October 19, 2004 Matls. IM 531
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TEST METHOD FOR COMBINING AGGREGATE GRADATIONS

When the aggregate gradations for a PCC mixture are sampled and tested individually, the results must be mathematically combined to create a theoretical combined gradation. This combined gradation is based on their relative percent volume in the mixture.

Each individual aggregate gradation shall start with the largest appropriate sieve for that material and shall include all the consecutive smaller sieve sizes through the #200 (75-µm) sieve. They shall include: 1/2-in. (37.5-mm), 1-in. (25-mm.), 3/4-in. (19-mm), 1/2-in. (12.5-mm), 3/8-in. (9.5-mm), #4 (4.75-mm), #8 (2.3-mm), #16 (1.18-mm), #30 (600-µm), #50 (300-µm), #100 (150-µm), and #200 (75-µm) sieves. For coarse and intermediate aggregates, the #16 (1.18-mm) through #100 (150-µm) sieves may be determined mathematically.

The following methods outline the procedures to be used to determine the combined gradation. Method A is generally used for most aggregate combinations. Method B should be used when the specific gravity of the individual aggregates differ by more than 0.25.

METHOD A

Multiply relative percentage by the percent passing and sum all aggregates for each sieve size.

P = Aa + Bb + Cc
P = Combined percent passing of a given sieve
A,B,C = Percent passing given sieve for aggregate A, B, and C
a,b,c = Relative percent of total aggregates A, B, and C

Convert combined percent passing to combined percent retained by subtracting the combined percent passing on the top sieve from 100 and the combined percent passing from each subsequent sieve, thereafter.

Sieve	Coarse Aggregate	Intermediate Aggregate	Fine Aggregate	Theoretical Combined Gradation % Passing	Theoretical Combined Gradation % Retained
Relative Percent→	0.472	0.118	0.410		
1 1/2 inch	100	100	100	100	0.0
1 inch	83	100	100	92	8.0
3/4 inch	65	100	100	83.4	8.5
1/2 inch	35	100	100	69.3	14.2
3/8 inch	14	100	100	59.4	9.9
No. 4	2.1	33	96	44.2	15.2
No. 8	0.9	2.8	82	34.4	9.8
No. 16	0.8	2.3	63	26.5	7.9
No. 30	0.7	1.8	37	15.7	10.8
No. 50	0.5	1.2	9.4	4.3	11.4
No. 100	0.4	0.7	1	0.7	3.6
No. 200	0.3	0.1	0.4	0.3	0.4

METHOD B

STEP 1:

The percent volume of each of the aggregates is determined from the volume proportions of the mixture design. The relative proportion of each aggregate of the total aggregate is determined by dividing the individual aggregate portion in the mix by the total aggregate portion in the mix.

Example:

A mixture design has the following mix proportions by volume:

Cement	0.110
Water	0.150
Air Entraining	0.070
Fine Aggregate (PCC Sand)	0.270
½ inch Intermediate Aggregate (Limestone Chip)	0.100
1½ inch Coarse Aggregate (Limestone PCC Stone)	0.300
Total	1.000

The total aggregate portion is: 0.270 + 0.100 + 0.300 = 0.670

The relative percent retained portion for each aggregate by volume is determined as follows:

Fine Aggregate (0.270/0.670) = 0.403
Intermediate Aggregate (0.100/0.670) = 0.149
Coarse Aggregate (0.300/0.670) = 0.448

Check the total aggregate relative portions. They should equal 1.000.

0.403 + 0.149 + 0.448 = 1.000 (OK)

STEP 2:

These volume proportions are then adjusted by the specific gravity of the aggregates, since gradations are based on percent weight retained on each sieve. The proportion retained by weight is determined by multiplying each aggregate's volume proportion by its specific gravity. These weights are then summed to obtain a total weight. The proportion by weight is then determined by dividing each aggregate's weight by the total weight.

Example:

Aggregate	Proportion Volume	Specific Gravity	Weight	Proportion By Weight
Fine	0.403	2.67	1.07601	(1.07601/2.64912) = 0.406
Intermediate	0.149	2.59	0.38591	(0.38591/2.64912 = 0.146
Coarse	0.448	2.65	1.18720	(1.18720/2.64912) = 0.448
Total	1.000		2.64912	1.000

STEP 3:

Determine the theoretical combined gradation from the individual gradations. This is done by multiplying the percent retained on each sieve for the individual gradations by the relative portion of the aggregate volumes. Then total the percent retained of each product for each sieve size. This is the theoretical combined percent retained for each sieve. The total of these percents retained should equal 100.0. If the total is off due to rounding, prorate the rounding error.

Example:

Coarse Aggregate

Sieve	% Retained	Relative Volume	Adjusted % Retained
1 1/2 inch	0.0	0.448	0.0
1 inch	1.4	0.448	0.6
3/4 inch	23.7	0.448	10.6
1/2 inch	31.0	0.448	13.9
3/8 inch	24.5	0.448	11.0
No. 4	14.1	0.448	6.3
No. 16	0.7	0.448	0.3
No. 30	0.8	0.448	0.4
No. 100	0.4	0.448	0.2
No. 200	0.2	0.448	0.1
Minus 200	0.8	0.448	0.4

Similar calculations are done for the intermediate and fine aggregates.

STEP 4:

The individual adjusted gradations are summed to get the theoretical combined gradation, percent retained. The theoretical combined gradation, percent passing, may be calculated by subtracting subsequent sieves beginning with 100, as per IM 302. The following table shows the calculations:

Sieve	Coarse Aggregate	Intermediate Aggregate	Fine Aggregate	Theoretical Combined Gradation % Retained	Theoretical Combined Gradation % Passing
1 1/2 inch	0.0			0.0	100
1 inch	0.6			0.6	99.4
3/4 inch	10.6	0.0		10.6	88.8
1/2 inch	13.9	3.2		17.1	71.7
3/8 inch	11.0	5.4	0.0	16.4	55.3
No. 4	6.3	4.9	2.0	13.2	42.1
No. 8	0.9	0.4	4.1	5.4	36.7
No. 16	0.3	0.3	5.6	6.2	30.5
No. 30	0.4	0.1	12.9	13.4	17.1
No. 50	0.1	0.2	12.0	12.3	4.8
No. 100	0.2	0.1	3.1	3.4	1.4
No. 200	0.1	0.1	0.2	0.4	1.0
Minus 200	0.4	0.2	0.4	1.0	0.0

The theoretical combined gradations are used in graphically displaying aggregate blends of PCC mixture designs and for plotting control charts to compare target gradation with working ranges of the mixture design.