IV. Superpave Aggregates

Superpave refined existing methods for testing and specifying aggregates for HMA. The objectives of this section will be to:

- describe the Superpave aggregate test procedures
- explain the Superpave aggregate specification requirements and how they are used in preventing permanent deformation and fatigue cracking
- discuss the Superpave aggregate gradation evaluation procedure

AGGREGATE TESTS AND SPECIFICATIONS

Consensus Properties

It was the consensus of the SHRP pavement researchers that certain aggregate characteristics were critical and needed to be achieved in all cases to arrive at well performing HMA. These characteristics were called "consensus properties" because there was wide agreement in their use and specified values. Those properties are:

- coarse aggregate angularity,
- fine aggregate angularity,
- flat, elongated particles, and
- clay content.

COARSE AGGREGATE ANGULARITY

This property ensures a high degree of aggregate internal friction and rutting resistance. It is defined as the percent by weight of aggregates larger than 4.75 mm with one or more fractured faces.

The test procedure for measuring coarse aggregate angularity is ASTM D 5821, *Standard Test Method for Determining the Percentage of Fractures Particles in Coarse Aggregate.* The procedure involves manually counting particles to determine fractured faces. A fractured face is defined as any fractured surface that occupies more than 25 percent of the area of the outline of the aggregate particle visible in that orientation.

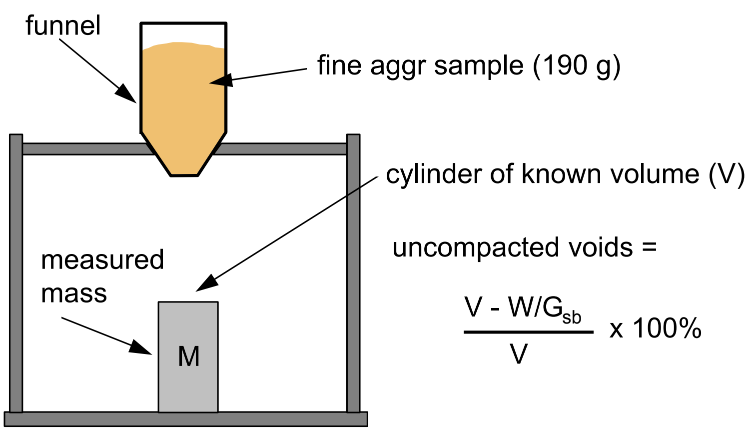
The required minimum values for coarse aggregate angularity are a function of traffic level and position within the pavement. These requirements apply to the final aggregate blend, although estimates can be made on the individual aggregate stockpiles.

Superpave Coarse Aggregate Angularity Requirements		
Traffic, million ESALs	Percent, Minimum	
	Depth from Surface	
	< 100 mm	> 100 mm
< 0.3	55/-	-/-
0.3 to < 3	75/-	50/-
3 to < 10	85/80	60/-
10 to < 30	95/90	80/75
$\geq$ 30	100/100	100/100
Note: "85/80" means that 85 % of the coarse aggregate has one fractured face and 80 % has two fractured faces.		

FINE AGGREGATE ANGULARITY

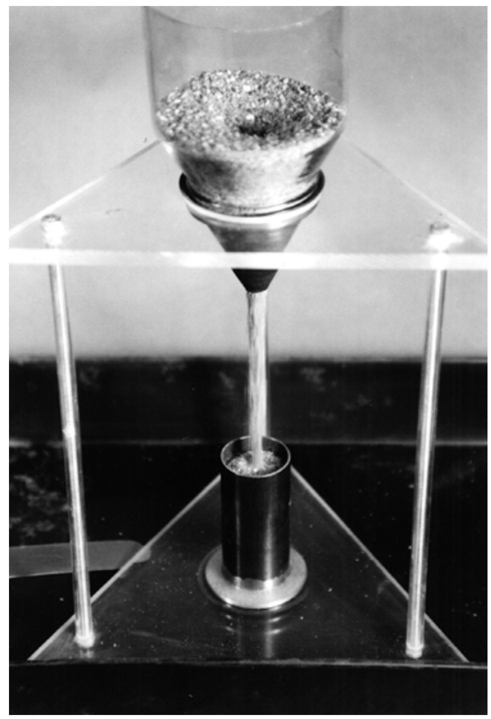
This property ensures a high degree of fine aggregate internal friction and rutting resistance. It is defined as the percent air voids present in loosely compacted aggregates smaller than 2.36 mm. Higher void contents mean more fractured faces.

The test procedure used to measure this property is AASHTO T 304 "*Uncompacted Void Content - Method A.*" In the test, a sample of fine aggregate is poured into a small calibrated cylinder by flowing through a standard funnel. By determining the weight of 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 fine aggregate volume.



uncompacted voids =

$$\frac{V - W/G_{sb}}{V} \times 100\%$$



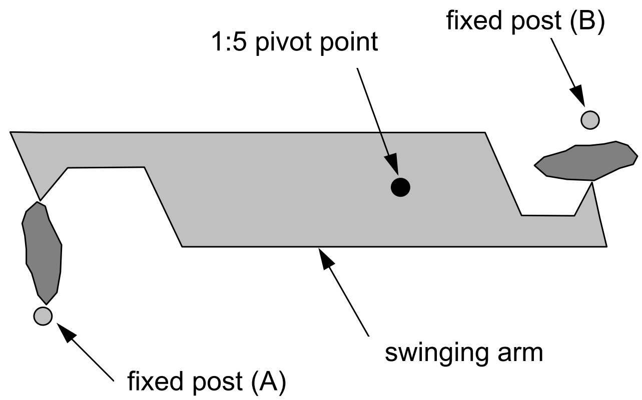
The required minimum values for fine aggregate angularity are a function of traffic level and position within pavement. These requirements apply to the final aggregate blend, although estimates can be made on the individual aggregate stockpiles.

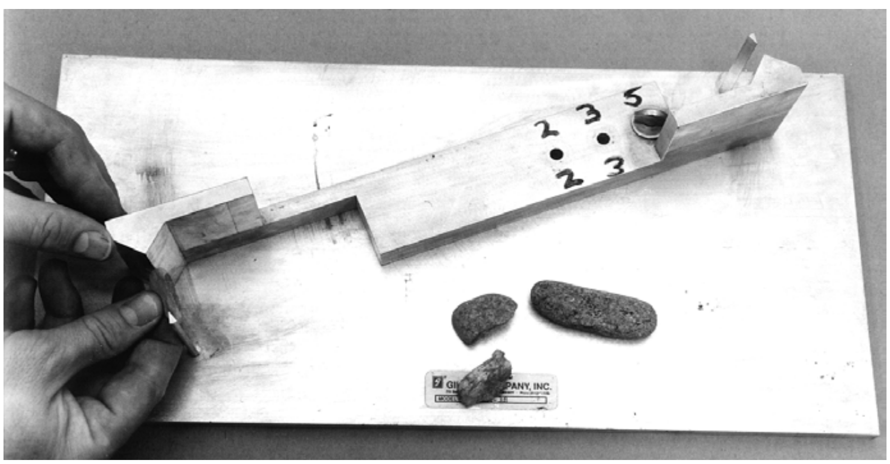
Superpave Fine Aggregate Angularity Requirements		
Traffic, million ESALs	Percent, Minimum Depth from Surface	
	< 100 mm	> 100 mm
< 0.3	-	-
0.3 to < 3	40	40
3 to < 10	45	40
10 to < 30	45	40
$\geq$ 30	45	45
Note: Criteria are presented as percent air voids in loosely compacted fine aggregate.		

FLAT, ELONGATED PARTICLES

This characteristic is the percentage by weight of coarse aggregates that have a maximum to minimum dimension of greater than five. Elongated particles are undesirable because they have a tendency to break during construction and under traffic.

The test procedure used is ASTM D 4791, *Standard Test for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate* and it is performed on coarse aggregate larger than 4.75 mm. The procedure uses a proportional caliper device to measure the dimensional ratio of a representative sample of aggregate particles. The aggregate particle is first placed with its largest dimension between the swinging arm and fixed post at position A. The swinging arm then remains stationary while the aggregate is placed between the swinging arm and fixed post at position B. If the aggregate passes through this gap, then it is counted as a flat or elongated particle. The total flat, elongated, or flat and elongated particles are measured.





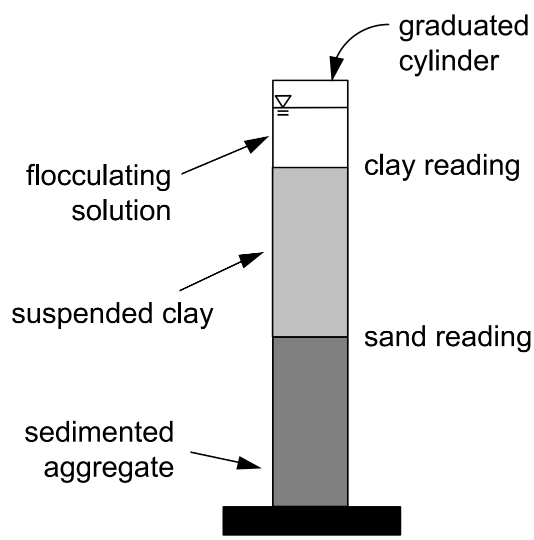
The required maximum values for flat, elongated particles in coarse aggregate are a function of traffic level. These requirements apply to the final aggregate blend, although estimates can be made on the individual aggregate stockpiles.

Superpave Flat, Elongated Particle Requirements	
Traffic, million ESALs	Percent, maximum
< 0.3	-
0.3 to < 3	10
3 to < 10	10
10 to < 30	10
≥ 30	10
Note: Criteria are presented as maximum percent by weight of flat and elongated particles.	

CLAY CONTENT

Clay content is the percentage of clay material contained in the aggregate fraction that is finer than a 4.75 mm sieve. It is measured by AASHTO T 176, *Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test*.

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. The sand equivalent value is computed as a ratio of the sand to clay height readings expressed as a percentage.



The required clay content values for fine aggregate are expressed as a minimum sand equivalent and are a function of traffic level. These requirements apply to the final aggregate blend, although estimates can be made on the individual aggregate stockpiles

Superpave Clay Content Requirements	
Traffic, million ESALs	Sand Equivalent, minimum
< 0.3	40
0.3 to < 3	40
3 to < 10	45
10 to < 30	45
≥ 30	50

Source Properties

In addition to the consensus aggregate properties, pavement experts believed that certain other aggregate characteristics were critical. However, critical values of these properties could not be reached by consensus because needed values were source specific. Consequently, a set of "source properties" were recommended. Specified values are established by local agencies. While these properties are relevant during the mix design process, they may also be used as source acceptance control. Those properties are:

- toughness,
- soundness, and
- deleterious materials.

TOUGHNESS

Toughness is the percent loss of materials from an aggregate blend during the Los Angeles Abrasion test. The procedure is stated in AASHTO T 96, "Resistance to Abrasion of Small Size Coarse Aggregate by Use of the Los Angeles Machine." This test estimates the resistance of coarse aggregate to abrasion and mechanical degradation during handling, construction, and in-service. It is performed by subjecting the coarse aggregate, usually larger than 2.36 mm, to impact and grinding by steel spheres. The test result is percent loss, which is the weight percentage of coarse material lost during the test as a result of the mechanical degradation. Maximum loss values typically range from approximately 35 to 45 percent.

SOUNDNESS

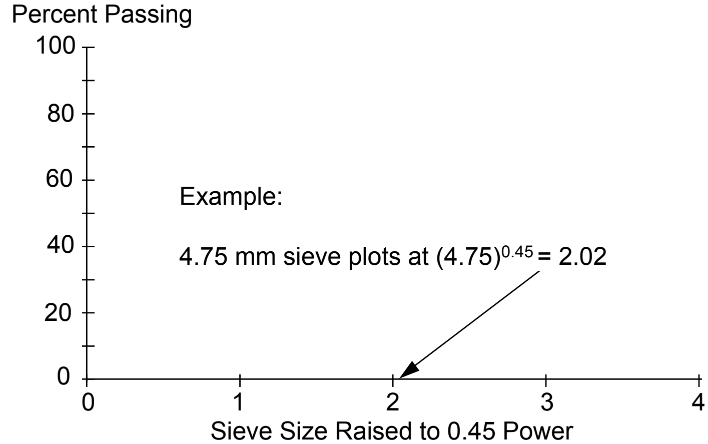
Soundness is the percent loss of materials from an aggregate blend during the sodium or magnesium sulfate soundness test. The procedure is stated in AASHTO T 104, "Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate." This test estimates the resistance of aggregate to weathering while in-service. It can be performed on both coarse and fine aggregate. The test is performed by alternately exposing an aggregate sample to repeated immersions in saturated solutions of sodium or magnesium sulfate each followed by oven drying. One immersion and drying is considered one soundness cycle. During the drying phase, salts precipitate in the permeable void space of the aggregate. Upon re-immersion the salt re-hydrates and exerts internal expansive forces that simulate the expansive forces of freezing water. The test result is total percent loss over various sieve intervals for a required number of cycles. Maximum loss values range from approximately 10 to 20 percent for five cycles.

DELETERIOUS MATERIALS

Deleterious materials are defined as the weight percentage of contaminants such as shale, wood, mica, and coal in the blended aggregate. This property is measured by AASHTO T 112, "Clay Lumps and Friable Particles in Aggregates." It can be performed on both coarse and fine aggregate. The test is performed by wet sieving aggregate size fractions over prescribed sieves. The weight percentage of material lost as a result of wet sieving is reported as the percent of clay lumps and friable particles. A wide range of maximum permissible percentage of clay lumps and friable particles is evident. Values range from as little as 0.2 percent to as high as 10 percent, depending on the exact composition of the contaminant.

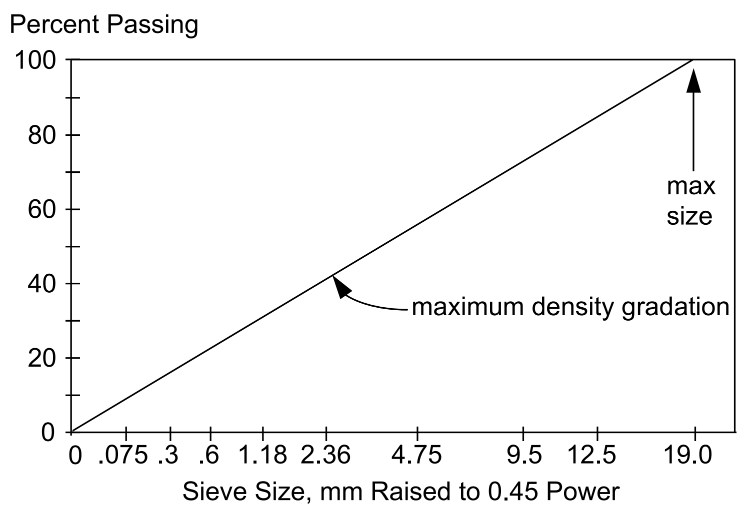
Gradation

Superpave uses the 0.45 power gradation chart to define a permissible gradation. This chart uses a unique graphing technique to judge the cumulative particle size distribution of a blend of aggregate. The ordinate of the chart is percent passing. The abscissa is an arithmetic scale of sieve size in millimeters, raised to the 0.45 power. As an example, the 4.75 mm sieve is plotted at 2.02 units to the right of the origin, This number, 2.02, is the sieve size, 4.75 mm, raised to 0.45 power. Normal 0.45 power charts do not show arithmetic abscissa labels arithmetically. Instead, the scale is annotated with the actual sieve size.



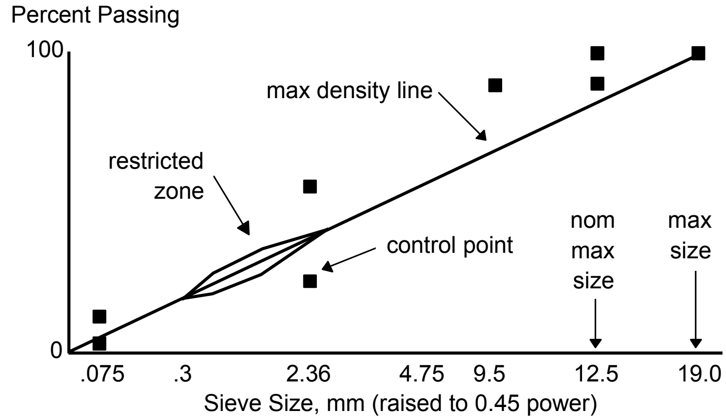
An important feature of this chart is the maximum density gradation. This gradation plots as a straight line from the maximum aggregate size through the origin. Superpave uses a standard set of ASTM sieves and these definitions with respect to aggregate size (Appendix B shows sieve sizes used by Superpave):

- Maximum Size: One sieve size larger than the nominal maximum size.
- Nominal Maximum Size: One sieve size larger than the first sieve to retain more than 10 percent.

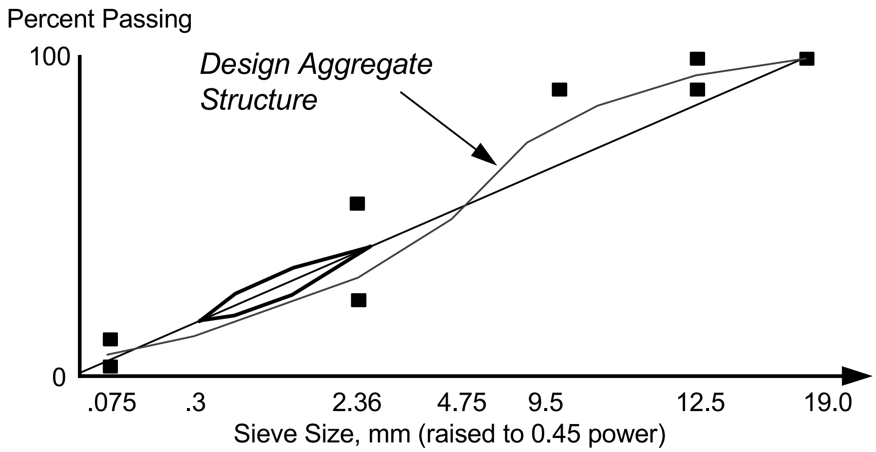


The maximum density gradation represents a gradation in which the aggregate particles fit together in their densest possible arrangement. This is a gradation to avoid because there would be very little aggregate space within which to develop sufficiently thick asphalt films for a durable mixture.

To specify aggregate gradation, two additional features are added to the 0.45 power chart: control points and a restricted zone. Control points function as master ranges through which gradations must pass. They are placed on the nominal maximum size, an intermediate size (2.36 mm), and the dust size (0.075 mm).



The restricted zone resides along the maximum density gradation between the intermediate size (either 4.75 or 2.36 mm, depending on the maximum size) and the 0.3 mm size. It forms a band through which gradations should not pass. Gradations that pass through the restricted zone have often been called "humped gradations" because of the characteristic hump in the grading curve that passes through the restricted zone. In most cases, a humped gradation indicates a mixture that possesses too much fine sand in relation to total sand. This gradation practically always results in tender mix behavior, which is manifested by a mixture that is difficult to compact during construction and offers reduced resistance to permanent deformation during its performance life. Gradations that violate the restricted zone may possess weak aggregate skeletons that depend too much on asphalt binder stiffness to achieve mixture shear strength. These mixtures are also very sensitive to asphalt content and can easily become plastic.

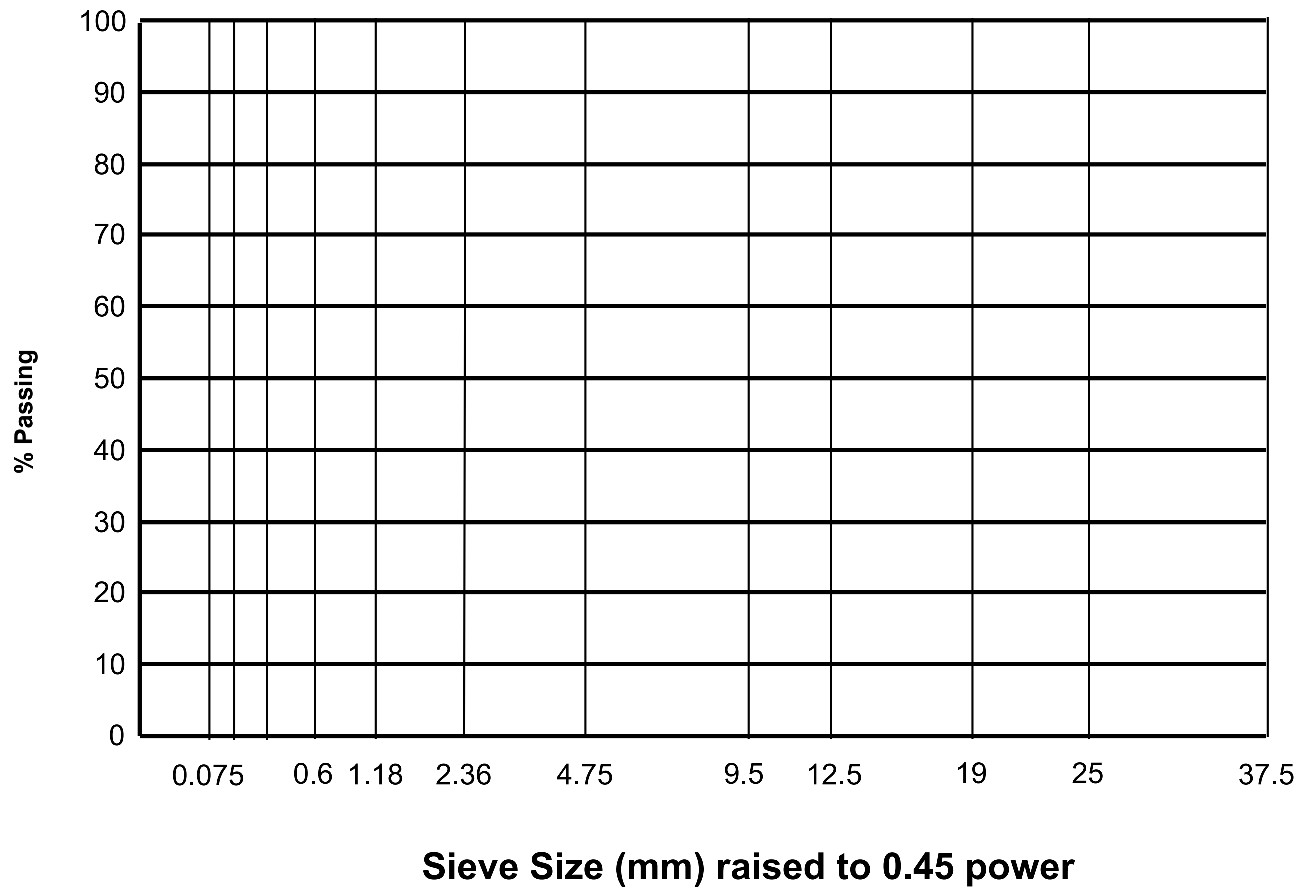


The term used to describe the cumulative distribution of aggregate particle sizes is the *design aggregate structure*. A design aggregate structure that lies between the control points and avoids the restricted zone meets the requirements of Superpave with respect to gradation. Superpave defines five mixture types as defined by their nominal maximum aggregate size. Appendix B shows the gradation limits for the five Superpave mixtures.

Superpave Mixtures		
Superpave Mixture Designation	Nominal Maximum Size, mm	Maximum Size, mm
37.5 mm	37.5	50
25 mm	25	37.5
19 mm	19	25
12.5 mm	12.5	19
9.5 mm	9.5	12.5

Superpave recommends, but does not require, mixtures to be graded below the restricted zone. It also recommends that as project traffic level increases, gradations move closer to the coarse (lower) control points. Furthermore, the Superpave gradation control requirements were not intended to be applied to special purpose mix types such as stone matrix asphalt or open graded mixtures.

Superpave Aggregate Gradation Example



Sieve	Gradation
25.0 mm	*100.0*
19.0 mm	*97.6*
12.5 mm	89.5
9.5 mm	77.7
4.75 mm	44.3
2.36 mm	*31.9*
1.18 mm	22.2
600 µm	14.5
300 µm	7.9
150 µm	4.1
75 µm	*3.5*

Nominal Maximum Size -

Maximum Size -

Draw Maximum Density Line

Plot Control Points

Plot Restricted Zone

Plot Gradation

Meet criteria?