Superpave Volumetric Mix Design

Four major steps in the testing and analysis process :

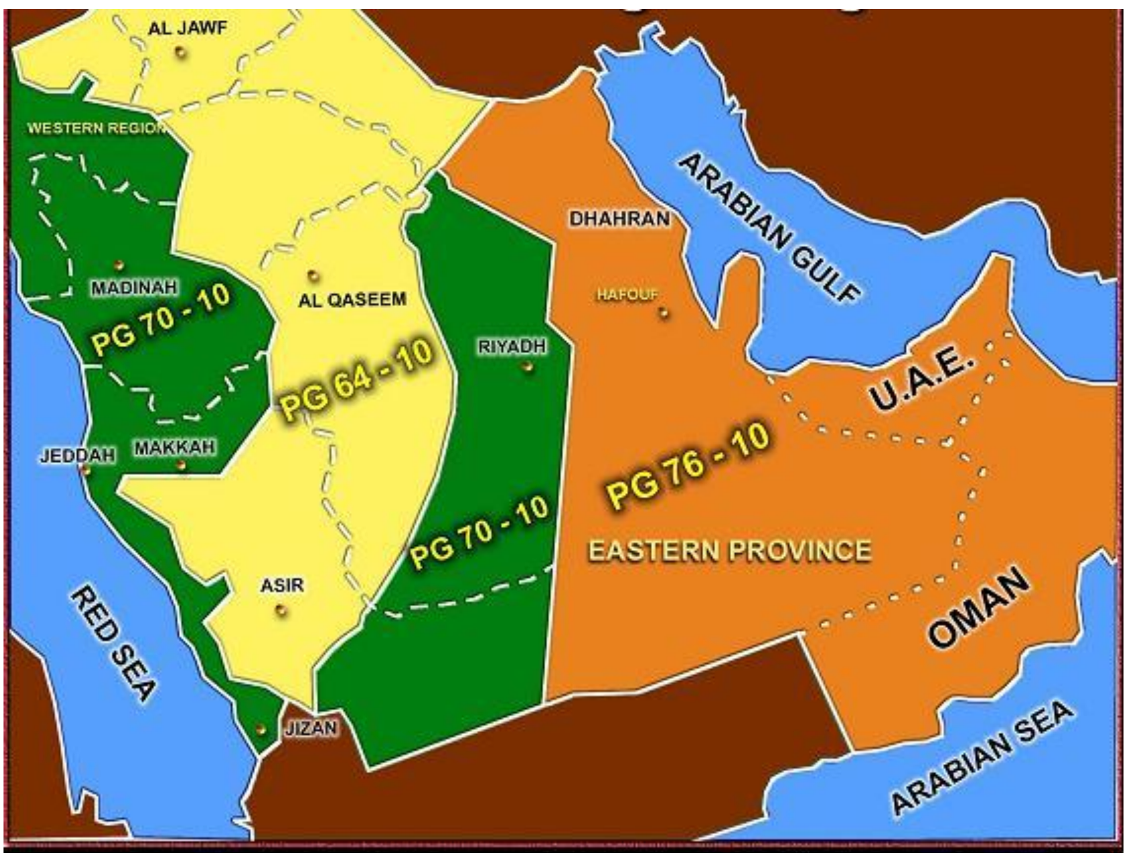
1. Selection of materials (aggregate, binders, modifiers, etc.)
2. Selection of a design aggregate structure
3. Selection of a design asphalt binder content.
4. Evaluation of moisture sensitivity of the design mixture.

Materials Selection :

1. Traffic level 25 million ESALs
2. Average High Air Temperature 40 ºC
3. Standard Speed
4. Bituminous Wearing Course 19 mm Nominal Size of Aggregate
5. To be placed at a depth less than 100 mm from surface of pavement

Binder Selection :

Binder selection is based on environmental data i.e. temperature (the average 7 days maximum and one day minimum pavement temperature) and on speed and traffic level.



Design ESAL's [1] (Millions)	Adjustment to Binder PG Grade [2]		
	Traffic Load Rate		
	Standing (Avg. Speed < 20 km/hr	Slow (Avg. Speed 20 to 70 km/hr	Standard (Avg. Speed < 70 km/hr
< 0.3	- [3]	-	-
0.3 to < 3	2	1	-
3 to <10	2	1	-
10 to < 30	2	1	1[3]
$\geq$ 30	2	1	1

(1) Design ESAL's are anticipated project traffic level expected on the design lane over a 20 years period. Regardless of the actual design life of the roadway, determine the design ESAL's for 20 years and choose appropriate N_{design} level.

(2) Increases the high temperature grade by the number of grade equivalents indicate (1 grade equivalent to 6^{o}C).

(3) Consideration should be given to increasing the high temperature grade by 1 grade .

Aggregate Selection :

1. Performed washed sieve analysis on all individual hot bin, in this case 2 coarse aggregate, crushed sand and cement dust.
2. Performed specific gravity and absorption on all individual hot bins.
3. Performed aggregate quality test such as Coarse Aggregate Angularity, Fine Aggregate Angularity, Flat & Elongated Particles, Sand Equivalent Test (Consensus Properties)
4. Source properties use to qualify local sources of aggregate such as Soundness, Abrasion, Clay Lumps & Friable Particles.

Consolidated Aggregate Consensus Property Table For Superpave

Design ESAL's [1] (Millions)	Coarse Aggregate Angularity (Min. %)		Uncompacted Void Content of Fine Aggregate Angularity (Min. %)		Sand Equivalent (Min. %)	Flat and Elongated [3] (Max. %)
	< 100 mm	> 100 mm	< 100 mm	> 100 mm		
< 0.3	55/-	-/-	-	-	40	-
0.3 to < 3	75/-	50/-	40	40	45	10
3 to <10	85/80 [2]	80/-	45	40	45	
10 to < 30	95/90	80/75	45	40	45	
$\geq$ 30	100/100	100/100	45	45	50	

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(2) "80/85" denotes that 85% of the coarse aggregate has one fractured face and 80% has two or more fractured faces.

(3) Criterion based upon 5:1 maximum to minimum ratio.

Select Design Aggregate Structures :

1. Establish trial blends by mathematically combining the gradations of the individual materials into a single gradation.
2. The blend gradation is then compared to the Specification requirements for the appropriate sieves.
3. Gradation control is based on four control sieves: the maximum sieve, the nominal maximum sieve, no.8 sieve and no.200 sieve.

The nominal maximum sieve is one sieve size larger than the first sieve to retain more than ten percent of combined aggregate. The maximum sieve size is one sieve size greater than the nominal maximum sieve.

Select Trial Asphalt Binder Content :

Evaluate the trial blends by compacting specimens and determining the volumetric properties of each trial blend. For each blend, a minimum of two specimens will be compacted using the Superpave Gyratory Compactor (SGC). The trial asphalt binder content can be estimated based on experience with similar materials. If there is no experience, the trial binder content can be determined for each trial blend by estimating the specific gravity of the blend.

Calculations for estimating the trial asphalt binder content can be divided into four steps.

1. Estimate aggregate effective specific gravity
2. Estimate volume of absorbed binder
3. Estimate volume of effective binder
4. Estimate trial binder content

Step 1 : Estimate the effective specific gravity (Gse) of the trial blends :

$$Gse = Gsb + 0.8 \times (Gsa - Gsb)$$

The factor 0.8 can be adjusted at the discretion of the designed.

Step 2 : Estimate the volume of asphalt binder (Vba) absorbed into the aggregates.

$$Vba = \frac{Ps \times (1 - Va)}{(Pb / Gb + P s/ Gse)} \times \left(1 / Gsb - 1 / Gse \right)$$

where Vba = volume of absorbed binder, cm^3/cm^3 of mix
Pb = percent of binder (assumed 0.05)
Ps = percent of aggregate (assumed 0.95)

Gb = specific gravity of binder (assumed 1.023)
Va = volume of air voids (assumed 0.04 cm^3/cm^3 of mix)

Step 3 : Estimate the volume of effective binder (Vbe) of the trial blends.

$$Vbe = 0.176 - [\, 0.0675 \times \log (Sn) \,]$$

where Sn = nominal maximum sieve size of the aggregate in mm.

Step 4 : Estimate initial trial asphalt binder (Pbi) content for the trial blends.

$$Pbi = \frac{Gb \times (Vbe + Vba)}{[\, Gb \times (Vbe + Vba)] + Ws}$$

where Pbi = percent (by weight of mix) of binder
Ws = weight of aggregate, grams

$$Ws = \frac{Ps \times (1 - Va)}{[\, Pb / Gb + Ps / Gse \,]}$$

Specimens are mixed at the appropriate mixing temperature. Gmm specimens are then short-term aged by placing the loose mix in a flat pan in a forced draft oven at the compaction temperature, for 2 hours.

ESAL's	GCE			Traffic Description
	N ini	N des	N max	
< 0.3	6	50	75	Very light traffic
0.3 to < 3	7	75	115	Light traffic
3 to < 30	8	100	160	Medium to heavy traffic
≥ 30	9	125	205	Very Heavy traffic

Each specimen is compacted to the design number of gyrations, with the specimen height data collected during compaction process.

During compaction, the height of the specimen is continuously monitored. After compaction is complete, the specimen is extruded from the mold and allowed to cool. Next, the bulk specific gravity (Gmb) of the specimen is determined using AASHTO T 166. The Gmm of each blend is determined using AASHTO T 209. Gmb is then divided by Gmm to determine the %Gmm @ Ndes. The %Gmm at any number of gyrations (Nx) is then calculated by multiplying %Gmm @ Ndes by the ratio of the heights at Ndes and Nx.

Evaluate Trial Blends :

1. The average %Gmm is determined for Nini and Ndes for each trial blend.

2. The %Gmm for Nmax must also be evaluated. Two additional specimen can be compacted to Nmax on the selected trial blend.
3. The percent Air Voids (AV) and Voids in Mineral Aggregate (VMA) are determined at Ndes.

$$\%\ \text{Air Voids},\quad AV = 100 - \%Gmm\ @\ Ndes$$

$$\%\ V.M.A. = 100 - \frac{(\%Gmm\ @\ Ndes \times Gmm \times Ps)}{Gsb}$$

4. Estimate asphalt binder content to achieve 4 % Air Voids (96 % Gmm @ Ndes)

$$Pb\ \text{estimated} = Pbi - (0.4 \times (4 - Va)$$

where Pb estimated = estimated percent binder
Pbi = initial binder content (trial AC)
Va = percent Air Voids at Ndes (4 %)

5. The volumetric (VMA and VFA) and mixture compaction properties are then estimated at this asphalt binder content using the equations below.

$$\%\ VMA\ \text{estimated} = \%\ VMA\ \text{initial} + c \times (4 - Va)$$

where % VMA initial = % VMA from trial asphalt binder content
c = constant (either 0.1 or 0.2)
Note : c = 0.1 if Va is less than 4.0 % of c = 0.2 if Va is greater than 4.0 %

$$\%\ VFA\ \text{estimated} = 100 \times \frac{(\%VMA\ \text{estimated} - 4)}{\%VMA\ \text{estimated}}$$

5. Computation for % Gmm estimated at Nini

$$\%\ Gmm\ \text{estimated}\ @\ Nini = \%\ Gmm\ \text{trail}\ @\ Nini - (4 - Va)$$

6. Finally, there is a required range on the dust proportion. This criterion is constant for all levels of traffic. It is calculated as the percent by mass of the material passing no.200 sieve divided by the effective asphalt binder content. The effective asphalt binder content is calculated using :

$$Pbe\ \text{estimated} = Pb - (Ps \times Gb) \times \left(\frac{Gse - Gsb}{Gse \times Gsb}\right)$$

Dust Proportion is calculated using :

$$DP = \frac{P_{0.075}}{Pbe_{estimated}}$$

Superpave Volumetric Mixture Design Requirements

<table>
<tr><th rowspan="3">Design ESAL's (1)
(Millions)</th><th colspan="3" rowspan="2">Required Density
(Percent of Gmm)</th><th colspan="5">Voids in Mineral Aggregate (VMA)
(Minimum Percent)</th><th rowspan="3">Voids Filled with Asphalt (VFA)
(Min. %)</th><th rowspan="3">Dust-Proportion

(D/P)</th></tr>
<tr><th colspan="5">Nominal Maximum Aggregate Size (mm)</th></tr>
<tr><th>$N_{initial}$</th><th>N_{design}</th><th>N_{max}</th><th>37.5</th><th>25.0</th><th>19.0</th><th>12.5</th><th>9.5</th></tr>
<tr><td>< 0.3</td><td>≤ 91.5</td><td rowspan="5">96.0</td><td rowspan="5">≤98.0</td><td rowspan="5">11 [4]</td><td rowspan="5">12</td><td rowspan="5">13</td><td rowspan="5">14</td><td rowspan="5">15</td><td>70-80 [2]</td><td rowspan="5">0.6-1.2[4]</td></tr>
<tr><td>0.3 to < 3</td><td>≤ 90.5</td><td>65-78 [2]</td></tr>
<tr><td>3 to <10</td><td rowspan="3">≤ 89.0</td><td rowspan="3">65-75 [2]</td></tr>
<tr><td>10 to < 30</td></tr>
<tr><td>≥ 30</td></tr>
</table>

(1) Design ESAL's are anticipated project traffic level expected on the design lane over a 20 years period. Regardless of the actual design life of the roadway, determine the design ESAL's for 20 years and choose appropriate N_{design} level.

(2) For 25.0 mm nominal maximum size mixtures the specified VFA range shall be 67-80% for design traffic levels ≥ 3 million ESAL's.

(3) For 37.5 mm nominal maximum size mixtures the specified lower limit of the VFA shall be 64-80% for design traffic levels ≥ 3 million ESAL's and 64-78 % for design traffic level 0.3-3.0 million ESAL's.

(4) If the gradation line passes below PCS, considered it as coarse gradation with DP requirement of 0.8-1.6% and considered fine gradation if line passes above PCS.

Primary Control Sieve (PCS)

Nominal Maximum Size	37.5mm	25mm	19mm	12.5mm	9.5mm
Primary Control Sieve	9.5mm	4.75mm	4.75mm	2.36mm	2.36mm
% Passing PCS	47	40	47	39	47

Select Design Asphalt Content

Select the best and economical blend meeting the design criteria.
Specimens are compacted at varying asphalt binder contents. The mixture properties are then evaluated to determine the design asphalt binder content.

A minimum of two specimens are compacted at each of the following asphalt contents, estimated binder content, ± 0.5 % & + 1.0 %.
A minimum of two specimens is also prepared for determination of maximum theoretical specific gravity at the estimated binder content.

A. Gyratory compact two specimens @ each binder content to Ndes. Determine Gmb.
B. Determine Gmm @ each binder content.
C. Use the same formulas in the selection of DAS to compute :
    a. % Gmm @ Ninitial & Ndesign
    b. Volumetric properties (Air Voids, VMA, VF, Pba, Pbe)
    c. Dust Proportion (DP)
    d. Generate graphs for each property versus binder content
D. From the graphs and @ 4.0 % Air Voids, determine DAC
E. Check VMA, VFA and % Gmm @ Nini
F. Compare with Superpave criteria and adjust the design as needed.

Ndes & Nmax Verification

A. Gyratory compact 2 specimen each @ Ndes & @ Nmax
B. Compute % Gmm @ Nmax, Ndes, & Nini
C. Compare with Superpave criteria and adjust the design as needed.