OHD L-52
Aggregate Proportioning Guide for Optimized Gradation Concrete Mix Designs

General

This guide covers procedures for developing a well-graded aggregate combination for use in Optimized Gradation Portland Cement Concrete paving. It is the responsibility of the mix designer to design a mix with appropriate properties for the intended application and placement method. The mixture should be economical, meet workability and finishing requirements and allow for a proper air void system at a minimum water/cementitious ratio. Regardless of how the mix performs in controlled conditions, ultimately it must be evaluated on how well it performs during production and placement in the field. For both Class A and AP concrete pavements, a good OGCMD, Optimized Gradation Concrete Mix Design, should have aggregate retained on the 1" (25mm) sieve. OGCMD mixes that are deficient in coarse aggregate may not be approved by the Materials Engineer.

Concrete mixtures produced with a well-graded aggregate combination tend to reduce the need for water, provide and maintain adequate workability, require minimal finishing and consolidate without segregation. These characteristics tend to enhance placement properties as well as strength and long-term performance. Concrete mixtures produced with a gap graded aggregate combination tend to segregate easily, contain higher amounts of fines, require more water and increase susceptibility to shrinkage. These characteristics tend to limit placement properties as well as strength and long term performance.

Achieving a uniform gradation may require the use of three or more aggregate sizes. It is the responsibility of the mix designer to consider particle shape when designing a mix. When using the coarseness/workability chart it is assumed that particles are rounded or cubical shaped. Rounded or cubical shaped aggregates typically enhance workability and finishing characteristics. Flat and elongated aggregates typically limit workability and finishing characteristics.

Coarseness/workability Chart

The mathematically combined gradation, expressed as percent retained, shall be calculated for each sieve size specified in the specification. The coarseness and workability factors shall be calculated and then plotted on a coarseness/workability chart.

$$\text{CoarsenessFactor} = \frac{100 - \%\text{passing } 3/8\,\text{in.}(9.5\text{mm})\,\text{sieve}}{100 - \%\text{passing No. } 8\,(2.36\text{mm})\,\text{sieve}} \times 100$$

Workability Factor = % passing No. 8 (2.36mm) Sieve*

*The workability factor shall be increased by 2.5% for each increase of 94 pounds of cement over 564 pounds per cubic yard.

Aggregate blends with a point in the middle of Area II will produce mixtures well suited for slipform paving. Aggregate blends that plot close to the bottom boundary line may tend to have too much coarse aggregate. Those blends which plot in Area V, below the bottom boundary line of Area II, will produce rocky mixtures with inadequate mortar and shall not be allowed. Blends that plot close to the top of Area II may tend to have too much fine aggregate. Aggregate blends which plot in Area IV, above the top boundary line of Area II, will produce sandy mixtures with high amounts of fines requiring higher water contents and potential segregation. Blends in Area I will produce gap graded mixtures with inadequate workability and high potential for segregation. Aggregate blends which plot in Area III produce suitable mixtures for aggregate sizes less than 3/4" (19.0mm), but are not acceptable for ODOT pavements.

0.45 Power Curve

The 0.45 power curve plot is based on the mathematically combined percent passing gradation. Historically, the 0.45 power curve has been used to develop uniform gradations for asphalt designs; however, it is increasingly being used to develop uniform gradations for Portland Cement Concrete mix designs.

To create a 0.45 power curve plot the mathematically combined percent gradation for each sieve on a semi-log chart having percent passing on the y-axis and sieve sizes (in microns) raised to the 0.45 power on the x-axis. Sieve sizes shall include the 1 ½ in. (37.5mm), 1 in. (25.0mm), ¾ in.(19.0mm), ½ in. (12.5mm), ⅜ in. (9.5mm), No. 4 (4.75mm), No. 8 (2.36mm), No. 16 (1.18mm), No. 30 (600µm), No. 50 (300µm), No. 100 (150µm), and the No. 200 (75µm). Connect the plotted points as shown in Figure 2. Plot the maximum density line from the origin of the chart to the one size larger than the first sieve to have 90 percent or less passing.

A well-graded aggregate combination will follow the maximum density line closely from the largest sieve down to the No.16 (1.18mm) sieve. The combined grading should follow the maximum density line within ± 7 percentage points deviation for each percent passing. A slight deviation below the maximum density line is to be expected from the No.16 (1.18mm) sieve down to the No. 200 (75µm) sieve to account for the effect of the fines provided by the cementitious materials. A gap graded aggregate combination will produce an “S-shaped” curve deviating above and below the maximum density line.

Percent Retained Chart

The percent retained chart is based on the mathematically combined percent retained gradation for each sieve. The percent retained chart has evolved from efforts to limit disproportionate amounts of material retained on any one sieve.

To create a percent retained chart plot the mathematically combined percent retained for

each sieve on a chart having retained on the y-axis and sieve sizes on the x-axis. Sieve sizes shall include the 1 ½ in. (37.5mm), 1 in. (25.0mm), ¾ in.(19.0mm), ½ in. (12.5mm), ⅜ in. (9.5mm), No. 4 (4.75mm), No. 8 (2.36mm), No. 16 (1.18mm), No. 30 (600µm), No. 50 (300µm), No. 100 (150µm), and the No. 200 (75µm). Connect the plotted points and plot the boundary lines as shown in figure 3.
A well-graded aggregate combination will have no significant peaks and/or dips. A gap graded aggregate combination will have peaks above 18 percent retained or dips below 8 percent retained.

Optimum Aggregate Blend

Determining an optimum combined aggregate blend will require the use of all three graphical representations as well as sound practical experience. The coarseness/workability chart should be the primary method used to develop an aggregate combination that will produce a mixture with appropriate properties for the intended application and placement method. The 0.45 power curve and the percent retained chart should be used as secondary means to verify the coarseness/workability chart results and to identify areas deviating from a well-graded aggregate combination.

FIGURE 1
COARSENESS FACTOR CHART

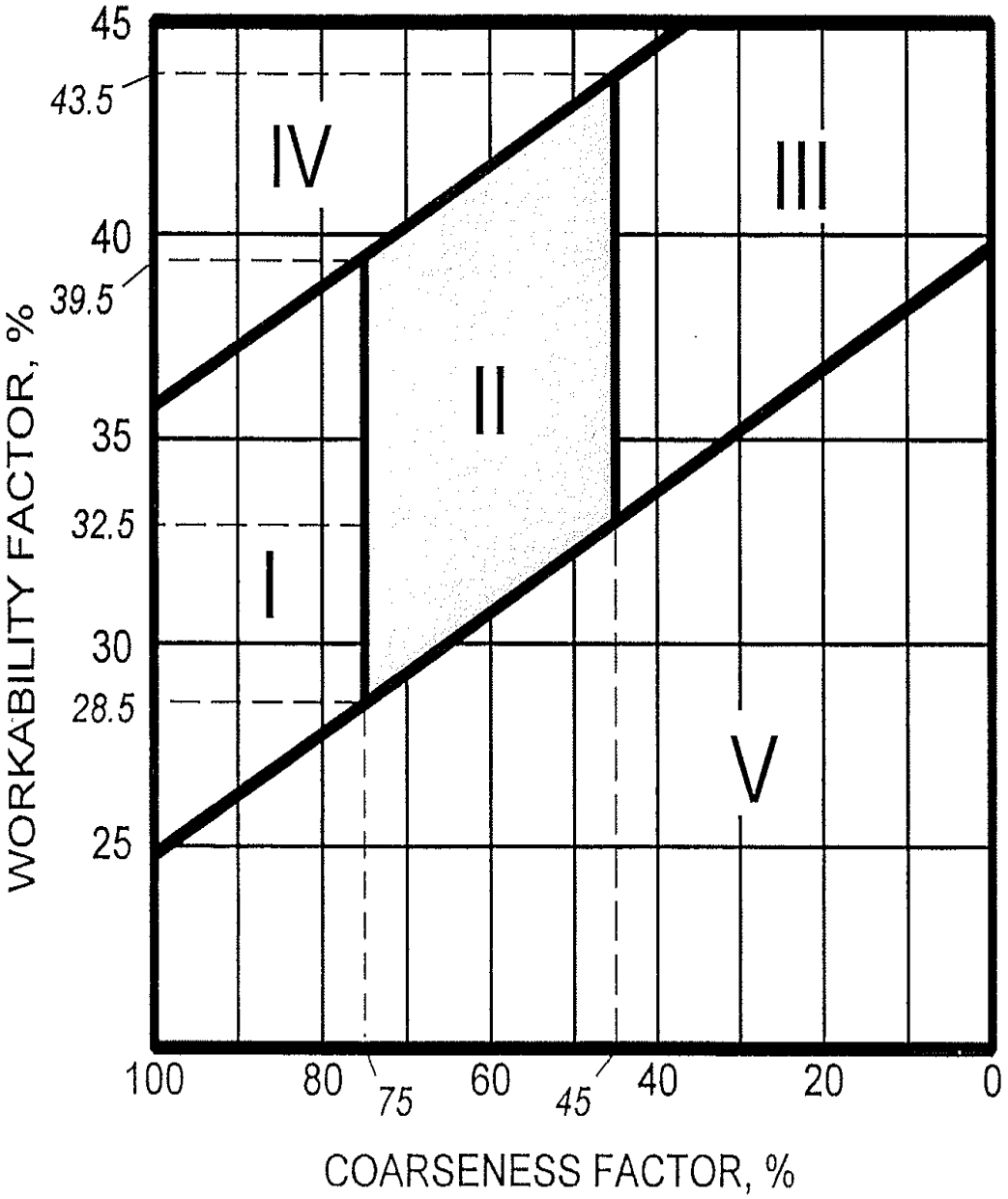


FIGURE 2

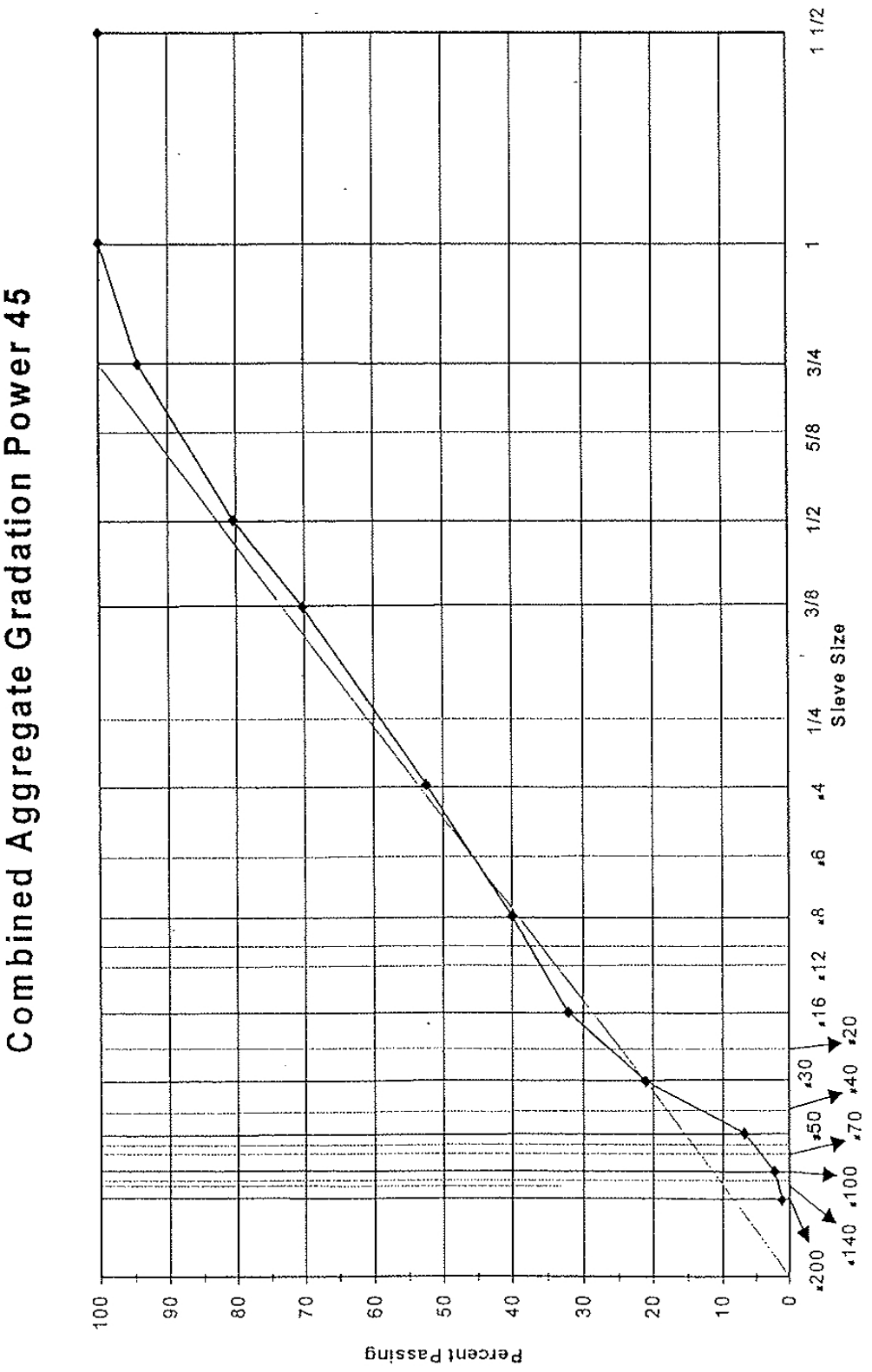
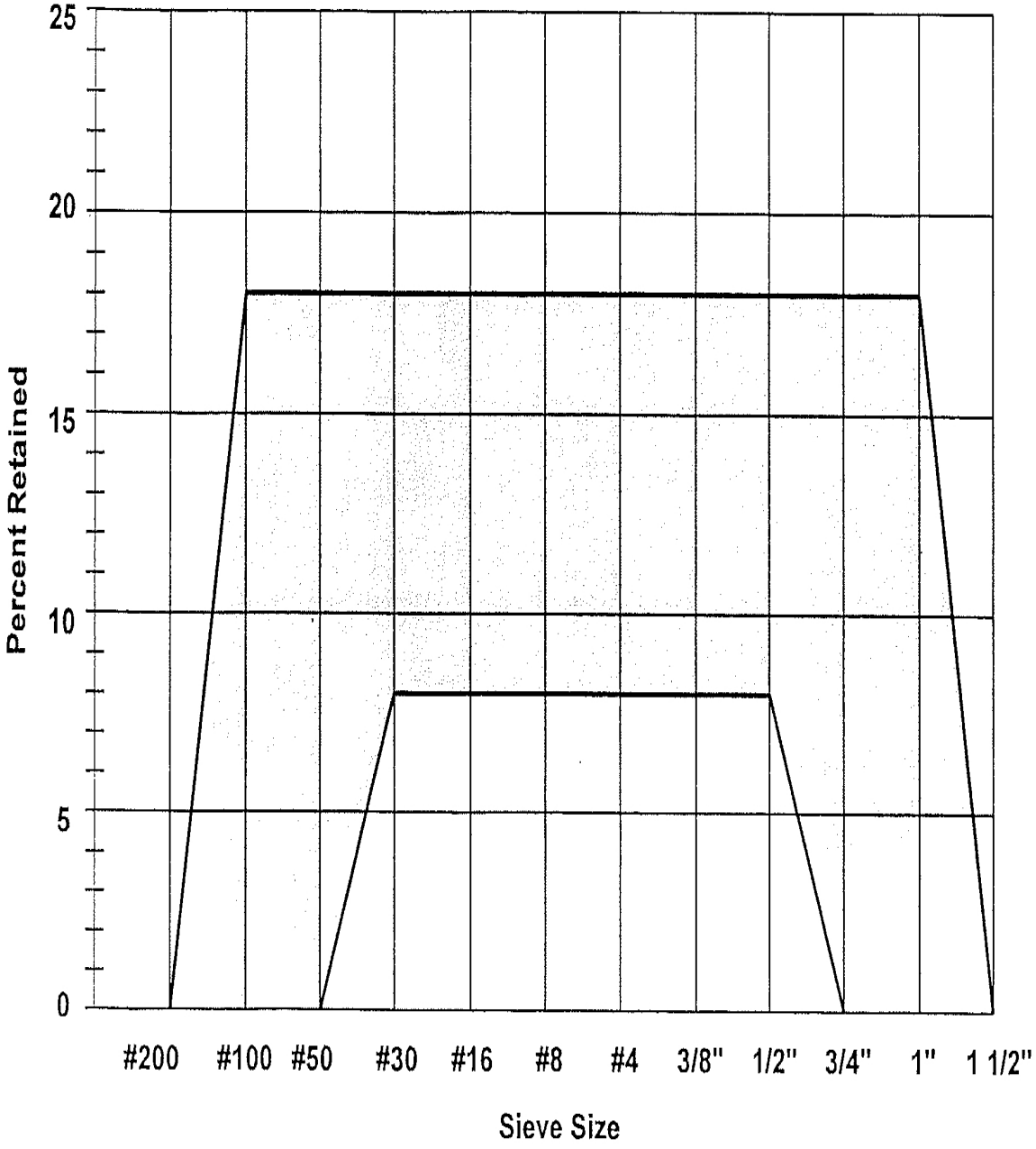

Combined Aggregate Gradation Power 45
Percent Passing
100
90
80
70
60
50
40
30
20
10
0
Sieve Size
1 1/2
1
3/4
5/8
1/2
3/8
1/4
#4
#6
#8
#12
#16
#20
#30
#40
#50
#70
#100
#140
#200

FIGURE 3
PERCENT RETAINED CHART



Revision Date	Revision Description
12/18/06	Defined OGCMP in first paragraph.
	Described Figure 1 in paragraph 1 of page 2 in more detail for areas I, II, IV and V.
	(Paragraph 4 page 2) Added: “closely from the largest sieve down” Added: “is to be expected from” Added: “down to the No. 200 (75µm sieve)” Removed: “will occur” Changed: +/- to ±Changed: ‘and “S-shaped”’ to ‘an “S-shaped”’.