WEST VIRGINIA DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
MATERIALS CONTROL, SOILS AND TESTING DIVISION

MATERIALS PROCEDURE

STANDARD METHOD FOR DETERMINATION OF OPTIMIZED AGGREGATE GRADATION IN PORTLAND CEMENT CONCRETE

1. PURPOSE

1.1 To establish a procedure for determination of optimized aggregate gradation in portland cement concrete.

1.2 To establish a uniform definition of optimized aggregate gradation.

2. SCOPE

2.1 This procedure shall apply in all cases where the specification allows the combined aggregate gradation test in portland cement concrete.

2.2 The combined aggregate gradation test is used to determine if the optimized aggregate gradation has been achieved.

3. DEFINITIONS

Optimized aggregate gradation characterizes the proportions of different sizes of aggregates in concrete mix designs. Optimized aggregate gradation helps to improve aggregate packing which involves minimizing the paste content while still producing a workable mixture.

4. PROCEDURE

4.1 Since the aggregates in a portland cement concrete mix consist of coarse and fine aggregates, this procedure will address the determination of optimized aggregate gradation through the combined aggregate gradation test.

4.1.1 The mass of each aggregate used in the concrete mix shall be used to determine the percent of each constituent aggregate in the optimized aggregate gradation.

4.1.1.1 Determine the total mass of aggregate:

$M_{ca(I)} + M_{ca(II)} + M_{fa(I)} + M_{fa(II)} = M_t$

Where:

$M_{ca(I)}$ = mass of coarse aggregate (I) (SSD) used in one cubic yard of concrete.

$M_{ca(II)}$ = mass of coarse aggregate (II) (SSD) used in one cubic yard of concrete.

$M_{fa(I)}$ = mass of fine aggregate (I) (SSD) used in one cubic yard of concrete.

$M_{fa(II)}$ = mass of fine aggregate (II) (SSD) used in one cubic yard of concrete

M_t = mass of total aggregate used in one cubic yard of concrete.

4.1.1.2 Determine the relative percent (R_A) of each type of aggregate.

Coarse aggregate (I) percent = $\frac{Mca(I)}{Mt} * 100$

Coarse aggregate (II) percent = $\frac{Mca(II)}{Mt} * 100$

Fine aggregate (I) percent = $\frac{Mfa(I)}{Mt} * 100$

Fine aggregate (II) percent = $\frac{Mfa(II)}{Mt} * 100$

4.1.2 Determine the gradation of each type of aggregate using AASHTO T 27 and T 11. Submit gradation reports showing the combined percent passing and the combined percent retained as shown in the attached example. Include in the report, each individual aggregate gradation starting with the largest appropriate sieve for that material and including all the consecutive smaller sizes through the No. 200 sieve. The passing percent of each type of aggregate shall be reported to nearest hundredth percent.

5. CALCULATIONS

5.1 Calculate the combined % passing on each sieve using the following equation:

$$C_P = \sum[\{(P_A)(R_A)\}/100]$$

where:

C_P = Combined % Passing
P_A = % Passing of each type of Aggregate
R_A = Relative % of each type of Aggregate (See Section 4.1.1.2)

5.2 Calculate the combined % retained on each sieve using the following equation:

$$C_R = C_{RX} - C_P$$

Where:

C_R = Combined % Retained
C_{RX} = Combined % Passing of next larger sieve size
C_P = Combined % Passing

5.3 The attached spreadsheet shall be used to calculate the values of the mass of total aggregate (M_t), relative percent (R_A) of each type of aggregate, combined percent passing (C_P), and combined percent retained (C_R). Once the percent passing of each type of aggregate is entered into the attached spreadsheet, the spreadsheet will automatically perform all the required calculation for optimized aggregate gradation. The spreadsheet will also plot the tarantula chart for optimized aggregate gradation.

6 EVALUATION

6.1 If the combined aggregate gradation meets the requirements of Section 601.3.2.4.1 of the Specification, the combined aggregate gradation shall be considered as Optimized Aggregate Gradation.

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RLS:Mtd
Attachment

EXAMPLE OF DETERMINATION OF OPTIMIZED AGGREGATE GRADATION IN PORTLAND CEMENT CONCRETE

1. Total mass of aggregates in one cubic yard of concrete:

   $M_{ca(I)}$ = Mass of SSD Coarse Aggregate (I) = 1511 lb.

   $M_{ca(II)}$ = Mass of SSD Coarse Aggregate (II) = 265 lb.

   $M_{fa(I)}$ = Mass of SSD Fine Aggregate (I) = 1260 lb

   $M_{fa(II)}$ = Mass of SSD Coarse Aggregate = 0

   M_t = Total mass of aggregates

1.1 Enter the mass of each type of aggregate in the attached spreadsheet. The spreadsheet will calculate the relative percent (R_A) of each type of aggregate.

2. Percent Passing of each type of aggregate from individual gradation.

Sieve Size	Coarse Aggregate (I)	Coarse Aggregate (II)	Fine Aggregate (I)
2 in	100.00	100.00	100.00
1½ in	100.00	100.00	100.00
1 in	98.00	100.00	100.00
¾ in	70.31	100.00	100.00
½ in	45.21	100.00	100.00
⅜ in	21.93	96.31	100.00
No. 4	4.93	19.18	99.12
No. 8	1.00	3.12	85.63
No. 16	1.00	1.00	65.32
No. 30	1.00	0.00	31.02
No. 50	1.00	0.00	12.21
No. 100	1.00	0.00	1.62
No. 200	0.80	0.90	0.60

2.1 Enter the percent passing of each type of aggregate in the attached spreadsheet. The spreadsheet will calculate the combined % passing (C_P) on each sieve, the combined % retained (C_R) on each sieve, Coarse Sand % Retained (#8 - # 30 Sieve), and Fine Sand % Retained (#30 - #200 Sieve). The spreadsheet will also plot the tarantula chart.

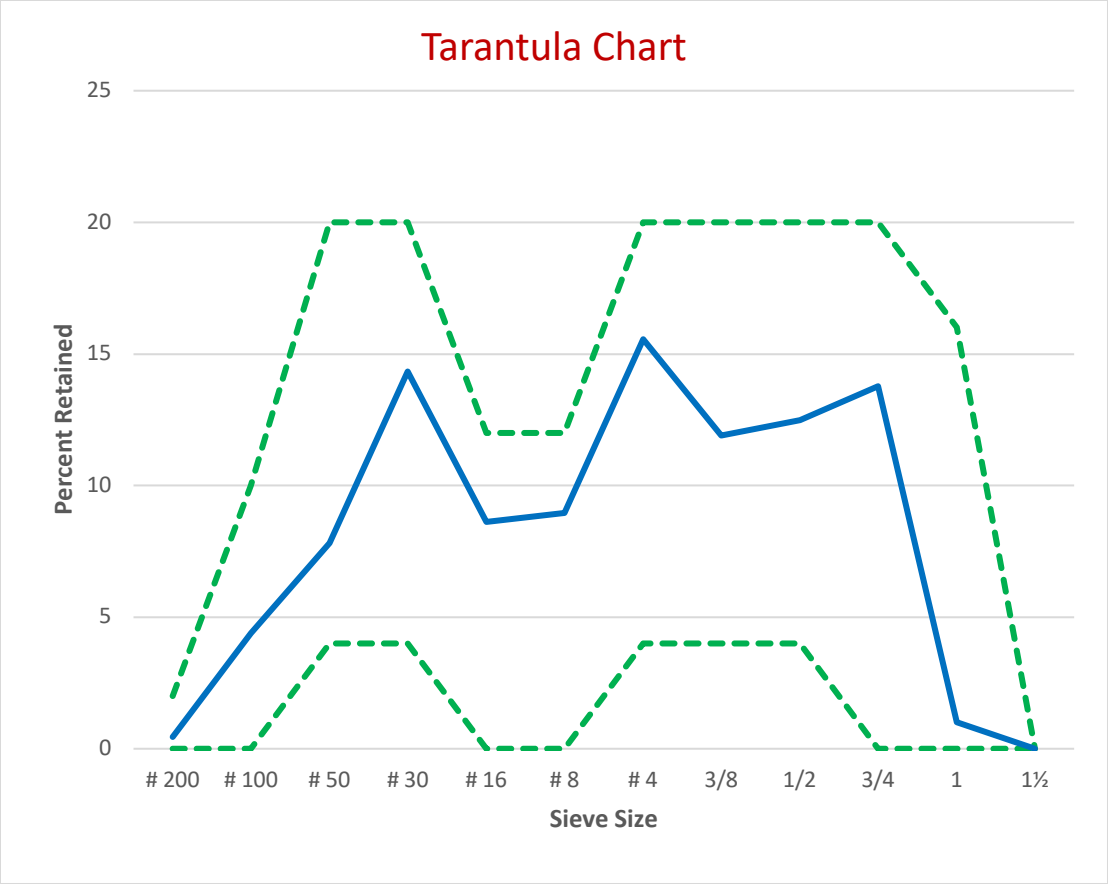
Table 1A

Aggregate Classification				
	Coarse Aggregate (I)	Coarse Aggregate (II)	Fine Aggregate (I)	Fine Aggregate (II)
Mass (lb)	1511	265	1260	0
Total Mass (M_t) (lb)	3036			
Relative (R_A) (%)	49.77	8.73	41.50	0.0

Table 1B:Sieve Analysis Example

Sieve Size	Coarse Aggregate (I)	Coarse Aggregate (II)	Fine Aggregate (I)	Fine Aggregate (II)	Combined % Passing (C_P)	Combined % Retained (C_R)	Meet Spec
Relative (R_A) %	49.77	8.73	41.50	0.00			
	% Passing (P_A)						
2 in	100.00	100.00	100.00	0.00	100.00	0.00	Yes
1½ in	100.00	100.00	100.00	0.00	100.00	0.00	Yes
1 in	98.00	100.00	100.00	0.00	99.00	1.00	Yes
¾ in	70.31	100.00	100.00	0.00	85.22	13.78	Yes
½ in	45.21	100.00	100.00	0.00	72.73	12.49	Yes
⅜ in	21.93	96.31	100.00	0.00	60.82	11.91	Yes
No. 4	4.93	19.18	99.12	0.00	45.26	15.56	Yes
No. 8	1.00	3.12	85.63	0.00	36.31	8.96	Yes
No. 16	1.00	1.00	65.32	0.00	27.69	8.61	Yes
No. 30	1.00	0.00	31.02	0.00	13.37	14.32	Yes
No. 50	1.00	0.00	12.21	0.00	5.57	7.81	Yes
No. 100	1.00	0.00	1.62	0.00	1.17	4.40	Yes
No. 200	0.80	0.90	0.60	0.00	0.73	0.44	Yes

Coarse Sand % Retained (#8 - # 30 Sieve) This range amount is a minimum of 15%	**31.89**	Yes
Fine Sand % Retained (#30 - #200 Sieve) This allowable range amount is between 24 - 34%	**27.0**	Yes


Tarantula Chart
25
20
15
10
5
0
Percent Retained
200
100
50
30
16
8
4
3/8
1/2
3/4
1
1½
Sieve Size