King Saud University
College of Engineering
Civil Engineering Department

CE 431: Highway Engineering
Tutorial Note 5: Chapter 18
Eng. Ibrahim Almohanna

18-1 it is desired to combine material A, which is the soil existing in the roadbed, with material B, which may be obtained from nearby borrow sources at low cost, to form a stabilized soil-aggregate surface course conforming to the specification recommended by AASHTO, Table 18-1, grading C. the sieve analysis of material A and B are shown in the following tabulation. Determine approximately the limiting proportions of A and B that should be used to produce a stabilized mixture of the desired gradation. That is, determine the greatest proportion of A that can be used in the mixture and still meet the specifications, then the smallest proportions of A that will meet the same objective.

	Percentage passing (by weight)	
Sieve Designation	***Material A***	***Material B***
1 in.	**100**	**100**
3/8 in.	**68**	**45**
No. 4	**46**	**28**
No. 10	**36**	**17**
No. 40	**32**	**7**
No. 200	**17**	**3**

By inspection, 100% of A will meet grading specification. Thus, the greatest proportion of A that can be used is 100%.

Let x = fraction of A; (1- x) = fraction of B

Consider the No. 200 fraction:

$(x)17 + (1 - x)\,3 = 5 \quad \Rightarrow x = 2/14 = 0.143$

$(x)\,17 + (1 - x)\,3 = 15 \quad \Rightarrow x = 12/14 = 0.857$

Consider the No. 40 fraction:

$(x)32 + (1 - x)\,7 = 15 \quad \Rightarrow x = 8/25 = 0.32$

$(x)\,32 + (1 - x)\,7 = 30 \quad \Rightarrow x = 23/25 = 0.92$

Consider the No. 10 fraction:

$(x)36 + (1 - x)\,17 = 25 \quad \Rightarrow x = 8/19 = 0.421$

$(x)\,36 + (1 - x)\,17 = 50 \quad \Rightarrow x = 33/19 = 1.736$, over 100%, use 100%

Consider the No. 4 fraction:

(x) 46 + (1 - x) 28 = 35 ➔ x = 7/18 = 0.389

(x) 46 + (1 - x) 28 = 65 ➔ x = 37/18 = 2.056, over 100%, use 100%

Consider the 3/8 in. fraction:

(x) 68 + (1 - x) 45 = 50 ➔ x = 5/23 = 0.217

(x) 68 + (1 - x) 45 = 85 ➔ x = 40/23 = 1.739, over 100%, use 100%

Thus, one could use any combination of material ranging from 14.3% to 100% of A and meet the given specifications.

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18-2 For the materials of Problem 18-1, the following are plasticity characteristics. Material A: liquid limit,40, plasticity index, 12. Material B: liquid limit, 13, plasticity index, 3. Estimate the liquid limit and plasticity index of the aggregate blend selected in problem 18-1. Assume 80% A, 20% B combination.

by equation 18-1,

$$PI_{mix} = \frac{\%A \times \%passing\ No.40, A \times PI, A + \%B \times \%passing\ No.40, B \times PI, B}{\%A \times \%passing\ No.40, A + \%B \times \%passing\ No.40, B}$$

$$PI_{mix} = \frac{0.8 \times 32 \times 12 + 0.2 \times 7 \times 3}{0.8 \times 32 + 0.2 \times 7}$$

$$PI_{mix} = \frac{307.2 + 4.2}{25.6 + 1.4} = 11.533$$

Similarly,

$$LL_{mix} = \frac{\%A \times \%passing\ No.40, A \times LL, A + \%B \times \%passing\ No.40, B \times LL, B}{\%A \times \%passing\ No.40, A + \%B \times \%passing\ No.40, B}$$

$$LL_{mix} = \frac{0.8 \times 32 \times 40 + 0.2 \times 7 \times 13}{0.8 \times 32 + 0.2 \times 7}$$

$$LL_{mix} = \frac{1024 + 18.2}{25.6 + 1.4} = 38.6$$

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18-3 Assuming that the compacted mixture of problem 18-1 has a dry unit weight of 120 lb/ft^3, determine how many tons of material B will be required per mile of road, assuming that the surface is to be 24 ft wide and will have compacted thickness of 7 in. Estimate the number of cubic yards (loose measure) of this material that will be required per mile, assuming that the loose material weighs 105 lb/ft^3. Assume %B = 20%.

$$No.of\ tons\ of\ B = \%B \times width \times thickness \times length \times unit\ weight$$

$$No.of\ tons\ of\ B = 0.2 \times (24ft) \times \left(\frac{7\ in}{12\ in/ft}\right) \times (5280\ ft/mile) \times \left(\frac{120\ lb/f^3}{2000\ lb/ton}\right)$$

$$No.of\ tons\ of\ B = 0.2 \times (24ft) \times (0.583ft) \times (5280\ ft/mile) \times (0.06\ ton/ft^3) = 887\ tons/mile$$

$$unit\ weght\ of\ loose\ material\ in\ \frac{lb}{yd^3} = 105\frac{lb}{ft^3} \times 27\frac{ft^3}{yd^3} = 2835\ \ \frac{lb}{yd^3}$$

$$Volume\ of\ B = \frac{887\ \frac{tons}{mile} \times 2000\frac{lb}{ton}}{2835\frac{lb}{yd^3}} = 626\ yd^3/mile$$

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18-4 if the compacted mixture of problem 18-1 has a dry unit mass density of 1830kg/m^3, estimate the mass in kilograms of material B required per kilometer of road, given road width = 7.0 m and surface thickness = 0.25m. if loose material has a mass density of 1700 kg/m^3, how many cubic meters of loose material will be needed? Assume 20% B .

$$No.of\ tons\ of\ B = \%B \times width \times thickness \times length \times unit\ weight$$

$$No.of\ tons\ of\ B = 0.2 \times (7m) \times (0.25m) \times (1000m/km) \times (1830kg/m^3)$$

$$No.of\ tons\ of\ B = 640500\ kg/km$$

$$Volume\ of\ B = \frac{640500\ kg/km}{1700kg/m^3} = 377\ m^3/km$$

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18-5 Assume that a pressure distributer has a spray bar that is 12 ft long. If the pump discharge is at the rate of 270 gallons per minute, with the pump operating at the proper speed for the material that is being used, determine the rate of the bituminous material in gallons per square yard when the distributor is travelling at the rate of 1050 ft/min. Also, determine the reading that must be maintained on the truck tachometer to maintain this rate of application if the tachometer is calibrated to read 100 times the truck speed in miles per hour. Assume that all the pumped material passes pit through the spray bars and is applied to the road surface.

$$Rate\ of\ application = \frac{pump\ discharge\ is\ at\ the\ rate}{distributor\ speed \times length\ of\ spray\ bar}$$

$$Rate\ of\ application = \frac{270\,\frac{gal}{min}}{1050\,\frac{ft}{min} \times 12\ ft} = 0.0214\ gal/ft^2$$

$$Rate\ of\ application = 0.0214 \times 9\,\frac{ft^2}{yd^2} = 0.193\ gal/yd^2$$

$$tachometer\ reading = speed \times magnifier$$

$$tachometer\ reading = 1050\,\frac{ft}{min} \times 100 = 105000\ \frac{ft}{min}$$

$$tachometer\ reading = \frac{105000\,\frac{ft}{min} \times 60\,\frac{min}{hr}}{5280\,\frac{ft}{mile}} = 1193.2\ \frac{mile}{hr}$$

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18-6 A pressure distributor that has a spray bar 3.5 m wide travels 20 km/hr while spraying at the rate of 15 L/sec. Determine the rate of application in liters per square meter.

$$Rate\ of\ application = \frac{pump\ discharge\ speed}{distributor\ speed \times length\ of\ spray\ bar}$$

$$Rate\ of\ application = \frac{15\,\frac{L}{sec}}{20\,\frac{km}{hr}\left(\frac{1000}{3600}\right) \times 3.5\ m} = 0.77\ L/m^2$$

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18-7 A new granular type base is to be covered with a double surface treatment, meeting the requirements of FHWA Type AT-60. Assuming that the base is to be 24 ft wide, compute the quantities of bituminous material and crushed stone required for 1 mile of pavement if the specific gravity of the stone is 2.70.

$$Area\ of\ 1\ mile\ long\ segment = 24\ ft\ \times 5280\frac{ft}{mile} = 126720\frac{ft^2}{mile} = 14080\ \frac{yd^2}{mile}$$

By Table 18-6, use 60 lb/yd^2

$$Quantity\ of\ aggregate = 60\frac{lb}{yd^2}\times 14080\ \frac{yd^2}{mile} = 844800\frac{lb}{mile} = 422.4\frac{tons}{mile}$$

By Table 18-6, use 0.6 gal/yd^2

$$Quantity\ of\ bituminous\ material = 0.6\frac{gal}{yd^2}\times 14080\ \frac{yd^2}{mile} = 8448\frac{gal}{mile}$$

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18-9 Determine the quantities of bituminous material and aggregate required for 1 km of double bituminous surface treatment meeting the requirements of FHWA Type AT-50, Table 18-6. The pavement is to be 7.0 m in width, and the specific gravity of the aggregate is 2.68.

$$Area\ of\ 1\ mile\ long\ segment = 7\ m\ \times 1000\frac{m}{km} = 7000\frac{m^2}{km}$$

By Table 18-6, use 27 kg/m^2

$$Quantity\ of\ aggregate = 27\frac{kg}{m^2}\times 7000\ \frac{m^2}{km} = 189000\frac{kg}{km} = 189\frac{tons}{km}$$

By Table 18-6, use 2.3 L/m^2

$$Quantity\ of\ bituminous\ material = 2.3\frac{L}{m^2}\times 7000\ \frac{m^2}{km} = 16100\frac{L}{km}$$

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