

State of Nevada  
Department of Highways  
Materials and Testing Division

CALCULATIONS PERTAINING TO GRADINGS  
AND SPECIFIC GRAVITIES

SCOPE

These examples illustrate: (1) acceptable methods for adjusting and/or combining gradings, and (2) methods of correcting for differences in specific gravities.

Samples, as received in the laboratory, can seldom be tested without some adjustment of gradings. These adjustments are usually necessary in order to meet specification grading requirements or to obtain a suitably graded sample for a particular test.

A. GRADING ADJUSTMENTS ON SINGLE SAMPLES.

1. Single sample with oversize to be rejected. In order to compute the as-used grading, increase to 100 percent the as-received percent passing the size on which the sample is to be scalped, and increase the as-received percent passing of the other sizes in the same proportion.

Example: Assume an aggregate which has a grading with 90 percent passing the 3/4-inch sieve and the sample has to be scalped on the 3/4-inch sieve. The as-used grading is calculated as follows:

Sieve	As-received percent passing	Calculations	As-used percent passing
1-1/2"	100		
1"	95		
3/4"	90		100
3/8"	80	$\frac{100 \times 80}{90}$	89
No. 4	70	$\frac{100 \times 70}{90}$	78

The percentages of material passing the sieve sizes smaller than the No. 4 sieve are computed in the same manner.

2. Single sample with a portion of the passing No. 4 to be wasted.

It is frequently necessary to waste a portion of the passing No. 4 material in order to bring the grading into specifications. The procedure can best be explained by an example.

Example: Given an aggregate with the following grading:

Sieve size	Percent passing
3/4"-----	100
3/8"-----	90
No. 4-----	70
No. 8-----	55

It is necessary to reduce the percent passing the No. 4 sieve from 70 to 60 percent in order to conform to specifications.

The new grading will be:

Sieve size	Percent passing
3/4"	100
3/8"	$60 + (90 - 70) \frac{100 - 60}{100 - 70} = 87$
No. 4	60
No. 8	$\frac{60}{70} \times 55 = 47$

Sizes smaller than the No. 8 sieve are computed in the same manner as for the No. 8 sieve.

It is generally desirable to know what percentage of the total sample is to be wasted. The following method may be used:

Consider a unit amount of material.

Let  $W$  = Percent of total sample to be wasted.

$P_1$  = Original percent passing No. 4 sieve.

$P_2$  = Final percent passing No. 4 sieve.

Then:

$$W = \frac{P_1 - P_2}{100 - P_2} \times 100$$

$$= \frac{70 - 60}{100 - 60} \times 100 = 25 \text{ percent of total sample wasted.}$$

### 3. Single sample with a portion of the retained No. 4 to be wasted.

The following example illustrates a method of adjusting grading by wasting a portion of the retained No. 4 material:

Given an aggregate with the following grading.

Sieve size	Percent passing
3/4"-----	100
3/8"-----	90
No. 4-----	70
No. 8-----	40

It is necessary to waste enough of the retained No. 4 sieve size fraction to increase the percent passing the No. 4 sieve from 70 to 80 percent.

The new grading will be:

Sieve size	Percent passing
3/4"-----	100
3/8"-----	$80 + (90 - 70) \frac{100 - 80}{100 - 70} = 93$
No. 4-----	80
No. 8-----	$\frac{80 \times 40}{70} = 46$

Sizes smaller than the No. 8 sieve size are computed in the same manner as for the No. 8 sieve.

It is generally desirable to know what percentage of the total sample is to be wasted. The following method may be used:

Consider a unit amount of material.

Let  $W$  = Percent of total sample to be wasted.

$R_1$  = Percent retained No. 4 originally

$R_2$  = Percent retained No. 4 finally.

Then:

$$W = \frac{R_1 - R_2}{100 - R_2} \times 100$$

$$= \frac{30 - 20}{100 - 20} \times 100 = 12.5 \text{ percent of total sample to be wasted}$$

4. Single sample with all of the material passing the No. 4 sieve to be wasted.

Subtract the percent passing the No. 4 sieve from each sieve size retained, then readjust to equal 100 percent.

Example:

Sieve size	Original grading	Subtraction	Corrected to 100 percent *
3/4"-----	100	100 - 53 = 47	100
1/2"-----	82	82 - 53 = 29	62
3/8"-----	73	73 - 53 = 20	43
No. 4-----	53	53 - 53 = 0	0
No. 8-----	37		
No. 16-----	24		
No. 30-----	15		

$$*47 : 100 :: 29 : X, X = 62$$

$$47 : 100 :: 20 : X, X = 43, \text{ etc.}$$

5. Single sample with a portion of the passing No. 200 sieve size material to be wasted.

The percent of material wasted is subtracted from the percent passing each sieve size. This gives a grading less than 100 percent, which is corrected proportionately to equal 100 percent.

Example: From a sample it is desired to remove material passing the No. 200 sieve in order to meet specified grading.

Sieve size	Specified limits percent passing	Original grading percent passing	Excess percent passing No. 200	Grading less than 100 percent	Corrected to 100 percent*
1"-----	100				
3/4"-----	95-100	100	15 =	85	100
3/8"-----	67-85	80	15 =	65	76
No. 4-----	50-65	64	15 =	49	58
No. 8-----	37-50	49	15 =	34	40
No. 16-----		42	15 =	27	32
No. 30-----	18-28	35	15 =	20	24
No. 50-----		29	15 =	14	16
No. 100-----		23	15 =	8	9
No. 200-----	3-8	19	15 =	4	5

$$*85 : 100 = 65 : X, X = 76$$

$$\text{Also } 85 : 100 = 49 : X, X = 58, \text{ etc.}$$

To waste the passing No. 200 for laboratory testing the waste will be made from the material passing the No. 4 sieve previously separated when processed and graded. For example:

10,000 g. of material graded from coarse to fine will be required for 2 tests and passing No. 200 equal to 15 percent of the sample is to be wasted from the total sample; therefore,

$$\frac{10,000}{.85} = 11,765 \text{ g. total amount of material required before wasting}$$

11,765 - 10,000 = 1,765 g. of the passing No. 200 sieve to be screened out of the total sample.

Since 58 percent of the 10,000 g. needed for testing is passing the No. 4 sieve, it follows that  $.58 \times 10,000 = 5,800$  g. of passing No. 4 material will be needed after wasting and  $5,800 + 1,765 = 7,565$  g. of the passing No. 4 material will be the amount necessary to use before screening No. 200 material.

NOTE: In most instances it should be possible to remove the passing No. 200 material by dry sieving; however, when large quantities such as are shown in the above example are to be removed it will probably be necessary to employ washing.

6. Single sample requiring that retained 1-inch material be replaced by that passing the 1-inch sieve and retained on the No. 4 sieve when a maximum size larger than 1 inch is specified. This procedure is used only for cement treated bases, classes A and B, and cement treated subgrades.

The percentage of material passing the No. 4 sieve is held constant and the percentage passing the 1-inch sieve is equated to 100 percent. The intermediate sizes, between the 1 inch and No. 4, are proportioned in the same ratio as the original grading.

The following example shows a grading before and after the retained 1-inch material has been replaced by that passing 1 inch and retained on the No. 4 sieve.

Sieve size	As-received percent pass.		Adjusted grading percent passing
1-1/2"-----	100		
1"-----	90		100
3/4"-----	80	$60 + \frac{20 \times 40}{30}$	= 87
3/8"-----	70	$60 + \frac{10 \times 40}{30}$	= 73
No. 4-----	60		60

**B. GRADING ADJUSTMENTS ON MULTIPLE SAMPLES**

1. Combining two or more samples.

The first step is to decide what proportion of each sample to use. This generally depends upon the specification requirements. It is usually quicker to use the trial method for arriving at the proportions. An experienced operator can usually determine the proportions in the first or second trial.

Example: Assume combination consisting of 80 percent of sample No. 1, and 20 percent of sample No. 2.

Sieve	AS-RECEIVED PERCENT		PROPORTIONED GRADING		Combined percent passing	As-Used (scalp 3/4 in.) percent passing
	No. 1	No. 2	80 percent No. 1	20 percent No. 2		
1"-----	100	100	80	20	100	
3/4"-----	90	100	72	20	92	100
3/8"-----	80	95	64	19	83	90
No. 4-----	70	90	56	18	74	80

2. Crushing oversize from sample and recombining with uncrushed material.

The gradings are considered individually, i.e., crushed and uncrushed. Each grading is then proportioned as to its relative percentage of the original sample and recombined.

Example: A sample was separated on the 3/4-in. sieve. The oversize, 46 percent, was crushed to pass the 3/4-in. sieve, then recombined with the original portion.

Sieve size	Original sample percent passing	Oversize crushed percent passing	Proportioning	Combined sample original and crushed
3/4"-----	54	100	$100 \times .46 = 46$	$54 + 46 = 100$
3/8"-----	45	56	$56 \times .46 = 26$	$45 + 26 = 71$
No. 4-----	39	35	$35 \times .46 = 16$	$39 + 16 = 55$
No. 8-----	37	20	$20 \times .46 = 9$	$37 + 9 = 46$
No. 16-----	34	15	$15 \times .46 = 7$	$34 + 7 = 41$
No. 30-----	20	11	$11 \times .46 = 5$	$20 + 5 = 25$
No. 50-----	16	9	$9 \times .46 = 4$	$16 + 4 = 20$
No. 100-----	10	8	$8 \times .46 = 4$	$10 + 4 = 14$
No. 200-----	4	4	$4 \times .46 = 2$	$4 + 2 = 6$

3. Wasting material from the uncrushed portion of sample in which the oversize is crushed.

When an adjustment is necessary to produce a specified grading from a sample that has had the oversize crushed, the wasted material shall be taken from the uncrushed portion of the aggregate. This will change the proportions of crushed and uncrushed, and an adjustment is necessary.

Example: From a sample having originally 50 percent uncrushed and 50 percent crushed it was necessary to waste a portion of the total sample equivalent to 25 percent in order to conform to the grading requirement. This 25 percent is to be removed from the uncrushed portion and it is

desired to obtain the proportions of crushed and uncrushed after this material has been wasted.

Let  $W$  = Percent of total to be wasted

$X$  = Original percent uncrushed

$X_1$  = Final percent uncrushed

$Y$  = Original percent crushed

$Y_1$  = Final percent crushed

$X + Y = 100$ , also  $X_1 + Y_1 = 100$

$$\frac{100 - W}{100} = \frac{X - W}{X_1} \text{ then } X_1 =$$

$$\frac{X - W}{100 - W} \times 100$$

$$\text{Also } \frac{100 - W}{100} = \frac{Y}{Y_1} \text{ then } Y_1 = \frac{100Y}{100 - W}$$

Substituting into the above equation

$$X_1 = \frac{50 - 25}{100 - 25} \times 100 = \frac{25}{75} \times 100 = 33 \text{ percent}$$

$$\text{also } Y_1 = \frac{50}{100 - 25} \times 100 = \frac{50}{75} \times 100 = 67 \text{ percent}$$

The final grading will contain 33 percent uncrushed and 67 percent crushed material.

### C. CORRECTION FOR VARIATION IN SPECIFIC GRAVITY OF MINERAL AGGREGATE

1. Grading analyses and grading limits of mineral aggregates are generally expressed as a percentage by weight of the total passing each sieve size. However, this method of expression is correct only when the aggregates are of uniform specific gravity. To correctly show particle size distribution, it is necessary to consider the grading analysis from a by-volume basis; consequently when variation in specific gravity between the fine and coarse material exceed 0.20 it will be necessary to compensate for this variation in order to obtain batching weights that will produce the proper volumetric proportions. This is accomplished by use of the average specific gravity of the aggregate.
2. Let us assume that we have two stockpiles of aggregates which we are going to use for producing a bituminous paving mixture. One stockpile contains the passing No. 4 aggregates having a specific gravity of 2.73 and the other contains the retained No. 4 aggregates having a specific gravity

of 2.32, a difference of 0.41. These stockpiles are to be blended in the proper proportions to conform to specified grading limits. To demonstrate the effect this 0.41 variation in specific gravity has upon the volumetric proportions of the mixture the following example is given. All calculations used in the various stages of the example will be described in order of their use at the conclusion of the text.

3. The first step is to combine the retained No. 4 and the passing No. 4 materials in by-weight proportions that will produce a grading conforming to the specified limits irrespective of the specific gravity. The grading as shown under (1) represents proportions by weight of 49 percent and 51 percent respectively of the retained No. 4 and passing No. 4 stockpiled materials. With the difference of 0.41 in specific gravity the next step is to determine whether or not a by-volume grading produced from material batched by weight from the grading shown under (1) would conform to the grading limits. When the grading was corrected to by-volume (as in 2) by means of the average specific gravity of the aggregate, it was found to be out of grading limits on the No. 4 and No. 8 sieves. The correction to by-volume has changed the percentage passing the No. 4 sieve from 51 percent to 47 percent with other amounts passing the various sieves changing proportionately. To produce a grading conforming to specification limits from these materials it was necessary to arbitrarily adjust the by-weight proportioning of the stockpiles (as shown in 3). For this adjustment the percentage by weight was changed from 51 percent to 54 percent with other amounts passing the various sieves changed proportionately. Step (4) simply involves changing the by-weight grading in (3) to by-volume. With this correction the 54 percent by weight amounts to 50 percent by volume with other amounts passing the various sieve sizes changed proportionately.

Sieve size

Sieve size	Grading limits	(1) By-wt. blend of stockpiles conforming to spec. grading limits percent passing	(2) Corrected to by-vol. percent passing	(3) By-wt. grading adjusted to produce by- vol. grading conforming to specs. percent pass.	(4) Final by-vol. grading percent passing
3/4"-----	100	100	100	100	100
3/8"-----	60-75	65	62	67	64
No. 4-----	50-65	51	47	54	50
No. 8-----	37-50	38	35	40	37
No. 16-----		29	27	31	29
No. 30-----	18-28	19	18	21	19
No. 50-----		14	13	15	14
No. 100-----		9	8	9	8
No. 200-----	3-8	4	4	5	5

Specific gravity coarse = 2.32.  
Specific gravity fine = 2.73.

Formulae and calculations for the example are:

$$G_a = \frac{100}{\frac{Pw_1}{G_1} + \frac{Pw_2}{G_2}}$$

$$Pv = \frac{PwG_a}{G}$$

$G_a$  = Average specific gravity of aggregate

$Pw$  = Percent of sample by weight

$G$  = Specific gravity of aggregate

$Pv$  = Percent of sample by volume

- 1) Grading produced by combining retained No. 4 and passing No. 4 stockpiles in proportions to 49 percent and 51 percent by weight, respectively, without considering specific gravity.
- 2) Grading corrected to by-volume.

Average specific gravity

$$= \frac{100}{\frac{Pw_1}{G_1} + \frac{Pw_2}{G_2}} = \frac{100}{\frac{49}{2.32} + \frac{51}{2.73}} = 2.51$$

$$\text{Percent retained No. 4} = \frac{PwG_a}{G} =$$

$$\frac{49 \times 2.51}{2.32} = 53 \text{ percent}$$

$$\text{Percent pass No. 4} = \frac{PwG_a}{G} = \frac{51 \times 2.51}{2.73}$$

$$= 47 \text{ percent}$$

Change remainder of grading in proportion to the change from 51 percent to 47 percent on the passing No. 4, i.e.,

Passing 3/8-inch =

$$47 + (65 - 51) \frac{100 - 47}{100 - 51} = 62$$

$$\text{Passing No. 8} = \frac{47}{51} \times 38 = 35$$

- 3) By-weight grading determined by trial adjustment that will, after correcting to absolute volume, conform to the specific grading limits.
- 4) Adjusted by-weight grading corrected to absolute volume.

Average specific gravity

$$= \frac{100}{\frac{Pw_1}{G_1} + \frac{Pw_2}{G_2}} = \frac{100}{\frac{46}{2.32} + \frac{54}{2.73}} = 2.52$$

Percent retained No. 4

$$= \frac{PwGa}{G} = \frac{46 \times 2.52}{2.32} = 50 \text{ percent}$$

Percent Pass No. 4

$$= \frac{PwGa}{G} = \frac{54 \times 2.52}{2.73} = 50 \text{ percent}$$

Change remainder of grading in proportion to the change from 54 percent to 50 percent as in (2).

#### PRECAUTIONS

No adjustments to gradings should be made in the laboratory that cannot be economically duplicated in the field. The limitations of the screening plants, crushers, hot plants and mixers should be recognized.

#### REFERENCE

California Method