Asphalt Pavement Mixture Selection

A. Scope

This section is intended for the engineers and technicians who specify asphalt paving material criteria for urban projects, generally ranging from low to medium volume, up to 10M ESALs. Vehicle volumes exceeding 10M $ESAL_{20}$, or projects outside of these design standards, may require more detailed design and/or expert consultation. The section provides a step-by-step process for determining the appropriate mixture criteria and gives the designer additional background information on specific mixture criteria. The section is intended to assist in selecting the mixture criteria that best satisfy the project demands and limitations. Statewide use of this section will improve the standard application of current accepted gyratory mix design technology. In accordance with AASHTO and Iowa DOT Materials I.M. 510, mixture selection involves the use of a 20 year design life whereas pavement thickness design is based on a 50 year design life.

B. Definitions

Equivalent Single Axle Load (ESAL): A standard unit of pavement damage created by a single pass of a vehicle axle.

Car axle = 0.0002 ESAL 18kip truck axle = 1.0 ESAL 24kip truck axle = 3.0 ESAL

$ESAL_{20}$: Estimated cumulative ESALs over a 20 year period.

N: The number of gyratory compaction revolutions at which HMA mixture properties are measured. N_{des} represents 20 years of traffic loading.

Gyratory Mix Design: A laboratory process for achieving desired pavement performance by determining the optimum proportions of aggregates and asphalt binder for hot mix asphalt using a SHRP Superpave gyratory compactor.

Lift Designation (Surface, Intermediate, Base): The terms for the lifts in the hot mix asphalt pavement structure. The surface lift is the top lift, about 1 1/2 inches thick. The intermediate lift(s) is one or more lifts placed under the surface lift, generally 2 to 4 inches thick. The base lift(s) is all mixture placed below the intermediate lift, generally limited to full depth construction.

Modified Asphalt Binders: For design traffic levels greater than 1,000,000 ESALs (High, Very High, and Extremely High), the binders may need to be modified and thus may be more costly.

Nominal Maximum Aggregate Size (NMAS): The mixture size designation used for the combined aggregate gradation. Defined as one sieve size larger than the first sieve to retain more than 10%.

Performance Graded (PG): National asphalt binder grading system, developed by AASHTO, based on high and low pavement operating temperatures (°C). A PG binder is identified using a nomenclature of PG XXYY, followed by an ESAL designation (L, S, H, V, E). The XX is the high pavement temperature in degrees Celsius in which the binder should resist rutting. The YY, in negative Celsius, is the low pavement temperature in which the binder should resist cracking. For example a PG 58-28S should resist rutting to 58 °C and cracking of the pavement to a temperature of -28 °C under standard (0.3 M to 1 M ESALs) traffic loading.

C. Design Checklist

Designers should follow the steps below to ensure that the material criteria selected will best meet the needs of the project and the constraints of the owner agency.

1. **Determine the Level of Traffic Forecasted for the Next 20 Years:** Both current and future traffic levels are needed to determine the appropriate asphalt mixture for the project. Even if the project is not expected to remain in place for 20 years, the material selection levels are based on 20 year values. Common values are average daily traffic (ADT) for the current year, ADT for the 20 year forecast, and percent trucks. In addition to these annualized daily values, the designer should consider potential seasonal high truck volumes, and give particular attention to point sources and future development areas that may generate heavy truck volumes, like quarries, industrial parks, and bus lanes. Seasonal truck volumes may reflect a rate of pavement loading well in excess of the annualized values.

2. **Understand the Pavement Section Design or Rehabilitation Strategy:** In order to make the proper mixture selection, the designer must have knowledge of the proposed pavement construction or rehabilitation and intended pavement performance. The thickness of the pavement will also affect the material and mixture selection. Particular parameters include required structural thickness, existing pavement cross section and condition (dominant distress patterns), traffic patterns and speed, and past maintenance.

3. **Determine the Regional Climate Conditions:** Iowa's 1 day low pavement temperature ranges approximately 5°C from north to south. Adjusted for 98% reliability, the values range from -28 °C to -24 °C. The 7 day high pavement temperature across the state only varies by 3 °C. These values are computed from daily high air temperatures. Adjusted for 98% reliability, the pavement temperature values range from 56 °C to 59 °C. Climate details for a specific location can be obtained from the LTPPB software package available on the FHWA website (https://infopave.fhwa.dot.gov/). See Figures 5D-1.01 and 5D-1.02.

4. **Compute the Anticipated 20 Year Pavement Loading:** The design pavement loading is the starting point for selecting the material and mixture selection criteria. The design pavement loading is measured in ESALs, not ADT. To determine the design ESALs on the project, use the traffic conditions from Step 1 and compute the $ESAL_{20}$. Use the examples outlined in Examples 5D-1.01 and 5D-1.02, for two lane, two way traffic; use Example 5D-1.03 for urban multi-lane situations. Design ESAL levels for asphalt criteria selection are divided into relatively large brackets. While a firm understanding of the traffic and pavement loading is important, good approximations of truck traffic are normally sufficient to determine the design requirements.

5. **Identify Any Special Conditions that Impact the Pavement:** The standard selection process is based on high speed traffic with a broad distribution of vehicle types. There are numerous special conditions that may, through engineering judgement, require changes in the standard pavement materials/mixture selection. These special conditions are outlined below.

   a. **Heavy Trucks:** If the pavement's history has regularly been impacted by heavy trucks, the designer may consider increasing either the binder grade through the designation of a higher design traffic loading, the mix designation (ESAL level), or both. Typical examples of this condition are routes adjacent to quarries, grain elevators, or regional commercial freight distribution centers.

   b. **Slow/Stop/Turning:** Urban roadways normally require slower running speeds and often include signed or signaled intersections. The pavement loading condition significantly increases at slower speeds (less than 45 MPH) and stopped vehicles at intersections. The designer may consider increasing the binder grade through the designation of a higher design traffic loading and/or the percent of crushed aggregate to account for this condition. Economics will determine if the higher grade of binder can be applied to the whole project, or just the impacted length of pavement (i.e. intersection and approaches).

   c. **Durability:** Many low-volume asphalt pavements are more susceptible to failure due to long term aging than to rutting or fatigue. For pavements with good maintenance histories the designer may want to ensure that the mixture selection will provide adequate durability and, if economically necessary, sacrifice some reliability against rutting or fatigue. This can be accomplished through the selection of a lower compaction level and/or the selection of a softer grade of binder.

   d. **Urban vs. Rural:** Separate from the issue of traffic speed, rural projects that pass through urban locations should consider mix sizes (NMAS) that will appeal to the pedestrian traffic. In general, smaller mix sizes will have a better surface appearance than larger mix sizes. The designer can specify smaller mix sizes than those provided in the material selection guide table, but should also consider the availability of the aggregates when making that decision. Similarly, the designer may choose to use a larger mix size on rural sections for the purpose of reducing the asphalt binder content in the mixture.

   e. **New Construction vs. Rehabilitation:** The design guide takes into account the major pavement performance factors including rutting, fatigue, and low temperature cracking. When an overlay is placed directly on a slab to be rehabilitated, the existing pavement distress influences the overlay performance and thus the design. If the underlying pavement is PCC or asphalt with thermocracking, the reflective cracking in the overlay will dominate over low temperature cracking so the design parameters related to low temperature cracking for the overlay become less of a factor in the design. If a stress relief layer is included in the overlay design, low temperature cracking should be considered.

   f. **Seasonal Traffic:** Seasonal traffic occurs over a relatively short period of time and may create pavement damage in excess of the normal traffic. For example, grain harvest, Iowa State Fair, festivals, etc. may generate higher volumes (in terms of ESALs) of traffic for a short period of time. This does not only take into account traffic volumes, but also pavement loads.

   g. **Mixture Workability:** Smaller mixture sizes are easier to use for hand work.

6. **Select the HMA Mixture Criteria for Each Pavement Layer:** Using the information developed in steps 1 through 5, select the PG binder grade, mixture size, mix design level, and aggregate properties.

   a. **PG Asphalt Binder Grade:** Engineers should evaluate the initial costs, traffic loadings, historical experience, and potential maintenance costs when selecting the appropriate binder for a project. The designer should select a binder that nominally satisfies 98% temperature reliability for both the 7 day high pavement temperature and the 1 day low pavement temperature (see 5D-1, C, 3). The 98% reliability level described by LTPP Bind designates the areas that are covered to the most extreme high and low temperatures in Iowa. When evaluating the binder to select, the engineer should balance initial costs for the binder and the likelihood of maintenance requirements caused by rutting/shoving for high pavement temperatures and low temperature cracking during the 1 day cold temperatures. In Iowa, PG 58-28S binders will provide full 98% reliability.

Engineers may designate an "H" binder, such as PG58-28H, to accommodate higher truck traffic and/or slower stop and go traffic. For the very highest volume roadways, a PG-58-28V should be considered.

For all base and intermediate layers that are 3 to 4 inches below the surface, PG 58-28S is the recommended binder. The surface binders will insulate the lower layers from the severe one day low temperature event. For projects in the central and southern parts of the state that involve overlays, it may be appropriate to use PG 64-22S. If no method is used to retard the reflective cracking, such as an interlayer, rubblization, or crack and seat, the resistance to low temperature cracking is not critical. If there are methods employed to retard the reflective cracking, a PG 58-28S or PG 58-28H should be used.

Agencies in the central and southern part of the state who have had historical success using PG 64-22S may continue use of that binder grade.

Table 5D-1.01: Asphalt Binder for Local Agencies

Asphalt Mixture		**Criteria**			
Design Traffic (1 x 10^6 ESALs)	**Mix Designation**	**Design Traffic (1 x 10^6 ESALs)**		**Design Speed (MPH)**	**PG Binder**
≤ 0.3 M	LT	≤ 0.3 M	and	≤ 45	58-28S
0.3 M to 1 M	ST	0.3 M to 1 M	and	> 45	58-28S
0.3 M to 1 M	ST	0.3 M to 1 M	and	15 to 45	58-28S[1]
1 to 10 M	HT	1 to 10 M	and	15 to 45	58-28H
Overlays	LT/ST/HT	≤ 10M	and	15 to 45	64-22S[2] or 58-28S or H

L = Low S = Standard H = High

[1] Use of PG 58-28H should be considered if heavy truck or bus traffic is present.
[2] If methods are used to retard reflective cracking, PG 58-28S or H is recommended.

b. HMA Mixture Size: Each mixture size (NMAS) is a function of the available aggregates, project conditions, and lift thickness. Minimum lift thickness is a function of density and mixture constructability. The following table shows the minimum lift thickness for the following mix sizes:

Mix Size	**Minimum Lift Thickness**
3/8"	1"
1/2"	1 1/2"
3/4"	2 1/4"
1"	3"

c. Mix Design Level: Based on the projected $ESAL_{20}$ value, seasonal traffic loading and current pavement distress, the designer must select a mix design level. The boundaries of the design levels are not absolute, so the designer should take into consideration the assumptions used to compute the ESAL value.

d. Aggregate Properties: The mixture design criteria (Table 5D-1.03) is derived from Iowa DOT Materials I.M. 510. Table 5D-1.03 specifies a 15% increase in percent crushed aggregate for surface and intermediate mixes 1 M ESALs and less to account for slow, stop, and turning conditions. This will be a local decision based on past performance and available aggregates. The actual percent crushed needed to achieve the mix design gyratory compaction volumetrics will vary with the quality of the aggregates used. Both the specified percent crushed and the gyratory compaction volumetrics must be satisfied by the asphalt mixture.

7. Check for Availability of Materials to Meet the Mix Design Criteria: Review the mix design criteria selected in step 6 and determine if the binder and aggregates required to meet the mix design criteria are readily available or accessible at a reasonable cost. Contact local producers and/or district materials engineers, if the designer plans to use non-standard criteria. Imported aggregates and modified binders generally cause higher costs. The designer should be ready to justify the mix selection decision.

8. Place Mix Criteria in the Project Plans and Proposal: The following information should be placed in the plans and proposal:

a. Traffic and $ESAL_{20}$ Projections: The traffic and $ESAL_{20}$ projections should be listed on the title sheet of the plans. The $ESAL_{20}$ value should coincide with the selected mix design level. If seasonal ESALs are used for design, the title sheet should note that the $ESAL_{20}$ value is based on seasonal loading. The following is an example title sheet.

Traffic	
Current ADT	________
Future ADT	________
Present Trucks	________
$ESAL_{20}$	________

b. HMA Mixture: Each asphalt mixture bid item is defined by the ESAL level, lift designation, and aggregate size. The mixture properties for each mixture level are specified in the specifications and Table 5D-1.03. If the designer specifies a different percent crushed aggregate, this should be identified in the bid item note on the plans. The designer should avoid placing the mix size in additional sections of the plans to minimize errors associated with duplication. The exception to this guide would be a bid item note or tabulation intended to identify locations of different mix sizes for the same lift.

c. Asphalt Binder Grade PG XX -YY: The asphalt binder grade should be specified in the bid item. The designer should avoid placing the binder grade in additional sections of the plans to minimize errors associated with duplication. The exception to this guide would be a bid item note or tabulation intended to identify binder use when multiple binders are specified. The following is an example bid item.

Lift Designation / Mix Size / Binder Grade / Mix Design Level

HMA Standard Traffic (ST) Surface, 3/8", PG 58-28S

D. Material Properties

1. **Typical PG Grades and Their Application:** PG 58-28S is the common conventional binder used in Iowa.

   Some applications utilize specific binder grades. Use PG 58-34E meeting AASHTO T-321 with a minimum of 100,000 cycles to failure for asphalt interlayer applications. Use PG 58-34E+ meeting AASHTO T-324 with a minimum 90% elastic recovery for high performance thin lift applications.

   When recycled asphalt materials (RAM) are used and they exceed 20% replacement of the total binder, the binder grades may need to be modified. See Iowa DOT Materials I.M. 510.

   If warm mix asphalt (WMA) technologies are utilized, the binder grade selection is based on plant mixing temperatures and the level of field compaction. See Iowa DOT Materials I.M. 510 for information on the appropriate binder grade.

2. **Aggregate Source Properties:** Aggregate source properties are defined in Iowa DOT Specifications Section 4127. The mixture criteria listed in Table 5D-1.03 defines the aggregate type for each mixture level specified for the project. Each individual source of aggregate is expected to meet these criteria. The designer may specify a different aggregate type in the bid item note.

3. **Aggregate Consensus Properties:** Aggregate consensus properties are listed in Table 5D-1.03 for each mixture level. These properties include percent crushed aggregate, fine aggregate angularity, clay content (sand equivalent), and flat and elongated particles. These aggregate properties are measured on the combined aggregate, not individual aggregates.

   If the designer specifies a value different from Table 5D-1.03, the value selected should be based on the local practice and desired pavement performance. The asphalt mixture must satisfy both the percent crushed aggregate and laboratory compaction volumetric criteria. The percent crushed aggregate specified is interdependent on the compaction level and the quality of the aggregate.

E. Use of Mixture Selection Guide and Design Criteria Tables

Two tables in Subsection H are provided to assist designers with the selection of asphalt materials for projects. The Asphalt Mixture Selection Guide (Table 5D-1.02) provides the project designer with a set of standard material selections that will satisfy most projects. The Asphalt Mixture Design Criteria (Table 5D-1.03) is derived from Iowa DOT Materials I.M. 510 and provides the mix designer with the detailed mix criteria for each mixture level. The mixture selection guide and mixture design criteria represent the current understanding of accepted asphalt properties for application on urban routes.

The Asphalt Mixture Selection Guide (Table 5D-1.02) represents commonly used mixture parameters, but does not preclude the project designer from deviating from the "recommended" values. The designer should understand the impact of any modification. The first two columns define the standard mixture levels based on traffic loading. The middle columns establish lift thickness and mix size relationships. It should be noted that Table 5D-1.02 does not address required pavement thickness to meet structural needs (Section 5F-1). The Bid Item Designation column ties the mixture levels to the bid items. The final column gives a general statewide guide for the estimated binder content. Local binder content experience may be more appropriate for project estimated quantities. This table does not address the need for special friction aggregate. In general terms, urban routes do not require special friction aggregate.

As mentioned earlier, the Asphalt Mixture Design Criteria (Table 5D-1.03) is derived from Iowa DOT Materials I.M. 510. However, the table differs from I.M. 510. For the surface and intermediate layers of the LT mixes, the amount of crushed aggregate was increased by 15% and for the ST mixes, all layers have an additional 15% crushed aggregate. A different aggregate type and the percent crushed aggregate may be specified by the designer for the project. These values established in the table are prescribed for each mixture and care should be exercised if altered by the project designer. The designer should only change these values when familiar with the material properties and mixture performance for the local area. The bid item plan note must include these values, if it differs from the value in Table 5D-1.03.

F. Example Plans

1. **Title Page:** The traffic and $ESAL_{20}$ projections should be listed on the title sheet of the plans. The $ESAL_{20}$ value should coincide with the selected mix design level. If seasonal ESALs are used for design, the title sheet should note that the $ESAL_{20}$ value is based on seasonal loading.

2. **Typical Section:** Lift thickness should be shown on the typical section. The lift thickness should match or exceed the recommended lift thickness for the mixture size selected, provided compactive requirements are also achieved. The lift should be designated as surface, intermediate, or base. Mixture size or design $ESAL_{20}$ level should not be added to the typical section (it is specified in the bid item).

3. **Bid Items:** Unless otherwise specified, each bid item covers the mixture and binder grade selected. The corresponding bid item note must specify the minimum percent crushed aggregate, if it differs from the value in Table 5D-1.03.

G. Examples for Determination of Traffic ESALs

Similar to pavement thickness design, the asphalt mixture is designed for the frequency and size of the load applied to the pavement. While it is important to have a good understanding of the traffic, it is possible to select the asphalt paving materials based on reasonable approximations. If the designer has actual traffic data, including a distribution of truck types and loads, the current annual ESAL value can be computed from the AASHTO pavement design tables. For most projects however, the designer will determine estimated values based on a general familiarity with the route. The following examples can be used to approximate the design $ESAL_{20}$ for a project.

Example 5D-1.01: Two Lane, Two Way Traffic, Low Volume Street

Step	Task	Values
1	Given: Current AADT Percent Trucks Percent Annual Growth Rate Design Period	1,000 5% 2% 20 years
2	Base Year Design ESALs *[from Section 5F-1, Table 5F-1.08]*	8,000 ESALs
3	Growth Factor *[from Section 5F-1, Table 5F-1.11]*	24.3
4	Compute $ESAL_{20}$ *[8,000 ESALs x 24.3]*	194,400 ESALs
5	Select HMA mixture design level *[from Table 5D-1.02, HMA Mixture Selection Guide]*	**≤ 0.3 M**

Example 5D-1.02: Two Lane, Two Way Traffic, High Volume Street

Step	Task	Values
1	Given: Current AADT Percent Trucks Percent Annual Growth Rate Design Period	10,000 3% 3% 20 years
2	Base Year Design ESALs *[from Section 5F-1, Table 5F-1.08]*	50,000 ESALs
3	Growth Factor *[from Section 5F-1, Table 5F-1.11]*	26.9
4	Compute $ESAL_{20}$ *[50,000 ESALs x 26.9]*	1,345,000 ESALs
5	Select HMA mixture design level *[from Table 5D-1.02, HMA Mixture Selection Guide]*	**1 to 10 M**

Example 5D-1.03: Four Lane Street

Step	Task	Values
1	Given: Current AADT Percent Trucks Percent Annual Growth Rate Design Period	15,000 5% 2% 20 years
2	Base Year Design ESALs *[from Section 5F-1, Table 5F-1.10]*	75,000 ESALs
3	Growth Factor *[from Section 5F-1, Table 5F-1.11]*	24.3
4	Compute $ESAL_{20}$ *[75,000 ESALs x 24.3]*	1,822,500 ESALs
5	Select HMA mixture design level *[from Table 5D-1.02, HMA Mixture Selection Guide]*	**1 to 10 M**

H. Tables and Figures

Table 5D-1.02: Mixture Selection Guide

Design $ESAL_{20}$ (Millions)	Layer Designation	Lift Thickness[3] *min*	*rec*	*max*	Mix Size[1]	Bid Item Designation	Binder Content[2]
≤ 0.3	Surface	1.5	1.5	2.5	1/2”	Low Traffic (LT)	6.00
	Intermediate	1.5	1.5	3			
	Base	1.5	3	4.5			
0.3 to 1.0	Surface	1.5	1.5	2.5	1/2”	Standard Traffic (ST)	6.00
	Intermediate	1.5	1.5	3			
	Base	1.5	3	4.5			
1.0 to 10.0	Surface	1.5	2	2.5	1/2”	High Traffic (HT)	6.00
	Intermediate	2	2.5	3	3/4”		5.50
	Base	3	4	4.5	1”		5.25

[1] The Common mix size is shown. When other mix sizes are used, the minimum lift thickness also changes (see Section 5D-1, C, 6, b).

[2] These values are for estimating quantities only. The actual asphalt binder content is established in the approved job mix formula.

[3] Some lift thickness values in this guide may conflict with traffic control or allowable compaction criteria.

Table 5D-1.03: Mixture Design Criteria
(derived from Iowa DOT Materials I.M. 510)

Mix	Layer Designation	Gyratory Density N_{des}	Design % G_{mm} (target)	Film Thickness	Aggregate[2] Quality Type	Crush (min)	FAA (min)	Sand Equivalent (min)
LT	0.3 M S	50	96.0	8.0 - 15.0	A[1]	60[1]	---	40
	0.3 M I							
	0.3 M B		97.0		A[1]	45		
ST	1M S	50	96.0	8.0 - 15.0	A	75[1]	40	40
	1M I				A[1]	60[1]		
	1M B		97.0				---	
HT	10M S	75	96.0	8.0 - 15.0	A	75	43	45
	10M I							
	10M B		96.5		A[1]	60		
For mix design levels exceeding 10M ESALs, see Iowa DOT Materials I.M. 510.								

[1] Requirements differing from Iowa DOT Materials I.M. 510; for base mixes, aggregate quality improved from B to A and percent crushed aggregate increased by 15%.

[2] Flat & Elongated 10% maximum at a 5:1 ratio