

5-692.800
FORMULAS AND COMPUTATIONS

5-692.802 COMPUTATION OF STABILIZED GRAVEL MIXTURE

COMPUTATION OF STABILIZED GRAVEL MIXTURE							
TABLE A							
Percent Passing Sieve	25 mm	19 mm	9.5 mm	4.75 mm	2 mm	425 μ m	75 μ m
Original Gravel	85	80	75	60	50	20	2
Screened Gravel (Oversized Removed)	100	94	88	71	59	24	2.4
Oversize Gravel Crushed	100	90	70	30	10	2	-----
Recombining:							
85% Screened Gravel	85	80	75	60	50	20	2
15% Crushed Oversize	15	13	11	5	2	----	----
Recombined Gravel	100	93	86	65	52	20	2
Binder Soil	100	100	100	100	100	80	50
Computation of Mixture:							
90% Gravel	90	84	77	59	47	18	1.8
10% Binder Soil	10	10	10	10	10	8	5.0
Mixture	100	94	87	69	57	26	6.8
Allowable Spec. Range	100	90-100	50-90	35-80	20-65	10-35	3-10

5-693.803M COMPUTATION OF QUANTITIES FOR BASE CONSTRUCTION (METRIC)

The total quantities of dry base required per kilometer of roadway may be calculated by multiplying the cubic meters (m^3) of compacted dry material required by the dry density (kg/m^3) of the compacted base.

Example:

Depth of base = 150 mm

Average width of base = 10 m

Dry density of compact base = 2160 kg/m^3

One sq. meter (m^2) of base 25 mm thick requires:

$$1 \text{ m} \times 1 \text{ m} \times .025 \text{ m} \times 2160 = 54 \text{ kg} / m^2 / 25 \text{ mm}$$

Area per kilometer by 10 meters wide = 1000 m x 10 m = 10000 m^2

One kilometer of base 150 mm thick requires:

$$\frac{10000 \times 54}{1000} \times \frac{150}{25} = 3240 \text{ metric ton (t)}$$

To correct for moisture contained in the base multiply the weight of base by percent moisture and add it to the weight of dry material required.

Example:

% moisture of dry weight - 3.5%

$$\text{Wt. of moist aggregate} = 3240 + \frac{(3240 \times 3.5)}{100} = 3353 \text{ t}$$

5-693.803E COMPUTATION OF QUANTITIES FOR BASE CONSTRUCTION (ENGLISH)

The total quantities of dry base required per mile of roadway may be calculated by multiplying the cubic yards of compacted dry material required by the dry density (lb. per ft.³) of the compacted base.

Example:

Depth of base = 6 in.

Average width of base = 30 ft.

Dry density of compact base = 140 lb. per ft.³

One sq. yd. of base one inch thick requires:

$$3 \times 3 \times 1/12 \times 140 = 105 \text{ lb. per yd.}^2 \text{ per inch}$$

$$\text{Area per mile 30 ft. wide} = \frac{5280 \times 30}{9} = 17,600 \text{ yd.}^2$$

One mile of base 6 inches thick requires:

$$\frac{17,600 \times 105 \times 6}{2000} = 5,544 \text{ tons}$$

To correct for moisture contained in the base multiple the weight of base by percent moisture and add it to the weight of dry material required.

Example:

% moisture of dry weight - 3.5%

$$\text{Wt. of moist aggregate} = 5,544 + \frac{(5,544 \times 3.5)}{100} = 5,738 \text{ tons}$$

5-692.804M EXAMPLE CALCULATIONS FOR DETERMINING QUANTITIES OF INGREDIENTS PER KILOMETER OF BASE CONSTRUCTION (METRIC)

Given:

Proportion %: 90% gravel and 10% binder soil.

Assume 3240 metric ton of dry base aggregate is used per kilometer of base construction.

Assume moisture content:

Gravel - 3.5%

Binder Soil - 5.0%

Assume the dry density of the gravel is 1680 kg [1.68 metric ton (t)] per cubic meter and the dry density of the binder soil is 862 kg [0.86 metric ton per cubic meter (m³)].

Then:

1. Weight of dry gravel in 1 km of base construction is
 $3240 \times 0.9 = 2916$ metric ton (t).
 Weight of dry binder soil in 1 km of base construction is
 $3240 \times 0.1 = 324$ metric ton (t).

2. Volume of gravel in 1 km of base is:

$$\frac{2916 \text{ metric ton}}{1736 \text{ cubic meters}} = 1.68 \text{ metric ton / cubic meter}$$

Volume of binder soil in 1 km of base is:

$$\frac{324 \text{ metric ton}}{377 \text{ cubic meters}} = 0.86 \text{ metric ton / cubic meter}$$

3. Weight of moist gravel taken from pit is:

$$2916 \times 1.035 = 3018 \text{ metric ton (t)}$$

Weight of moist binder soil taken from pit is:

$$324 \times 1.05 = 340 \text{ metric ton (t)}$$

4. Water for compaction.
 Assume: mixture contains 4% water. Optimum moisture content for mixture is 8%.
 Required additional moisture is 4%.
 One metric ton (t) of dry mixture requires:

$$0.04 \times 1000 \text{ kg} = 40 \text{ kg}$$

Since 1 kg = 1000 g and 1 g = 1 ml

Therefore:

$$1 \text{ kg} = 1000 \text{ ml or 1 liter (1)}$$

$$\frac{40}{1} = 40 \text{ liter(1)}$$

One kilometer (km) requires: 40 liters x 3240 = 129600 liters (l) or 129.6 kl.

The designed gradation of the stabilized mixture is based upon the average gradation of gravel and binder soil which are expected to be produced from the designated sources. If, when production of material for construction has been started, it is found that the actual gradation of gravel varies from that assumed in design, some adjustment of proportions may be necessary.

In making field adjustments of proportions, the following formula may be helpful:

$$A = 100 \frac{(P - C)}{(B - C)}$$

Where:

A = percent of binder soil in mix.

B = percent of binder soil which passes certain sieve size.

C = percent of gravel which passes certain sieve size.

P = desired percent of stabilized mixture passing certain sieve size.

Examples:

1. If, in the previous example of design of a stabilized mixture, it is desired to maintain 26% passing the 425 μm sieve and the gravel has 22% passing the 425 μm , the formula could be applied as follows:

$$A = 100 \frac{(26 - 22)}{(80 - 22)} = \frac{400}{58} = 6.9\%$$

Therefore:

Only 6.9% of binder soil would have to be added.

2. This formula, expressed in a different form, may also be used to determine what variation in gradation of gravel on a certain sieve size is allowable if the percentage of binder soil remains constant. For this purpose the formula is expressed as follows:

$$C = \frac{100 P - AB}{100 - A}$$

If the specifications require from 5% to 10% passing the 75 μm sieve for the stabilized mixture and 10% of binder soil containing 50% passing the 75 μm sieve were specified, then the maximum allowable percentage of gravel passing a 75 μm sieve could be determined as follows:

$$C = \frac{(100 \times 10) - (10 \times 50)}{100 - 10} = \frac{500}{.90} = 5.5$$

Therefore:

5.5% passing the 75 μm sieve is the maximum allowable for the gravel material.

5-692.804E EXAMPLE CALCULATIONS FOR DETERMINING QUANTITIES OF INGREDIENTS PER MILE OF BASE CONSTRUCTION (ENGLISH)

Assume 90% gravel and 10% binder soil.

1. Gravel

$$5,544 \times 0.9 = 4,990 \text{ tons of dry gravel}$$

Average moisture content of gravel from pits is approximately 3.5%.

Weight of moist gravel as taken from pit = $4,900 \times 1.035 = 5,164$ tons.

One cubic yard (yd³) of moist gravel loaded in truck may be assumed to contain 2,800 lbs. or 1.4 ton of dry gravel.

$$\text{Volume of gravel} = \frac{4,990}{1.4} = 3,564 \text{ yds.}^3$$

2. Binder soil

$5,544 \times 0.10 = 554.4$ tons of dry binder. To convert to cubic yards for volumetric measurement:

Average binder soil loaded in truck may be assumed to contain 1,900 lb. or 0.95 tons of dry material in one cubic yard.

$$\frac{554.4}{0.95} = 584 \text{ yd.}^3$$

3. Water for compaction.

Assume: Mixture contains 4% water. Optimum moisture content for mixture is 8%.

Required additional moisture is 4%.

One ton of dry mixture requires:

$$0.04 \times 2,000 = 80 \text{ lb. water}$$

$$\frac{80}{8.3} = 9.6 \text{ gallons}$$

One mile requires:

$$9.6 \times 5,544 = 53,222 \text{ gallons}$$

The designed gradation of the stabilized mixture is based upon the average gradation of gravel and binder soil which are expected to be produced from the designated sources. If, when production of material for construction has been started, it is found that the actual gradation of gravel varies from that assumed in design, some adjustment of proportions may be necessary.

In making field adjustments of proportions, the following formula may be helpful:

$$A = 100 \frac{(P - C)}{(B - C)}$$

Where:

A = percent of binder soil in mix.

B = percent of binder soil which passes certain sieve size.

C = percent of gravel which passes certain sieve size.

P = desired percent of stabilized mixture passing certain sieve size.

Examples:

1. If, in the previous example of design of a stabilized mixture, it is desired to maintain 26% passing the No. 40 sieve and the gravel has 22% passing the No. 40, the formula could be applied as follows:

$$A = 100 \frac{(26 - 22)}{(80 - 22)} = \frac{400}{58} = 6.9\%$$

Therefore:

Only 6.9% of binder soil would have to be added.

2. This formula, expressed in a different form, may also be used to determine what variation in gradation of gravel on a certain sieve size is allowable if the percentage of binder soil remains constant. For this purpose the formula is expressed as follows:

$$C = \frac{100 P - AB}{100 - A}$$

If the specifications require from 5% to 10% passing the No. 200 sieve for the stabilized mixture and 10% of binder soil containing 50% passing the No. 200 sieve were specified, then the maximum allowable percentage of gravel passing a No. 200 sieve could be determined as follows:

$$C = \frac{(100 \times 10) - (10 \times 50)}{100 - 10} = \frac{500}{.90} = 5.5$$

Therefore:

5.5% passing the No. 200 sieve is the maximum allowable for the gravel material.

5-692.805 PROCEDURE FOR "ROUNDING OFF"

- A. To "round off" a numerical value is to reduce the number of recorded figures to some predetermined point by dropping figures or by increasing the value of certain figures. For example, a computed, observed, or accumulated value such as 4,738,221 can be rounded off to the nearest million (5,000,000); to the nearest hundred thousand (4,700,000); to the nearest ten thousand (4,740,000); etc. Similarly, a value such as 47.382 can be rounded off to two decimal places (47.38); to one decimal place (47.4); to the nearest whole number or units place (47); etc.
- B. The general rule for rounding off are as follows:
1. When the figure next beyond the last figure or place to be retained is less than 5, the figure in the last place retained is unchanged. (4,738,221 rounded off to the nearest hundred thousand is 4,700,000 and 47.382 rounded to two decimal places is 47.38)
 2. When the figure next beyond the last figure or place to be retained is greater than 5, the figure in the last place retained is increased by 1 (4,738,221 rounded to the nearest million is 5,000,000 and 47.382 rounded to one decimal place is 47.4)
 3. When the figure next beyond the last figure to be retained is 5 followed by any figures other than zero(s), the figure in the last place retained is increased by 1 (4,500,001 rounded to the nearest million is 5,000,000 and 4.6501 rounded to one decimal place is 4.7)

4. When the figure next beyond the last figure to be retained is 5 followed by only zeros, the figure in the last place to be retained is left unchanged if it is even (0,2,4,6 or 8) or is increased by 1 if it is odd (1,3,5,7 or 9). When rounded to the nearest million 4,500,000 is 4,000,000; 5,500,000 is 6,000,000. When rounded to one decimal point 4.25 is 4.2; 4.15 is 4.2; 47.05 is 47.0 and 47.95 is 48.0.
5. Any number required to be rounded off shall be rounded off in one step, not by a series of rounding operations. For example, 47.3499 rounded to one decimal place is 47.3 not 47.4, which is the result if 47.3499 is rounded to 2 decimal places (47.35) and then rounded to 1 decimal place (47.4).

C. Application of Rounding Off Rules

1. Reading indications on graduated scales such as found on balances, gauges and dials.
 - a. When the indicator is between two graduations, read the value of the closest graduation.
 - b. When the indicator is midway between graduations, read the value of the “even” graduation, (if the indicator is midway between 9.8 and 9.9 read 9.8; if the indicator is midway between 9.9 and 10.0 read 10.0).
 - c. A special case exists when the graduations of all have even values. When the indicator is midway between 2 “even” graduations, read the intermediate or “odd” value (if the pointer on a Speedy moisture dial is midway between 10.6 and 10.8, read 10.7).

2. Rounding off to the nearest 50, 5, 0.5, 0.05, etc.

To round a number to the nearest 50, 5, 0.5, 0.05, etc. double the observed or calculated value, round the product to the nearest 100, 10, 1.0, 0.10, etc. in accordance with the rules in part B above and divide the rounded product by 2. (6025 rounded to the nearest 50 is 12,050 rounded to the nearest 1000 which is 12,000 and 12,000 divided by 2 is 6,000.)

3. Rounding common fractions

When rounding common fractions, the rules are applied to the numerators of the fractions which are reduced to a common denominator. The observed fraction is compared to the fraction “rounded to” and the remainder is dropped if it is less than $\frac{1}{2}$ of the fraction “rounded to” and increased if it is more than $\frac{1}{2}$ of the fraction “rounded to”; if the remainder is exactly $\frac{1}{2}$ of the fraction “rounded to” the odd-even rules are used. Consider the following examples:

When rounded to the nearest eighth ($4/32$):

$1-1/32$ becomes 1 because $1/32$ is less than $\frac{1}{2}$ of $4/32$ and is dropped.

$1-2/32$ becomes 1 because $2/32$ is exactly $\frac{1}{2}$ of $4/32$, the $2/32$ is dropped because the numerator of the preceding eighth ($0/8$) is even.

$1-3/32$ becomes $1-4/32$ or $1-1/8$ because $3/32$ is more than $\frac{1}{2}$ of $4/32$, therefore the fraction is increased or "rounded up" to the next eighth.

$1-5/32$ becomes $1-4/32$ or $1-1/8$ because $5/32$ is $1/32$ more than $4/32$, $1/32$ is less than $\frac{1}{2}$ of $4/32$ and therefore is dropped.

$1-6/32$ becomes $1-2/8$ or $1-1/4$ because $6/32$ is $2/32$ more than $4/32$ and the numerator of the preceding eighth ($1/8$) is odd, therefore the fraction is increased to the next eighth.

$1-7/32$ becomes $1-2/8$ or $1-1/4$ because $7/32$ is $3/32$ more than $4/32$ or an exact $1/8$ and $3/32$ is more than $\frac{1}{2}$ of $4/32$, therefore the fraction is increased to $2/8$ or "rounded up".

$1-10/32$ becomes $1-2/8$ or $1-1/4$ because $10/32$ is $2/32$ more than $8/32$ or an exact $2/8$, $2/32$ is $\frac{1}{2}$ of $4/32$, the numerator of the preceding eighth ($2/8$) is even, therefore the $2/32$ is dropped or "rounded down".

5-692.806 METRIC & ENGLISH EQUIVALENT GRADATION SIEVE SIZES

<u>METRIC</u>		<u>ENGLISH</u>	
75.0 mm	-	(3")	Sieve
50.0 mm	-	(2")	Sieve
37.5 mm	-	(1 1/2")	Sieve
31.5 mm	-	(1 1/4")	Sieve
25.0 mm	-	(1")	Sieve
19.0 mm	-	(3/4")	Sieve
16.0 mm	-	(5/8")	Sieve
12.5 mm	-	(1/2")	Sieve
9.5 mm	-	(3/8")	Sieve
4.75 mm	-	(#4)	Sieve
2.38 mm	-	(#8)	Sieve
2.00 mm	-	(#10)	Sieve
1.19 mm	-	(#16)	Sieve
850 µm	-	(#20)	Sieve
600 µm	-	(#30)	Sieve
425 µm	-	(#40)	Sieve
300 µm	-	(#50)	Sieve
180 µm	-	(#80)	Sieve
150 µm	-	(#100)	Sieve
75 µm	-	(#200)	Sieve