Chapter 6

Material Estimates

To obtain a satisfactory surface, combine bituminous materials and aggregate in various proportions. Material estimates must be as accurate as possible to avoid an inadequate supply or an oversupply. Base estimates on the sequence of operations and the materials needed for each construction step. Materials should arrive at the paving site shortly before needed; keep a minimum amount of materials on hand for a full-scale operation. The formulas in this chapter use 40 gallons per barrel as a conversion factor to deal with shrinkage that takes place when the bitumen cools after barreling operations. This does not consider the loss of bitumen in debarreling operations.

**PRIME COAT**

6-1. Estimate the amount of bitumen required for a prime coat. Multiply the area to treat by the rate of application. The estimate must include sufficient bitumen for an additional 1-foot width on each side of the surface course constructed on the primed base. Use the following formula to calculate material requirements for a prime coat:

\[
G \text{ or } B = \frac{L(W + 2)R_b(1.00 + H_b)}{cf}
\]

where—

\(G\) = amount of bitumen, in gallons

\(B\) = amount of bitumen, in barrels

\(L\) = length of surface, in feet (convert miles to feet)

\(W\) = width of surface, in feet

\(R_b\) = bitumen application rate, in gallons per square yard

\(H_b\) = handling loss factor for bitumen

\(cf\) = conversion factor, in square feet per square yard (use 9 for gallons and 360 [40 x 9] for barrels)

**Example:** Using the above base formula, determine the amount of bitumen, in gallons, needed to complete a prime coat with the following specifications:

\(L\) = 3 miles (3 x 5,280 = 15,840 feet)

\(W\) = 23 feet

\(R_b\) = 0.3 gallon per square yard

\(H_b\) = 5 percent
Solution:

\[ G = \frac{15,840(23 + 2)(0.3)(1.00 + 0.05)}{9} = \frac{15,840(25)(0.3)(1.05)}{9} \]
\[ G = \frac{124,740}{9} = 13,860 \text{ gallons} \]

**TACK COAT**

6-2. The procedure for estimating the bitumen requirement for a tack coat is similar to that for a prime coat. A tack coat is generally applied over the proposed width of the pavement. Use the following formula to calculate material requirements for a tack coat:

\[ G \text{ or } B = \frac{LWR_b(1.00 + H_b)}{cf} \]

where—
- \( G \) = amount of bitumen, in gallons
- \( B \) = amount of bitumen, in barrels
- \( L \) = length of surface, in feet (convert miles to feet)
- \( W \) = width of surface, in feet
- \( R_b \) = bitumen application rate, in gallons per square yard
- \( H_b \) = handling loss factor for bitumen
- \( cf \) = conversion factor, in square feet per square yard (use 9 for gallons and \( \frac{360}{40} \times 9 \) for barrels)

**Example:** Using the above base formula, determine the amount of bitumen, in barrels, needed to complete a tack coat with the following specifications:

- \( L = 2.7 \text{ miles} \times 5,280 = 14,256 \text{ feet} \)
- \( W = 23 \text{ feet} \)
- \( R_b = 0.5 \text{ gallon per square yard} \)
- \( H = 5 \text{ percent} \)

Solution:

\[ B = \frac{14,256(23)(0.5)(1.00 + 0.05)}{360} = \frac{163,944(1.05)}{360} \]
\[ B = \frac{172,141}{360} = 478 \text{ barrels} \]

**SURFACE TREATMENT**

6-3. The amount of bitumen needed for a surface treatment is determined the same way as a tack coat. Multiply the results by the number of treatment passes. In bituminous surface treatments, determine the quantities of bitumen and aggregate needed using a test strip. Use 1 gallon of bitumen for every 100 pounds of aggregate. Determine the weight of the aggregate, one stone in depth, required to cover 1 square yard by spreading the aggregate over a measured surface, weighing it, and computing the amount in pounds per square yard. Use the following formula to calculate material requirements for a surface treatment:
P or T = \frac{LWR_a (1.00 + H_a)}{cf}

where—
P = aggregate weight, in pounds
T = aggregate weight, in tons
L = length of surface, in feet
W = width of surface, in feet
Ra = aggregate application rate
Ha = handling loss factor for aggregate
cf = conversion factor, in square feet per square yard (use 9 for pounds and 18,000 for tons)

Example: A test strip with an area of 100 square yards was used to determine the quantities required for a single surface treatment. Materials were carefully controlled and handling losses were negligible. The materials used for the test strip were 1.5 tons of aggregate and 30 gallons of bitumen. Expect an aggregate handling loss of 10 percent and a bitumen handling loss of 5 percent. Determine the amount of aggregate, in tons, and the amount of bitumen, in barrels, needed to make a single surface treatment on a road that is 23 feet wide and 10 miles (52,800 feet) long.

Solution: Determine the aggregate application rate.

\[ Ra = \frac{(1.5 \text{ tons})(2,000 \text{ pounds per ton})}{100 \text{ square yards}} = 30 \text{ pounds per square yard} \]

Calculate the amount of aggregate needed for the project (round up the amount).

\[ T = \frac{(52,800)(23)(30)(1.00 + 0.10)}{18,000} = \frac{(36,432,000)(1.10)}{18,000} = \frac{40,075,200}{18,000} \]

\[ T = 2,227 \text{ tons} \]

Determine the bitumen application rate.

\[ R_b = \frac{30 \text{ gallons}}{100 \text{ square yards}} = 0.3 \text{ gallons per square yard} \]

Calculate the amount of bitumen needed for the project (round up the amount).

\[ B = \frac{LWR_b (1.00 + H_b)}{cf} = \frac{(52,800)(23)(0.3)(1.00 + 0.05)}{360} = \frac{382,536}{360} \]

\[ B = 1,063 \text{ barrels} \]

**PENETRATION MACADAM**

6-4. Determine the amount of bitumen needed for a penetration macadam the same as a tack coat. The approximate bitumen application rate is 0.75 gallon per square yard per inch of compacted thickness.
Example: A 2-inch compacted thickness requires 1.5 gallons per square yard. To determine the loose volume of aggregate, multiply the area by the compacted thickness of the aggregate and the compaction factor. (The compaction factor is the ratio of the volume of loose aggregate to the volume of compacted aggregate.) The compaction factor for a 4-inch, loose layer of aggregate compacted to 2 inches is 2. If a 2-inch compacted thickness is desired and the compaction factor is 1.5, the loose thickness is 3 inches (1.5 x 2 inches). When determining the compaction factor in the field, consider the angularity and roughness of the aggregate, the loose thickness of the layer, and the weight of the roller. Compaction factors normally vary from 1.2 to 1.5.

Use the following formula to calculate material requirements for a penetration macadam:

\[ V = \frac{LW(FPT)(CF)(1.00 + H_a)}{cf} \]

where—
- \( V \) = loose volume of aggregate, in cubic yards
- \( L \) = length of surface, in feet
- \( W \) = width of surface, in feet
- \( FPT \) = finished pavement thickness, in inches (after compaction)
- \( CF \) = compaction factor or ratio of loose depth to FPT
- \( H_a \) = aggregate handling loss factor
- \( cf \) = conversion factor 324 (36 inches per yard x 9 square feet per square yard)

Determine the amount of bitumen, in barrels, and the amount of loose aggregate, in cubic yards, needed to complete a penetration macadam with the following specifications:

- \( L = 2 \text{ miles (10,560 feet)} \)
- \( W = 23 \text{ feet} \)
- \( FPT = 3 \text{ inches} \)
- \( CF = 1.5 \)
- \( R_b = 2.3 \text{ gallons per square yard} \)
- \( H_a = 10 \text{ percent} \)
- \( H_b = 5 \text{ percent} \)

Solution: Determine the amount of bitumen, in barrels, needed for the project (round up the amount).

\[ B = \frac{LWR_b(1.00 + H_b)}{cf} = \frac{(10,560)(23)(2.3)(1.05)}{360} = \frac{586,555.2}{360} = 1,630 \text{ barrels} \]

Determine the amount of loose aggregate, in cubic yards, needed for the project (round up the amount).

\[ V = \frac{(10,560)(23)(3)(1.5)(1.00 + 0.10)}{324} = \frac{1,202,256}{324} = 3,711 \text{ cubic yards} \]
ROAD MIX

6-5. Estimate the amount of aggregate needed for a road mix the same as a penetration macadam. Use the modified Marshall method (Chapter 2) to determine the amount of bitumen needed. The bitumen application rate is about 0.5 gallon per square yard for each compacted inch of pavement. (The application rate is based on the use of a well-graded aggregate with a 1-inch maximum particle size.)

Example: Determine the amount of bitumen, in barrels, and the amount of loose aggregate, in cubic yards, needed to complete a road mix with the following specifications:

- \( L = 1.1 \) miles \((1.1 \times 5,280 = 5,808 \) feet\)
- \( W = 23 \) feet
- \( FPT = 2 \) inches
- \( CF = 1.3 \)
- \( R_b = 0.5 \) gallons per square yard per inch of compacted pavement
- \( H_a = 10 \) percent
- \( H_b = 5 \) percent

Solution: Determine the amount of bitumen, in barrels, needed for the project (round up the amount). Based on the above information, use 1 gallon per square yard \((0.5 \times 2 \) inches \( \text{FPT} \)) for this project.

\[
B = \frac{LWR_b(1.00 + H_b)}{cf} = \frac{5,808(23)(1.0)(1.05)}{360} = \frac{140,263.2}{360} = 390 \text{ barrels}
\]

Determine the amount of loose aggregate, in cubic yards, needed for the project (round up the amount).

\[
V = \frac{LW(FPT)(CF)(1.00 + H_a)}{cf} = \frac{5,808(23)(2)(1.3)(1.10)}{324}
V = \frac{382,050.24}{324} = 1,180 \text{ cubic yards}
\]

PLANT MIX

6-6. Determine the amount of plant mix required for the pavement. Multiply the compacted volume (cubic feet) using the unit weight of the mix in pounds per cubic foot. The unit weight is determined by the Marshall method as described in FM 5-472. If the exact unit weight of the plant mix has not been determined, use an estimated weight of 150 pounds per cubic foot. (Unit weight is usually between 140 and 150 pounds per compacted cubic foot.) Use the following formulas to calculate the amount of mix needed:

- If the unit weight of the plant mix is known—

\[
T = \frac{(LW)(FPT)(UW)}{cf}
\]

- If the unit weight of the plant mix is unknown—

\[
T = \frac{(LW)(FPT)}{cf}
\]
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where—

\[ T = \text{weight of plant mix, in tons} \]
\[ L = \text{length of area, in feet} \]
\[ W = \text{width of area, in feet} \]
\[ \text{FPT} = \text{finished pavement thickness, in inches (after compaction)} \]
\[ \text{UW} = \text{unit weight of plant mix, in pounds per cubic foot} \]
\[ \text{cf} = \text{conversion factor. If the unit weight of the plant mix is known, use } 24,000 \text{ (2,000 pounds per ton x 12 inches per foot). If the unit weight of the plant mix is unknown, use } 160 \text{ (24,000/150 [maximum unit weight normally encountered])} \]

**Example:** A 110- by 650-foot parking lot requires 2 inches of plant mix. Determine the amount of plant mix, in tons, needed for this project if the unit weight of the plant mix is 147 pounds per cubic feet.

**Solution:** Since the unit weight of the plant mix is known, use the first base formula (round up the amount).

\[
T = \frac{(LW)(\text{FPT})(\text{UW})}{\text{cf}} = \frac{(650)(110)(2)(147)}{24,000} = \frac{21,021,000}{24,000} = 876 \text{ tons}
\]

6-7. Determine the proportion of each plant-mix component.

**Example:** The required amount of plant mix for the project is 800 tons. The aggregate blend is 50 percent CA, 40 percent FA, and 10 percent mineral filler. The bitumen content is 6 percent (calculated as a check for this example). Determine how many tons of each component is needed.

**Solution:** Determine the percent of each aggregate in the mix by multiplying its blend percentage from the above paragraph by 0.94, which is the total aggregate percent by weight (100 - 6 [bitumen content]).

\[
\begin{align*}
\text{CA} &= 47 \text{ percent of the total mix (0.94 x 50)} \\
\text{FA} &= 37.6 \text{ percent of the total mix (0.94 x 40)} \\
\text{Mineral filler} &= 0.094 \text{ percent of the total mix (0.94 x 10)}
\end{align*}
\]

Multiply the required tonnage of the plant mix (800) by the percentage of each component of the mix. Adjust the results, if necessary, so that the total amount of the components equals the required tonnage of the plant mix.

\[
\begin{align*}
\text{CA} &= 376 \text{ tons (800 x 0.470)} \\
\text{FA} &= 300.8 \text{ tons (800 x 0.376)} \\
\text{Mineral filler} &= 75.2 \text{ tons (800 x 0.094)} \\
\text{Bitumen} &= 48 \text{ tons (800 x 0.060)} \\
\text{Total} &= 800 \text{ tons}
\end{align*}
\]

**MILEAGE REQUIREMENTS**

6-8. Determine the number of miles of surfacing that can be constructed with a given amount of bitumen and aggregates. Compute the amount required for 1 mile using the appropriate formula in this chapter. Divide the results into the amount of available materials. In the following example, the aggregate is the controlling factor:
**Example:** Use the following specifications to calculate how many miles of single surface treatment can be applied on a road:

\[ W = 23 \text{ feet} \]
\[ R_a = 20 \text{ pounds per square yard} \]
\[ G = 30,000 \text{ gallons} \]
\[ T = 1,500 \text{ tons of available material} \]
\[ R_b = 0.2 \text{ gallon per square yard} \]
\[ H_a = 10 \text{ percent} \]
\[ H_b = 5 \text{ percent} \]
\[ T_1 = \text{tons of aggregate per mile} \]
\[ G_1 = \text{gallons of bitumen per mile} \]

**Solution:** Using the base formula for a surface treatment, determine how many tons of aggregate are needed for 1 mile of surface.

\[
T_1 = \frac{LWR_b(1.00 + H_a)}{cf} = \frac{(5,280)(23)(20)(1.10)}{18,000} = \frac{2,671,680}{18,000} = 148.4 \text{ tons per mile}
\]

Calculate how many miles of surface can be treated with the available aggregate.

\[
\text{Miles of available aggregate} = \frac{T}{T_1} = \frac{1,500}{148.4} = 10.1 \text{ miles}
\]

Using the base formula for a tack coat, calculate how many gallons of bitumen are needed for 1 mile of surface.

\[
G_1 = \frac{LWR_b(1.00 + H_b)}{cf} = \frac{(5,280)(23)(0.20)(1.05)}{9} = \frac{25,502.4}{9} = 2,833.6 \text{ gallons per mile}
\]

Calculate how many miles of surface can be treated with the available bitumen.

\[
\text{Miles of available bitumen} = \frac{G}{G_1} = \frac{30,000}{2,833.6} = 10.6 \text{ miles}
\]

The smallest number always governs; therefore, 10.1 miles is the maximum length of road that can be surfaced using the available materials.