Chapter 25

Dry Mix Design

25.1 Overview

The objective of dry mix design is to determine the amount of various sizes of mineral aggregates to use to get a mix of maximum density. The dry mix design involves three important steps, viz. selection of aggregates, aggregates gradation, and proportion of aggregates, which are discussed below.

25.2 Selection of aggregates

The desirable qualities of a bituminous paving mixture are dependent to a considerable degree on the nature of the aggregates used. Aggregates are classified as coarse, fine, and filler. The function of the coarse aggregates in contributing to the stability of a bituminous paving mixture is largely due to interlocking and frictional resistance of adjacent particles. Similarly, fines or sand contributes to stability failure function in filling the voids between coarse aggregates. Mineral filler is largely visualised as a void filling agent. Crushed aggregates and sharp sands produce higher stability of the mix when compared with gravel and rounded sands.

25.3 Aggregate gradation

The properties of the bituminous mix including the density and stability are very much dependent on the aggregates and their grain size distribution. Gradation has a profound effect on mix performance. It might be reasonable to believe that the best gradation is one that produces maximum density. This would involve a particle arrangement where smaller particles are packed between larger particles, thus reducing the void space between particles. This create more particle-to-particle contact, which in bituminous pavements would increase stability and reduce water infiltration. However, some minimum amount of void space is necessary to:

- provide adequate volume for the binder to occupy,
- promote rapid drainage, and
- provide resistance to frost action for base and subbase courses.

A dense mixture may be obtained when this particle size distribution follows Fuller law which is expressed as:

$$p = 100 \left[\frac{d}{D} \right]^n \tag{25.1}$$

where, p is the percent by weight of the total mixture passing any given sieve sized, D is the size of the largest particle in that mixture, and n is the parameter depending on the shape of the aggregate (0.5 for perfectly rounded particles). Based on this law Fuller-Thompson gradation charts were developed by adjusting the parameter n for fineness or coarseness of aggregates. Practical considerations like construction, layer thickness, workability, etc, are also considered. For example Table 25:1 provides a typical gradation for bituminous concrete for a thickness of 40 mm.

Table 25:1: Specified gradation of aggregates for BC surface course of 40 mm

Sieve size (mm)	Wt passing (%) Grade 1	Wt passing (%) Grade 2
20	-	100
12.5	100	80-100
10.0	80 - 100	70 - 90
4.75	55 - 75	50 - 70
2.36	35 - 50	35 - 50
0.60	18 - 29	18 - 29
0.30	13 - 23	13 - 23
0.15	8 - 16	8 - 16
0.075	4 - 10	4 - 10
Binder*	5 - 7.5	5 - 7.5

* Bitumen content in percent by weight of the mix

25.4 Proportioning of aggregates

After selecting the aggregates and their gradation, proportioning of aggregates has to be done and following are the common methods of proportioning of aggregates:

- **Trial and error procedure**: Vary the proportion of materials until the required aggregate gradation is achieved.
- **Graphical Methods**: Two graphical methods in common use for proportioning of aggregates are, Triangular chart method and Rothfuch's method. The former is used when only three materials are to be mixed.
- Analytical Method: In this method a system of equations are developed based on the gradation of each aggregates, required gradation, and solved by numerical methods. With the advent of computer, this method is becoming popular and is discussed below. The resulting solution gives the proportion of each type of material required for the given aggregate gradation.

25.5 Example 1

A hypothetical gradation given in table 28:1 in column 1 and 2. The gradation of available three aggregate A, B, and C are given in column 3, 4, and 5. To construct the system of simultaneous equations, the midpoint of the lower and upper limits of the required gradation is computed in column 6. The decision need to take is the proportion of aggregate A, B, C need to be blended to get the gradation of column 6.

Table 25:2: Gradation

Sieve size (mm) (1)	Required Gradation Range (2)	Filler (A) (3)	Fine Aggr. (B) (4)	Coarse Aggr. (C) (5)	Exact Gradation (6)
25.4	100.0	100.0	100.0	100.0	100
12.7	90-100	100.0	100.0	94.0	95.0
4.76	60-75	100.0	100.0	54.0	67.5
1.18	40-55	100.0	66.4	31.3	47.5
0.3	20-35	100.0	26.0	22.8	27.5
0.15	12-22	73.6	17.6	9.0	17.0
0.075	5-10	40.1	5.0	3.1	7.5

Let x_1, $x2$, x_3 represent the proportion of A, B, and C respectively. Equation of the form $ax_1+bx_2+cx_3 = p$ can be written for each seive size, where a, b, c is the proportion of aggregates A, B, and C passing for that sieve size and p is the required proportion for that sieve size. This will lead to following system to equation:

$$\begin{aligned}
x_1 + \quad x_2 + \quad x_3 &= 1 \\
x_1 + \quad x_2 + \quad 0.94x_3 &= 0.95 \\
x_1 + \quad x_2 + \quad 0.54x_3 &= 0.675 \\
x_1 + \quad 0.664x_2 + \quad 0.313x_3 &= 0.475 \\
x_1 + \quad 0.260x_2 + \quad 0.228x_3 &= 0.275 \\
.736x_1 + \quad 0.176x_2 + \quad 0.09x_3 &= 0.170 \\
.401x_1 + \quad 0.050x_2 + \quad 0.031x_3 &= 0.075
\end{aligned} \tag{25.2}$$

Solution to this problem is $x_1 = 0.05$, $x_2 = 0.3$, $x_3 = 0.65$. Table 28:1 shows how when these proportions of aggregates A, B, and C are combined, produces the required gradation.

Table 25:3: Result of mix design

Sieve size (mm) (1)	Filler (A) (2)	Fine Aggr. (B) (3)	Coarse Aggr. (C) (4)	Combined Gradation mix (5)
25.4	100x0.5=5.0	100x0.3=30	100x.65=65	100
12.7	100x0.5=5.0	100x0.3=30	94x0.65=61	96
4.76	100x0.5=5.0	100x0.3=30	54x0.65=35.1	70.1
1.18	100x0.5=5.0	66.4x0.3=19.8	31.3x0.65=20.4	45.2
0.3	100x0.05=5.0	26.3x0.3=7.8	22.8x.65=14.8	27.6
0.15	73.6x0.05=3.7	17.6x0.3=5.3	9x0.65=5.9	14.9
0.75	40.1x0.05=2.0	5x0.3=1.5	3.1x0.65=2.0	5.5

In this method proportioning of aggregates done by solving a system of linear equations which are constraints and the resulting solution gives the proportion of each type of material required for the given aggregate gradation. Let x_1, $x2$, x_3 and x_4 are the materials with their gradation and the required aggregate gradation are given in the table (Gradation of Materials and the Specified gradation). The proportion of Lime x_4 should not exceed 2%. With the given data, the required proportion of materials can be found out by solving the given constraints which are linear equations. e.g set of constraints are:

- $x_1 + x_2 + x_3 + x_4 = 1$
- $.85x_1 + x_2 + x_3 + x_4 \geq .95$
- $.85x_1 + x_2 + x_3 + x_4 \leq 1.0$
- ....
- $x_4 \leq 0.02$

The Solution to this problem is $x_1 = 0.285$, $x_2 = 0.358$, $x_3 = 0.02$ and $x_4 = 0.02$.

25.6 Summary

The various steps involved in the dry mix design were discussed. Gradation aims at reducing the void space, thus improving the performance of the mix. Proportioning is done by trial and error and graphical methods.

25.7 Problems

Table 25:4: Gradation of Materials and the Specified gradation

Size	Gradation of A	Gradation of B	Gradation of C	Gradation of D	Lower limit	Upper limit
26.5 mm	100	100	100	100	100	100
22.4 mm	85.08	100	100	100	95	100
11.2 mm	1.48	80.68	100	100	55	75
5.6 mm	0	17.72	100	100	40	60
2.8 mm	0	0	85.13	100	30	45
710 m	0	0	59.61	15	100	22
355 m	0	0	37.45	10	100	18
180 m	0	0	24.96	8	100	15
90 m	0	0	15.85	0	100	8