No. 30	g	g	%	%
No. 50	g	g	%	%
No. 100	g	g	%	%
No. 200	g	g	%	%
PAN	88.1 g	g	%	%
<u>DECANT</u> ORIGINAL	FINAL	GRAMS LOSS	PERCENT LOSS	PERCENT REQUIRED
5942.1 g	5885.2 g	56.9 g	1.0 %	%

5) The percent passing is calculated for each sieve by using the following formula:

$$\% \text{ Passing} = \frac{\text{Weight passing each sieve}}{\text{Original dry sample weight}} \text{ X } 100$$

Example:

3/4 in. $\frac{5251.5}{5942.1} \times 100 = 88.4\%$

1/2 in. $\frac{2788.8}{5942.1} \times 100 = 46.9\%$ etc.

TOTAL WEIGHT: 5942.1g				
SIEVE SIZE	**WEIGHT RETAINED**	**WEIGHT PASSING**	**PERCENT PASSING**	**PERCENT REQUIRED**
1½ in.	g	g	%	%
1 in.	0 g	5942.1 g	100 %	%
¾ in.	690.6 g	5251.5 g	88.4 %	%
½ in.	2462.7 g	2788.8 g	46.9 %	%
⅜ in.	1368.1 g	1420.7 g	23.9 %	%
No. 4	997.0 g	423.7 g	7.1 %	%
No. 8	264.5 g	159.2 g	2.7 %	%
No. 16	g	g	%	%
No. 30	g	g	%	%
No. 50	g	g	%	%
No. 100	g	g	%	%
No. 200	g	g	%	%
PAN	88.1 g	g	%	%
DECANT ORIGINAL	FINAL	GRAMS LOSS	PERCENT LOSS	PERCENT REQUIRED
5942.1 g	5885.2 g	56.9 g	1.0 %	%

6) If the test has been done accurately, the sum of all the fractional weights retained (including the material in the pan) and the weight of material removed by decantation will be approximately equal to the original dry weight. If the two weights differ by more than 0.3 percent, based on the original dry sample weight, the results are considered invalid.

$$\frac{\text{Original Dry weight - Summation Weights Measured}}{\text{Original Dry Weight}} \times 100$$

Example:

$$\frac{5942.1 - (690.6 + 2462.7 + 1368.1 + 997.0 + 264.5 + 89.1 + 56.9)}{5942.1} \times 100 =$$

0.2% = valid test

Fineness Modulus

The fineness modulus is related to gradation. This term is commonly associated with aggregates for portland cement concrete. The purpose is to determine the relative coarseness or fineness of the aggregate grading.

The fineness modulus is computed in accordance with **AASHTO T 27** by adding the cumulative percentages retained on the 3 1/2 in., 2 1/2 in., 2 in., 1 1/2 in., 3/4 in., 3/8 in., No. 4, No. 8, No. 16, No. 30, and No. 100 sieves, and then dividing by 100. A large number means a coarse material. A small number means a fine material.

Sieve Size	100	-	% Passing	=	% Retained
3/8 in.	100	-	100	=	0.0
No. 4	100	-	100	=	0.0
No. 8	100	-	89.2	=	10.8
No. 16	100	-	68.3	=	31.7
No. 30	100	-	45.1	=	54.9
No. 50	100	-	13.8	=	86.2
No. 100	100	-	2.6	=	97.4
					281.0

281.0 / 100 = 2.81 = Fineness Modulus

Sieve Analysis for Dense Graded (Long Graded) Materials

Dense graded materials, such as compacted aggregates and some B borrows or subbase, consist of substantial quantities of material retained on and passing the No. 4 sieve.

The procedure for performing a sieve analysis on a dense graded material is:

1) The entire sample is sieved and weighed in the same manner as well-graded materials, except the smallest sieve must be the No. 4 sieve.

2) The portion of the sample passing the No. 4 sieve is weighed.

3) Using a sand sample splitter, the portion of the sample passing the No. 4 sieve is reduced to approximately 500 grams.

4) The reduced sample is weighed and a proportionate factor is determined by dividing the weight of the portion of the sample passing the No. 4 sieve by the weight of the reduced sample.

   For example: If the total weight of the portion of material passing the No. 4 sieve is 2221.4 grams and the reduced sample weight is 503.4 grams, the proportionate factor would be equal to 2221.4 grams divided by 503.4 grams, which equals 4.413.

5) The reduced sample is sieved for 15 minutes.

6) The material on each sieve is weighed and multiplied by the proportionate factor. The calculated weight is recorded as the total weight of material retained on that sieve.

7) The calculations for percentage passing are completed as for well-graded aggregates.

An example, using the proportionate factor for all minus No. 4 sieve material, is shown below:

TOTAL WEIGHT: 6800.8g					
SIEVE SIZE	**LONG GRADED WEIGHT RET.**	**WEIGHT RETAINED**	**WEIGHT PASSING**	**PERCENT PASSING**	**PERCENT REQUIRED**
1½ in.		**0 g**	**6800.8 g**	**100 %**	**100 %**
1 in.		**312.9 g**	**6487.9 g**	**95.4 %**	**80-100 %**
¾ in.		**877.2 g**	**5610.7 g**	**82.5 %**	**70-90 %**
½ in.		**1228.3 g**	**4382.4 g**	**64.4 %**	**55-80 %**
⅜ in.		**580.5 g**	**3801.9 g**	**55.9 %**	**%**
No. 4		**1072.1 g**	**2729.8 g**	**40.1 %**	**35-60 %**
No. 8	**222.1 g**	**940.4 g**	**1789.4 g**	**26.3 %**	**25-50 %**
No. 16	**g**	**g**	**g**	**%**	**%**
No. 30	**192.7 g**	**815.9 g**	**973.5 g**	**14.3 %**	**12-30 %**
No. 50	**g**	**g**	**g**	**%**	**%**
No. 100	**g**	**g**	**g**	**%**	**%**
No. 200	**84.8 g**	**359.0 g**	**614.5 g**	**9.0 %**	**5.0-10.0 %**
PAN	**4.2 g**	**17.8 g**	**g**	**%**	**%**
DECANT	**ORIGINAL**	**FINAL**	**GRAMS LOSS**	**PERCENT LOSS**	**PERCENT REQUIRED**
	6800.8 g	**6220.7 g**	**580.1 g**	**8.5 %**	**%**
PROPORTIONATE FACTOR	**TOTAL WEIGHT PASSING No. 4**		**SAMPLE SIZE**		
	2133.2 g		**503.8 g**		**4.234**

DELETERIOUS MATERIALS

Most of the tests for deleterious materials apply to coarse aggregates. The only concern in fine aggregates is organic impurities.

Deleterious Materials in Coarse Materials

These tests are based on visual inspection and require training and judgment. Deleterious substances of concern are clay lumps and friable particles, non-durable materials, coke, iron, and chert. Coke and iron are only of concern in slag, and no guidelines are given.

Clay Lumps And Friable Particles

These particles are defined as the material remaining after decantation that can be mashed with the fingers. The test is performed according to **AASHTO T 112**.

A sample is made up from material retained on the No. 4 sieve and each sieve above the No. 4 sieve, following decantation of sieve analysis. The sample is soaked 24 hours, plus or minus 4 hours, in distilled water. After soaking, any material or particles that can be broken by the fingers and are removable by wet sieving are classified as clay lumps or friable material. The material retained after wet sieving is dried to constant weight and weighed.

The percent clay or friable material is calculated by:

$$\text{\% Clay or Friable} = \frac{\text{Dry Weight of Sample - Dry Weight Ret. (Wet Sieving)}}{\text{Dry Weight of Sample}} \times 100$$

Non-Durable Materials

Non-durable materials are divided into two types:

1) Soft material as determined by **ITM 206**; and

2) Structurally weak material as determined by visual inspection.

Both tests are performed on all the sample material retained on the 3/8 in. sieve and each sieve above the 3/8 in. sieve.

The Scratch Hardness Test applies only to gravel coarse aggregate. Each particle which is to be tested is subjected to a scratching motion of a brass rod, using a 2 lbf load. Particles are considered soft if a groove is made in them without deposition of metal from the brass rod or if separate particles are detached from the rock mass. A particle is classified as soft only if one-third or more of its volume is found to be soft.

Structurally weak materials are visually identified and include:

1) Ocher -- soft rock clay to sand particles cemented with iron oxide which ranges in color from tan through yellows, reds, and browns.

2) Unfossilized shells.

3) Conglomerates -- cemented gravels.

4) Shale -- laminated rock of clay-size minerals.

5) Limonite -- iron oxide, ranging from yellow-brown to black in color that is frequently a concretion around a soft core.

6) Weathered schist.

7) Coal, wood, and other foreign materials.

8) Materials with loosely cemented grains and/or a weathered coating.

9) Soft sandstone.

Particles determined to be soft or structurally weak are combined, and the percent by mass of non-durable material is calculated by:

$$\% \text{ Non-Durable} = \frac{\text{Weight of Non-Durable Material above 3/8 in. Sieve}}{\text{Weight of Sample Above the 3/8 in. Sieve}} \times 100$$

Chert

Chert is visually picked from coarse aggregates. It is a rock of varied color, composed of glassy silica, and very fine-grained quartz. Unweathered chert appears hard, dense, and brittle with a greasy texture. Weathered chert appears chalky and dull. Chert is likely to have concave surfaces with sharp outer edges when freshly broken.

Total chert is picked from the sample following decantation and gradation. Chert is picked from all the material retained on the 3/8 in. sieve and each sieve above the 3/8 in. sieve for aggregate sizes 2 through 8, 43, 53, and 73, and from all material retained on the No. 4 sieve and above for aggregate sizes 9, 11, 12, and 91. The procedure for determining the total chert includes:

1) All chert, including questionable chert, is picked from the sample.

2) All pieces of questionable chert are further tested by the following procedures:

   a) Scratching glass. Chert pieces will scratch glass.

   b) Breaking pieces. Chert breaks into rounded surfaces with sharp edges. If pieces do not break into rounded surfaces with sharp edges, they are added to the soft or non-durable material.

   c) Reaction with acid. Chert will not react with 0.1N hydrochloric acid.

3) All material determined to be chert is weighed and the percent of total chert is calculated using the formulas below:

For aggregate sizes 2 through 8, 43, 53, and73:

$$\% \text{ Total Chert} = \frac{\text{Weight of Chert above the 3/8 in. Sieve}}{\text{Total Weight of Sample above the 3/8 in. Sieve}} \times 100$$

For aggregate sizes 9, 11, 12, and 91:

$$\% \text{ Total Chert} = \frac{\text{Weight of Chert above the No. 4 Sieve}}{\text{Total Weight of Sample above the No. 4 Sieve}} \times 100$$

The percent chert requirement of **904.03(a)** applies to chert less than 2.45 bulk specific gravity. If the percent total chert exceeds this chert requirement, the sample is tested for lightweight chert pieces in accordance with **AASHTO T 113** to determine the percent chert less than 2.45 bulk specific gravity.

Deleterious Materials in Natural Sands

The purpose of the **AASHTO T 21** test is to furnish a warning that further tests on the sand are necessary before the sands are approved for use. The procedure is:

1) A glass bottle is filled with approximately 4 1/2 fl oz of the sand to be tested.

2) A 3 percent sodium hydroxide (NaOH) solution in water is added until the volume of the sand and liquid, indicated after shaking, is approximately 7 fl oz.

3) The bottle is stoppered, shaken vigorously, and allowed to stand for 24 hours.

4) The color of the supernatant liquid above the test sample is compared to reference standard colors.

5) If the color of the supernatant liquid is darker than that of the referenced color, the sand may contain injurious organic compounds, and further tests are to be made before approving the sand for use in concrete

The **AASHTO T 71** test compares the compressive strength of mortar specimens made from the suspect sand to the compressive strength of mortar made from acceptable sand.

The colorimetric test (**AASHTO T 21**) is conducted first. If the color in solution is lighter than a standard, the fine aggregate is acceptable. If the color is darker, further testing of the fine aggregate for strength in mortar, **AASHTO T 71**, is required. If the effect of any organic matter reduces the strength no more than 5 percent, the fine aggregate is acceptable. Also, observations should be made to determine whether the organic material retards the mortar set or changes the necessary air-entraining admixture dosage.

CRUSHED PARTICLES

ASTM D 5821 outlines the procedure for determining the quantity of crushed particles. Crushed particle requirements are used for gravel coarse aggregates in HMA (one and two-faced), compacted aggregates, and asphalt seal coats (except seal coats used on shoulders).

The test is conducted on all particles retained on the No. 4 sieve and is performed as follows:

1) The total sample is washed over the No. 4 sieve and dried to a constant weight.

2) Each particle is evaluated to verify that the crushed criteria is met. If the fractured face constitutes at least one-quarter of the maximum cross-sectional area of the rock particle and the face has sharp or slightly blunt edges, it is considered a crushed particle.

3) Particles are separated into two categories: (a) crushed particles, and (b) non-crushed particles.

4) When two-faced crushed particles are required for aggregates used in HMA the procedure is repeated on the same sample.

5) The percent of crushed particles is then determined by the following formula:

$$P = \frac{F}{F + N} \times 100$$

where:

P = percentage of crushed particles
F = weight of crushed particles
N = weight of uncrushed particles

FLAT AND ELONGATED PARTICLES

ASTM D 4791 outlines the procedure for determining the quantity of flat and elongated particles. The Standard Specifications define a flat and elongated particle as “one having a ratio of length to thickness greater than five.

The test is conducted on all particles retained on the 3/8 in. sieve and each sieve above the 3/8 in. sieve and is performed as follows:

1) The total sample retained on the 3/8 in. sieve is weighed.

2) Each size fraction above the 3/8 in. sieve present in the amount of 10% or more of the original sample is reduced until approximately 100 particles are obtained for each size fraction.

3) Each particle is measured with the proportionate caliper device (Figure 4.1) set at the required ratio.

4) The flat and elongated particles are weighed for each sieve.

5) The percent of the flat and elongated particles is then determined on each sieve by the following formula:

$$\%\ \text{Flat and Elong. Particles} = \frac{\text{Weight of F \&E Particles for each Sieve}}{\text{Total Weight of Reduced Sample for each Sieve}} \times 100$$

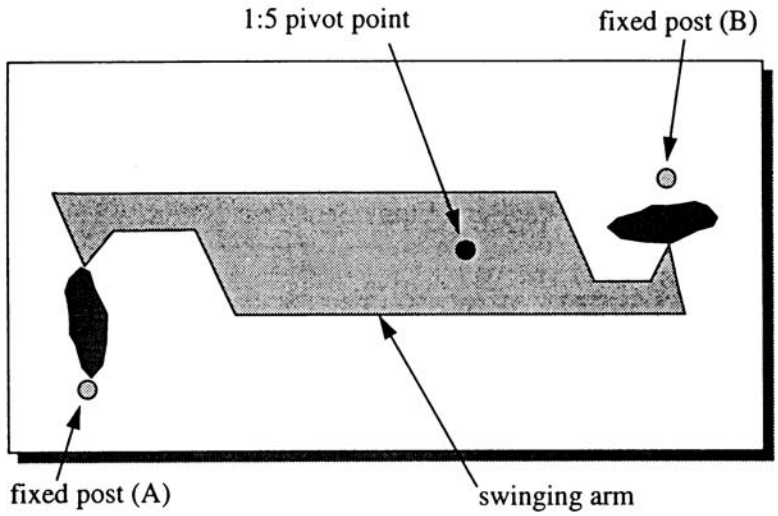


Figure 4.1 - Proportional Caliper Device to Measure Flat and Elongated Particles

CLAY CONTENT

Clay content is the percent of clay material contained in the aggregate fraction that is finer than a No. 4 sieve. The test used for determining the clay content is the Sand Equivalent Test (**AASHTO T 176**). In this test, a sample of fine aggregate is placed in a graduated cylinder with a flocculating solution and agitated to loosen clayey fines present in and coating the aggregate. The flocculating solution forces the clayey material into suspension above the granular aggregate. After a period that allows sedimentation, the cylinder height of suspended clay and sedimented sand is measured (Figure 4.2). The sand equivalent value is computed as a ratio of the sand to clay height readings expressed as a percentage.

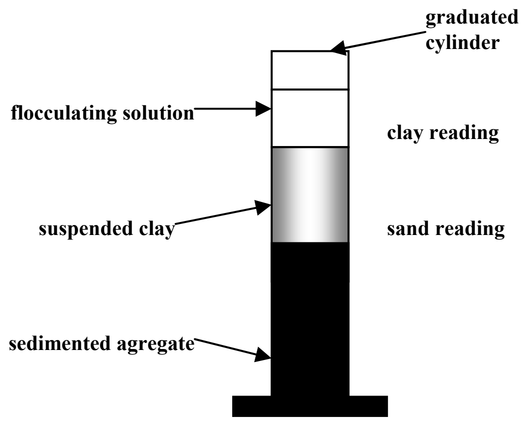


Figure 4.2 Sand Equivalent Test

FINE AGGREGATE ANGULARITY

Fine aggregate angularity is the percent air voids present in loosely compacted aggregates finer than the No. 8 sieve. The test used for determining the Fine Aggregate Angularity is the Uncompacted Void Content of Fine Aggregate Test (**AASHTO T 304 - Method A**). In the test, a sample of fine aggregate is poured into a small calibrated cylinder by flowing through a standard funnel (Figure 4.3). By determining the mass of the fine aggregate (W) in the filled cylinder of known volume (V), void content can be calculated as the difference between the cylinder volume and fine aggregate volume collected in the cylinder. The fine aggregate bulk specific gravity (G_{sb}) is used to compute the fine aggregate volume.

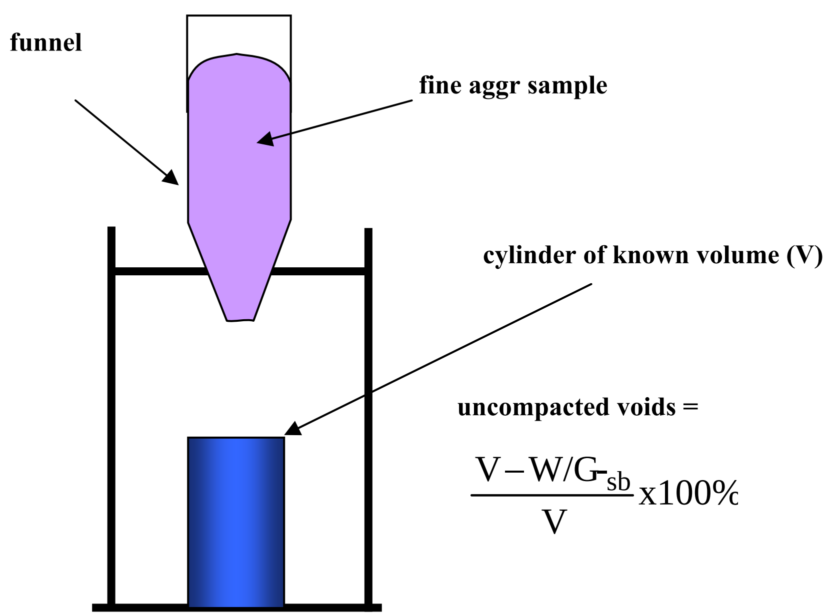


Figure 4.3 Fine Aggregate Angularity Apparatus

PLASTIC LIMIT

Compacted aggregate materials, fine aggregate for SMA, mineral filler for SMA, and coarse aggregate sizes 43, 53, and 73 require tests for determining the plastic limit and liquid limit of minus No. 40 sieve material. The plastic limit can be performed accurately only in a laboratory; however, the possibility of a plastic condition may be determined by a field check test. The liquid limit must be performed in the laboratory.

The plastic limit test **cannot** be performed on the same sample used for any other field tests. Therefore, in addition to the sample selected for the other field tests, the technician should split and dry a sample of approximately 1000 grams. The test is performed using a small spatula, a ground-glass plate, and an evaporating dish. The test is performed in accordance with **AASHTO T 90** as follows:

1) Using sufficient sieves, remove all the material above the No. 40 sieve. It is important to have all of the minus No. 40 sieve material in the sample. Any minus No. 40 sieve material clinging to the larger particles should be scraped free and all the dried composite particles retained above the No. 40 sieve should be broken up.

2) Thoroughly mix the minus No. 40 sieve material and select a sample of about 20 grams.

3) Place the sample in a suitable container, preferably an evaporating dish, and thoroughly mix with distilled or demineralized water until the material becomes plastic enough to be easily shaped into a ball.

4) Take about half of the sample and squeeze and form it into the shape of a small cigar. Place the specimen on a ground glass plate. With fingers, using just sufficient pressure, roll the specimen into a thread of uniform diameter throughout its length. The rate of rolling will be between 80 and 90 strokes per minute, counting a stroke as a complete motion of the hand forward and back to the starting position. The rolling will continue until the thread is 1/8 in. in diameter.

Most of the compacted aggregate materials do not contain plastic fines. If the specimen cannot be rolled into a thread of 1/8 in. diameter, the technician may assume that the material is either nonplastic or has a low plastic content, and no additional testing is needed. If the specimen can be rolled into a thread of 1/8 in., the material is considered plastic and further testing should be done for an accurate determination of plasticity index.

TOTAL MOISTURE CONTENT

When aggregates are used in portland cement concrete mixtures, the moisture on the aggregates is required to be determined to adjust aggregate weights for moisture content and to determine the moisture contribution to the mixing water.

When a moisture content is desired, the sample must be reduced to test size and the test run as quickly as possible after the sample has been taken. Any delay in running the test after the sample has been selected may allow the material to lose moisture and cause inaccurate results.

The test is performed in accordance with **AASHTO T 255** as follows:

1) Weigh the sample before drying and record the weight.

2) Dry the sample and allow to cool to room temperature.

3) Weigh the sample and record the weight.

4) Determine the moisture percent using this formula:

$$\% \text{ Moisture} = \frac{\text{Weight Wet} - \text{Weight Dry}}{\text{Weight Dry}} \times 100$$

5 Aggregate Specifications and Requirements

Physical Quality Requirements

Fine Aggregates
Coarse Aggregates

Physical Quality Tests

Absorption
Abrasion Resistance
Soundness
Deleterious
Special Requirements

General Usage Requirements

Fine Aggregates
Coarse Aggregates

Gradation Requirements

Fine Aggregates
Coarse Aggregates
B Borrow and Structure Backfill
Riprap
Aggregate Base
Subbase
Aggregate Pavement or Shoulders
Summary of Gradation Requirements

5 CHAPTER FIVE:
AGGREGATES SPECIFICATIONS and REQUIREMENTS

Specifications are generally clear, concise, quantitative descriptions of the significant characteristics of a construction material. The specifications required by INDOT are documented in the latest edition of the Standard Specifications and the current Supplemental Specifications. The specifications for aggregates are detailed in Section **904** and other sections for the various types of construction. These specifications are to be followed when inspecting aggregates.

There are two general types of requirements for aggregate: quality and gradation.

PHYSICAL QUALITY REQUIREMENTS

Physical quality requirements are all specification provisions other than those dealing with gradation or usage requirements. These requirements can be divided into five distinct groups as follows:

1) Absorption;
2) Abrasion resistance;
3) Soundness;
4) Restrictions on deleterious constituents; and
5) Special requirements.

Fine Aggregates

Section **904.02** defines the acceptable limits for all uses of fine aggregates.

Fine aggregates are not divided into classes. The quality ratings assigned to fine aggregates regarding their approval for use on highway construction projects are:

A5 = approved for all uses.

B5 = approved for all uses where manufactured fine aggregate is allowed.

G5 = not approved.

The “A” rating is for all natural sands. The “B” rating is for manufactured fine aggregates.

Coarse Aggregates

Section **904.03** defines the acceptable limits for all uses of coarse aggregates.

Coarse aggregates are divided into classes based on quality requirements as noted on the Classification of Aggregates table. Class AP is the highest class and is assigned to aggregates which meet the requirements for all INDOT uses. Some INDOT contracts specify type AP aggregates for use in on-grade application of portland cement concrete. Parameters concerning type AP aggregate are contained in **ITM 210**. Aggregates having restricted approval are rated Classes B, C, D, E, and F.

PHYSICAL QUALITY TESTS

Approval and use of aggregates is based upon meeting physical test requirements in the following physical tests.

Absorption

The absorption quality requirement applies only to coarse aggregates, but this data is necessary on fine aggregate for other purposes, such as mix design and water/cementitious ratios.

All aggregates are porous, but some are more porous than others. How porous an aggregate is determines how much liquid can be absorbed when soaked in water. The test method **AASHTO T 85** defines absorption as the increase in the weight of aggregate because of water in the pores of the material, but not including water adhering to the outside surface of the particles. Absorption is expressed as a percentage of the dry weight.

Absorption requirements are of concern only regarding aggregates used in hot mix asphalt and portland cement concrete. The intent is to avoid using highly porous, absorptive aggregates because extra water and cement or asphalt is needed to make a good mix. However, some aggregates, such as blast furnace slag, may be used despite their high absorptive capacity because of other characteristics that make them desirable, including skid resistance, economics, etc.

The maximum percentage of absorption allowed by the Standard Specifications is 5.0 percent and applies to aggregate classes AP, AS, A, B, and C only.

Abrasion Resistance

Abrasion resistance applies only to coarse aggregates.

Aggregates vary in their resistance to fracturing under impact (toughness) and breaking down into smaller pieces from abrasive action (hardness). The acceptable limits are set by the Los Angeles Abrasion Test in the test method **AASHTO T 96**. The limits vary from 30.0 to 50.0 percent, depending on the classification of the aggregate. The percentage is a measure of the degradation or loss of material as a result of impact and abrasive actions. Section **904.03** details the requirements. Abrasion requirements do not apply to blast furnace slag.

Soundness

The quality of soundness applies to both fine and coarse aggregates. The durability of aggregates or their resistance to the forces of weathering is undoubtedly one of the most important considerations in the selection of a material for highway construction. The primary exposure that INDOT is concerned with is alternate freezing and thawing.

INDOT uses three different test methods to evaluate soundness:

1) The water freeze and thaw test in accordance with **AASHTO T 103**, **Procedure A**

2) The sodium sulfate test in accordance with **AASHTO T 104**;

3) The brine freeze and thaw test in accordance with **ITM 209**.

The water freeze and thaw test requires the aggregates to be sealed and totally immersed in water and then be subjected to 50 cycles of freeze and thaw. The sodium sulfate test requires the aggregate to be immersed in a sodium sulfate solution and then be subjected to 5 cycles of alternate immersion and drying. The brine freeze/thaw requires the aggregate to be enclosed in a bag containing a 3 percent sodium chloride solution and then be subjected to 25 cycles of freeze and thaw.

The freezing and thawing in water test is the method that most accurately simulates actual field conditions, but the test requires a long period of time to conduct. The "quick" checks for soundness of the aggregate are the brine freeze/thaw and sodium sulfate test. If the aggregate fails the freeze and thaw test in water, the material is tested using either the brine freeze and thaw or sodium sulfate test. An aggregate that fails the freeze and thaw in water method but then passes the brine freeze and thaw or sodium sulfate test is an acceptable material for use on INDOT contracts.

Deleterious Materials

Certain substances in aggregates are undesirable for use in portland cement concrete. Therefore, the Standard Specifications limit the amount of deleterious constituents to a level consistent with the quality sought in the final product.

Organic impurities are the only concern in fine aggregates. Section **904.02** places a restriction for fine aggregate for use in portland cement concrete and mortar. No restrictions are placed on organic impurities in fine aggregate for use in other types of construction.

The limitations on the amount of organic impurities allowed in fine aggregates are determined by the test method for organic impurities **AASHTO T 21** and the test method for Mortar Strength **AASHTO T 71**. According to the Standard Specifications, materials failing the organic impurities test are to be tested for the effect of organic impurities using the mortar strength test. The results of the test are the basis for acceptance or rejection of the fine aggregate.

Section **904.03** includes a general statement regarding deleterious substances that applies to all classes of coarse aggregates. Section **904.03** also details more specific restrictions for other harmful substances as a maximum allowable percentage of the mass of each of the deleterious materials in a total sample of aggregates being tested. Figure 4-1 illustrates the materials which are classified as deleterious and the specification limits for each.

Clay Lumps and Friable Particles

Clay lumps and friable particles are materials that are easily crumbled or mashed with the fingers. Testing for these particles is performed by **AASHTO T 112**, Clay Lumps and Friable Particles in Aggregates.

Non-Durable Particles

Non-durable particles are divided into two types; soft materials as determined by **ITM 206**, Scratch Hardness, and structurally weak material as determined by visual inspection.

Coke and Iron

Coke and iron are of concern only with the slag materials. Coke is an ingredient in the iron making process. Slag from these furnaces normally are free of objectionable amounts of coke and iron.

Chert

Chert is a rock of almost any color and is composed of glassy silicon and very fine-grained quartz. Chert breaks into rounded surfaces with sharp edges. Unweathered chert appears hard, dense and brittle with a waxy or greasy texture. Weathered chert appears chalky or earthy and porous with a dull texture. Chert is picked visually.

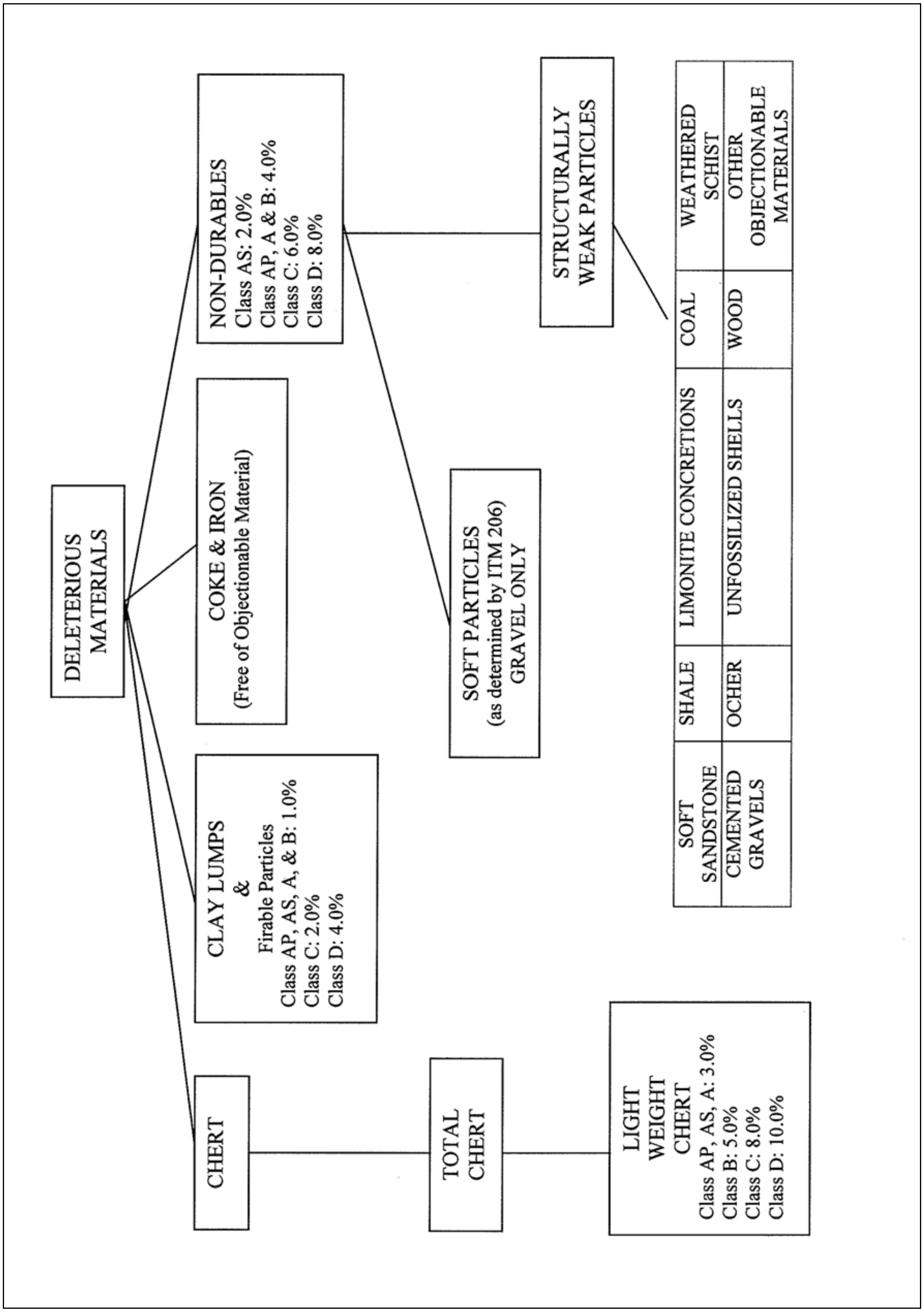


Figure 5-1. Deleterious Materials

SPECIAL REQUIREMENTS

In some cases, aggregates must meet special requirements for a particular use in construction as required in various Sections of **904**. Some contracts may specify a unique gradation or aggregate. Details pertaining to this special requirement will appear in the Special Provision section of the contract proposal booklet for that contract.

Fine Aggregates

All fine aggregates, except air-cooled blast furnace slag sand or granulated blast furnace slag sand, must have an acid insoluble content of not less than 40 percent. When using these slag sands, the acid insoluble content must not be less than 25 percent. The acid insoluble content is determined by **ITM 202**.

All fine aggregates used for HMA are required to be in accordance with **904.02** for soundness. If soundness testing cannot be conducted, the aggregate shall originate from a Category I source in accordance with **ITM 203**.

Coarse Aggregates

All Coarse Aggregates

A special requirement placed on all coarse aggregates deals with the restriction on the number of flat and elongated pieces. Section **904.03** sets the limits for the number of flat and elongated pieces. A flat and elongated piece is defined as one having a ratio of length to thickness greater than five. The method for determining the actual percentage of flat and elongated pieces is described in test method **ASTM D 4791**.

Dolomitic Aggregates

There is a special requirement to be met when dolomitic coarse aggregates are specified in HMA. These aggregates are specified for use under some conditions to obtain high-friction, skid-resistant hot mix asphalt surface courses. **ITM 205** is used to ensure that the aggregate proposed is carbonate rock containing at least 10.3 percent elemental magnesium.

Polish Resistant Aggregates

Aggregates that meet the requirements of **ITM 214** may be used in place of dolomitic aggregates in HMA surface mixtures. The procedure for approval requires initial British Polishing testing, placement of a test section on an INDOT project, and subsequent skid testing for two years.

Sandstone Aggregates

Coarse sandstone must meet the Class B quality requirements, and may only be used in HMA surface mixtures. The definition of sandstone is described in Section **904.02**.

Slag Aggregates

When slag is furnished as an alternate to natural aggregate, the payment is on a weight basis, adjustments must be made to compensate for the difference in specific gravity of the slag compared to the specific gravity of the natural aggregate. For any pay item less than 500 tons on a contract, no adjustment is made. The following typical values should be used.

TYPICAL VALUES FOR SPECIFIC GRAVITY	
Natural aggregates (both fine and coarse)	2.6
Air Cooled blast furnace slag coarse aggregate	2.3
Air cooled blast furnace slag fine aggregate	2.6
Granulated blast furnace slag fine aggregate	2.1
Steel furnace slag, both fine and coarse	3.2

Gravel Coarse Aggregates

There is a specific requirement for gravel coarse aggregates regarding crushed particles. This requirement applies, however, only when gravel coarse aggregates are used in HMA, compacted aggregates, and asphalt seal coats except asphalt seal coats used on shoulders. Crushed particles are defined as those particles having one or more sharp, angular, fractured faces. Fractured faces that have an area less than 25 percent of the maximum cross sectional area of the particle are not considered crushed. **ASTM D 5821** is used to determine the crushed particle content. Crushed gravel must comply with the requirements in Section **904.03**.

Type AS Aggregates

Aggregates used for stone matrix asphalt mixtures are required to meet the requirements of AS aggregates in accordance with Section **904.03 (a)**. These requirements include testing with the Micro-Deval abrasion apparatus **(AASHTO T 327)** and determination of the aggregate degradation in accordance with **ITM 220**. Additional requirements for control of the specific gravity of the steel furnace slag are included in Section **904.01**.

Type AP Aggregate

INDOT requires that contracts with on-grade portland cement concrete be constructed with AP aggregate. Details and parameters concerning AP aggregate are described in **ITM 210**.

Blended Aggregates

The total blended aggregate from the fine and coarse aggregates, and recycled materials used in HMA shall meet the fine aggregate angularity (FAA) requirements of Section **904.02(b)**. The procedure for determining the FAA value is described in **AASHTO T 304**.

The clay content of the blended aggregate shall meet the requirements of Section **904.02(b)**. The procedure for determining this value is described in **AASHTO T 176**.

GENERAL USAGE REQUIREMENTS

The general usage requirements first describes the type of material which is considered acceptable for the type of construction, and, second, describes the requirements which influence the acceptability of the material.

Fine Aggregates

Section **904.02** states that fine aggregate shall consist of natural sand or manufactured sand produced by crushing limestone, dolomite, steel furnace slag, air cooled blast furnace slag, or wet bottom boiler slag. At the time of use these materials shall be free from lumps or crusts of hardened or frozen materials. The detection of lumps or crusts of hardened or frozen materials is possible only through visual inspection.

THE SPECIFIC REQUIREMENTS OF FINE AGGREGATES IN ACCORDANCE WITH SECTION 904.02:	
TYPE OF CONSTRUCTION	*ACCEPTABLE FINE AGGREGATE*
Portland cement concrete for pavement or bridge decks	Natural sand
Portland cement concrete for other construction	Natural sand or crushed limestone, dolomite, or air-cooled blast furnace slag.
Hot mix asphalt	Natural sand or manufactured sand. Steel furnace slag sand is permitted only with Steel furnace slag coarse aggregate. Combination of natural sand and manufactured sand is permitted. However, not more than 20 percent of the total aggregate used in HMA surface mixtures with ESAL equal to or greater than 3,000,000 may be crushed limestone sand if the limestone sand is from a source not on the Approved Polish Resistant Aggregate List.
Pneumatic placement	Natural sand suitable for use with a pneumatic sand cement gun.
Mortar	Natural sand
Mineral Filler	Dust produced by crushing stone, portland cement, or other inert mineral matter.
Snow and ice abrasives	Steel furnace slag, air-cooled blast furnace slag, granulated blast furnace slag, natural sand, crushed stone sand, or cinders.

Quality Ratings

The minimum quality rating for a specified use of fine aggregate is as follows:

Portland Cement Concrete for Pavement or Bridge Decks	A5
All Portland Cement Concrete except pavement or Bridge Decks	A5 or B5
All HMA/CMA Mixtures	A5 or B5
Pneumatic Placement	A5
Mortar	A5
Mineral filler	(None Specified)

Description for quality ratings for fine aggregate

A5 Material meets quality requirements for all uses of Fine Aggregate

B5 Material meets quality requirements for all uses of Fine Aggregate permitting manufactured Fine Aggregate.

G5 Material does not meet Fine Aggregate quality requirements for any INDOT use.

Coarse Aggregates

Section **904.03** includes the general requirements for coarse aggregate. This section lists several of the types of materials that can be used as coarse aggregate, and their applications and limitations.

CLASS OF COARSE AGGREGATES REQUIRED FOR VARIOUS TYPES OF CONSTRUCTION	
TYPE OF CONSTRUCTION	*REQUIRED QUALITY CLASSIFICATION*
Aggregate Base	Class A, B, C, or D
Subbase	Class A or B (No. 8,) Class A, B, C, or D (No. 53)
Aggregate Pavements or Shoulders	Class A, B, C, or D
HMA base coarse	Class A, B, C, or D
HMA intermediate course	Class A, B, or C
HMA surface course	Class A or B
SMA surface course	Class AS
Asphalt seal coat	Class A or B
Portland cement concrete pavement	Class AP
Portland cement concrete structural-- exposed	Class A or AP
Portland cement concrete structural-- non-exposed	Class A or B
Cover (choke) aggregates coarse aggregate	Class A or B

When more than one aggregate classification is allowed, the contractor or producer has a choice, unless specified by provisions within a given contract. The class of aggregate can never be less than the lowest class for the designated use. For example, the highest class of aggregate for HMA surface course, Class A, may be used (with no additional payment to the contractor or producer). Class B aggregate may be used as the minimum requirement. For portland cement concrete pavement, the aggregate is required to be Class AP.

Quality Ratings

The minimum quality rating for a specified use of coarse aggregate is as follows:

No. 8 Exposed Concrete	A1
No. 11 Exposed Concrete	A3
No. 8 Non-Exposed Concrete	B1
HMA/CMA Surface	B1, B2, or B3
No. 8 Seal Coats	B1
No. 9 Seal Coats	B2
No. 11 Seal Coats	B3
No. 12 Seal Coats	B3
HMA/CMA Intermediate	C1, C2, or C3
HMA/CMA Base	D1
No. 43 Compacted Aggregate Base	B1
No. 53 Compacted Aggregate Base	D1
No. 73 Compacted Aggregate Base	D1
No. 8 Aggregate for Shoulder Drains	E1
No. 11 Aggregate for Shoulder Drains	E3
No. 12 Aggregate for Shoulder Drains	E3
Rip Rap	F1

<u>Description of quality ratings for coarse aggregate</u>

A0 Material meets requirements for all uses requiring AP Coarse Aggregates.

A1 Material meets quality requirements for all uses of Coarse Aggregate.

A2 Material meets quality requirements for all uses of Coarse Aggregate with a top size not exceeding 3/4 in.

A3 Material meets quality requirements for all uses of Coarse Aggregate with a top size not exceeding 1/2 in.

A4 Material meets quality requirements for Class A Coarse Aggregate, but is only approved for the special gradation submitted.

B1 Material meets quality requirements for all uses of Coarse Aggregate except for use in exposed Portland Cement Concrete.

B2 Material meets quality requirements for all uses of Coarse Aggregate with a top size not exceeding 3/4 in. except it is not approved for use in exposed Portland Cement Concrete.

B3 Material meets quality requirements for all uses of Coarse Aggregate with a top size not exceeding 1/2 in. except it is not approved for use in exposed Portland Cement Concrete.

B4 Material meets quality requirements for Class B Coarse Aggregate, but is only approved for the special gradation submitted.

C1 Material meets quality requirements for all uses of Coarse Aggregate except for use in Portland Cement Concrete or in HMA/CMA Surface Mixtures.

C2 Material meets quality requirements for all uses of Coarse Aggregate with a top size not exceeding 3/4 in. except it is not approved for use in Portland Cement Concrete or in HMA/CMA Surface Mixtures.

C3 Material meets quality requirements for all uses of Coarse Aggregate with a top size not exceeding 1/2 in. except it is not approved for use in Portland Cement Concrete or in HMA/CMA Surface Mixtures.

C4 Material meets quality requirements for Class C Coarse Aggregate, but is only approved for the special gradation submitted.

D1 Material meets quality requirements for all uses of Coarse Aggregate except for use in Portland Cement Concrete or in HMA/CMA Mixtures.

D2 Material meets quality requirements for all uses of Coarse Aggregate with a top size not exceeding 3/4 in. except it is not approved for use in Portland Cement Concrete or in HMA/CMA Mixtures.

D3 Material meets quality requirements for all uses of Coarse Aggregate with a top size not exceeding 1/2 in. except it is not approved for use in Portland Cement Concrete or in HMA/CMA Mixtures.

E1 Material meets quality requirements for Coarse Aggregate for use in granular subbase, subsurface drains, or rip rap.

E2 Material meets quality requirements for Coarse Aggregate for use in granular subbase, or subsurface drains with a top size not exceeding 3/4 in.

E3 Material meets quality requirements for Coarse Aggregate for use in granular subbase, or subsurface drains with a top size not exceeding 1/2 in.

E4 Material meets quality requirements for Class E Coarse Aggregate, but is only approved for the special gradation submitted.

F1 Material meets quality requirements for Rip Rap Aggregate.

F4 Material meets quality requirements for Class F Coarse Aggregate, but is only approved for the special gradation submitted.

G1 Material does not meet Coarse Aggregate quality requirements for any INDOT use.

GRADATION REQUIREMENTS

The gradation or particle-size distribution of an aggregate is usually specified to be within certain limits for various types of construction. There is a great difference between what is considered an acceptable grading for aggregates for HMA, for portland cement concrete, or for base layers. The gradation that aggregates are required to meet for specific types of construction is contained in the contract plans, special provisions, or standard specifications and is usually designated by the aggregate size.

Sections **904.02** and **904.03** contain tables describing the acceptable particle-size distribution for various sizes of both fine and coarse aggregates. Section **904.04** outlines the acceptable gradations for riprap and Section **904.05** specifies the sizes for structure backfill.

Fine Aggregates

The table found in Section **904.02** is used to accept six aggregates used for HMA, portland cement concrete, pneumatic placement mortar, mortar sand, mineral filler, and snow and ice abrasives. The table lists the six sizes of fine aggregates--number 23, 24, 15, 16, PP, and S & I. Number 16 is the finest aggregate, because 100 percent of the fine aggregate must pass the No. 30 sieve. Number 23 is the coarsest of the six sizes. Note that all fine aggregate particles are generally expected to pass the No. 4 sieve.

The aggregates for mortar sand must meet the gradation for size number 15 or an approved gradation from a CAPP source. The fine aggregates for pneumatic placement may meet size number 15, PP, or an approved gradation from a CAPP source. Mineral filler for SMA is required to meet size number 16.

Snow and ice abrasives must meet the gradation requirement of Section **904.02(f)**.

Coarse Aggregates

The table found in Section **904.03** applies to coarse aggregates. The table shows ten sizes of coarse aggregates--numbers 2, 5, 8, 9, 11, 12, 43, 53, 73, and 91. Number 2 is the coarsest size and number 12 is the finest. Numbers 53 and 73 are dense graded aggregates and number 91 is used for aggregates in pre-cast concrete. Note that the majority of the aggregate is retained on the No. 4 sieve and larger.

B Borrow and Structure Backfill

B Borrow and structure backfill requirements are listed in Section **211**.

Materials for B borrow are required to contain no more than 10 percent passing the No. 200 sieve and shall be otherwise suitably graded as noted in Section **211.02**. The use of an essentially one-size material will not be permitted unless approved.

Structural backfill gradations are listed in Section **904.05**. The percent of material required to pass varies by aggregate size. For example, for the 2 in. aggregate, at least 90 percent should pass the 2 in. sieve. For the 1 in. aggregate, at least 85 percent should pass the 1 in. sieve and for the No. 30 aggregate, at least 70 percent should pass the No. 30 sieve.

Riprap

Aggregate used for this purpose is found in Section **904.04**. These materials are typically large and are used as a protective coating as specified. Revetment, Class 1, Class 2, and Uniform Riprap shall meet the requirements of Section **904.04(f).** The other ripraps listed have general size limitations.

Aggregate Base

Section **301** includes the requirements for dense graded compacted aggregate material. No. 53 aggregate is used for this purpose.

Subbase

Section **302** includes the requirements for subbase placed on a prepared subgrade for PCCP. Subbase consists of a No. 8 or aggregate as the drainage layer over a No. 53 aggregate as the separation layer. Where a dense graded subbase is required, only No. 53 aggregate is used.

Aggregate Pavements or Shoulders

Section **303** includes the requirements for pavements or shoulders. No. 53 and No. 73 aggregate is used for this purpose except that No. 73 aggregate is only used for surface courses.

Summary of Gradation Requirements

The gradation requirements for fine and coarse aggregates as specified in various sections of the Standard Specifications for significantly different types of construction are summarized below. This listing is not all-inclusive, but covers the major uses of aggregates. A review of the Standard Specifications shall always be necessary.

TYPE OF CONSTRUCTION REQUIREMENTS	GRADATION
Aggregate Base * Coarse aggregate	 No. 53
Subbase * Coarse aggregate	 Nos. 8, 53
Aggregate Pavements or Shoulders * Coarse aggregate	 Nos. 53, 73
Asphalt Seal Coat * Fine aggregate * Coarse aggregate	 Nos. 23 or 24 Nos. 8, 9, 11, 12
Portland cement concrete pavement/structural * Fine aggregate * Coarse aggregate	 No. 23 No. 8

Appendices A-B

Appendix A - Indiana Test Methods

1. ITM No. 202
2. ITM No. 203
3. ITM No. 205
4. ITM No. 206
5. ITM No. 207
6. ITM No. 209
7. ITM No. 210
8. ITM No. 212
9. ITM No. 902
10. ITM No. 903
11. ITM No. 906
12. ITM No. 910

Appendix B - AASHTO Test Methods

1. AASHTO T2
2. AASHTO T11
3. AASHTO T27
4. AASHTO T84
5. AASHTO T85
6. AASHTO T112
7. AASHTO T248
8. AASHTO T304

ASTM Test Methods

1. ASTM D 4791
2. ASTM D 5821