

## Introduction

The current perpetual pavement design concept relies on thicker hot-mix asphalt (HMA) pavements with different functional layers to outlive traditional designs under high traffic volumes and high axle loads without the need for significant structural rehabilitation. The proposed Heavy-Duty Pavement (HDP) design methodology partially incorporates the perpetual pavement design concept, such as utilizing different functional HMA layers, while delivering economic and practical benefits, including reduced layer thickness through the application of quality materials and estimated performance over time utilizing the Texas Mechanistic-Empirical flexible pavement design and analysis (TxME) program. The HDP design philosophy is such that the pavement structure must:

- Have sufficient structural strength to resist structural distress including bottom-up fatigue cracking and rutting,
- Be durable enough to resist damage due to heavy traffic forces and environmental effects, and
- Perform throughout the design life without significant structural rehabilitation.

## Heavy-Duty Pavement Overview

### HDP Definition

HDP is defined as an asphalt pavement designed to last longer than 30 years without requiring major structural rehabilitation or reconstruction and needing only periodic surface renewal in response to distresses confined to the top of the pavement. HDP is not designed to last indefinitely like perpetual pavements or fail structurally after 20 years of service like traditional asphalt pavements.

### HDP Application

The primary application for HDP is for highway sections with a high functional and structural demand where recurrent closures for maintenance activities is not feasible. The Heavy-Duty Pavements Working Group identified a checklist of five critical factors (Figure 1) for HDP design: (1) project location, (2) cumulative 20-yr 18-kip equivalent single axle load (ESAL), (3) percent truck, (4) percent illegal gross vehicle weight (GVW) of Class 9 trucks, and (5) lower agency cost compared to other design options. As shown in Figure 1, if three or more factors are met, then a HDP design is warranted.

Pavement Design Factor	Meet Factor?	
	Yes	No
Project Location under the following <sup>1</sup> : <ul style="list-style-type: none"> <li>- Energy Sector Corridor,</li> <li>- Port of Entry,</li> <li>- National/Texas Highway Freight Network, or</li> <li>- Interstate Highway (IH)</li> </ul>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Cumulative 20-yr 18-kip ESAL <sup>2</sup> > 20 Million	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Percent Truck > 30%	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Percent Illegal GVW of Class 9 Trucks <sup>3</sup> > 20%	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Lower Agency Cost Compared to Other Design Options <sup>4</sup>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
<b>Recommended Design Alternative: <u>Heavy-Duty Pavement</u></b>		
1. Refer to Statewide Planning Map 2. Equivalent Single Axle Load (ESAL) 3. Legal weight of gross vehicle weight (GVW) = 80 kips 4. Agency cost includes only initial construction cost		

**Figure 1. HDP Example Application Checklist**

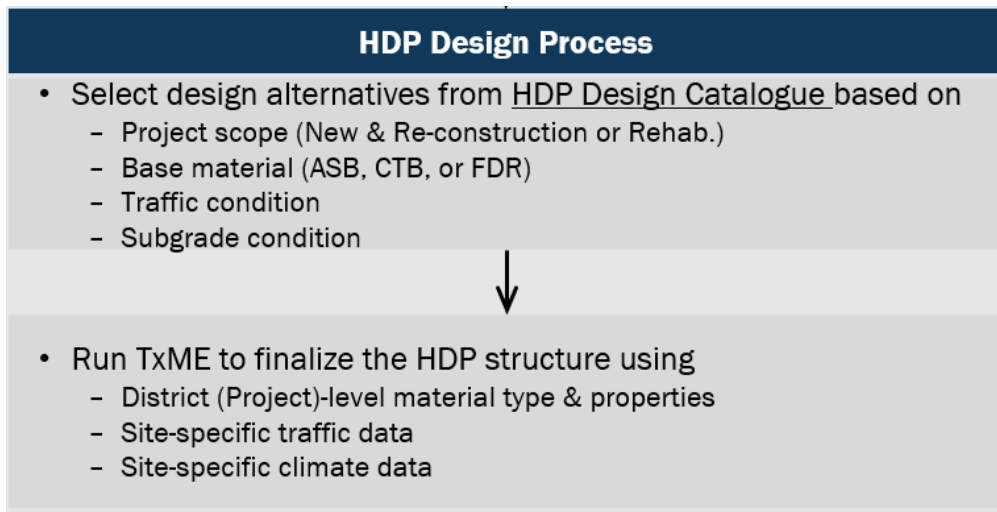
### HDP Design Criteria

HDP is designed using the TxME program which considers the full impact of pavement materials, subgrade, environment, and traffic loading on pavement life in terms of rutting and cracking. HDP structural layer thickness is selected based on the following design criteria (or maximum distresses after 30 years of service):

- Max. rut depth: 0.35 inch
- Max. fatigue cracking (% wheel path area): 15
- Max. thermal cracking length (ft/mile): 1056
- Max. fatigue cracking for CTB (if applicable) (% wheel path area): 15

## Heavy-Duty Pavement Design Process

As shown in Figure 2, HDP design is a two-step process. The first step is to select a HDP design structure from the HDP design catalogue based on project scope, preferred base material (asphalt stabilized base [ASB], cement treated base [CTB], or full-depth reclamation [FDR]), traffic condition, and subgrade condition. The second step is to run TxME to finalize the HDP design using District (or project)-level material and properties, site-specific traffic data, and site-specific climate data.

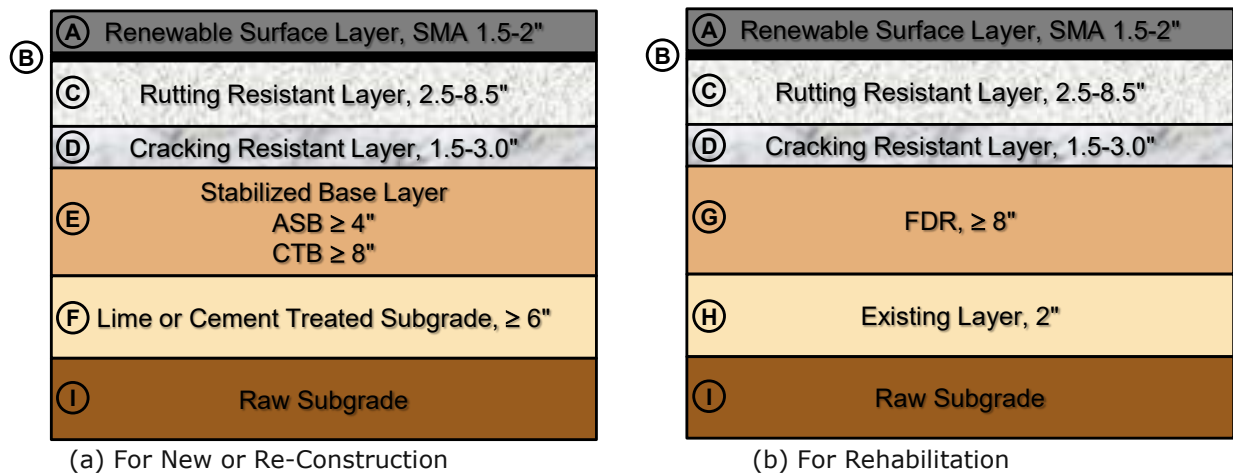


**Figure 2. HDP Design Process**

## HDP Layer Structure, Materials, and Design Catalogue

### HDP Layer Structure and Materials

Figure 3 shows generalized HDP layer structures for new (or re-construction) and rehabilitation with FDR. Table 1 describes materials recommended for each layer.



**Figure 3. Generalized HDP Layer Structure**

**Table 1. HDP Layer Materials**

<b>Layer</b>	<b>Layer composition</b>	<b>Spec Item</b>	<b>Preferred Mix Size</b>	<b>Preferred Lift Thickness</b>	<b>PG Grade</b>	<b>N<sub>des</sub></b>
A	Renewable surface	Item 346	SMA-D without RAP	1.5-2.0 in.	PG76-XX	50
B	Seal coat	Item 316 or 318	Grade 4 or 4S	-	-	-
C	Rutting-resistant layer	Item 344	SP-B with RAP*	2.5-8.5 in.	PG76-22	50
D	Cracking-resistant layer	Item 344	SP-C without RAP and no binder substitution	1.5-3 in.	PG64-28	50
E	Asphalt stabilized base Cement treated base	Item 292 Item 275	Min 200 psi UCS after conditioning	4 in. 8 in.	PG64-22	
F	Lime or cement treated subgrade	Item 260	Passing Tex 121E Part 1	6 in.		
G	Full depth reclamation	Item 275 Item 290 Item 291	Min 200 psi UCS after conditioning Passing wet/dry strength	8 in.	PG64-22	
H	Existing layer	-	To avoid cutting into subgrade	2 in.	-	-
I	Natural subgrade	-	-	-	-	-

\*Note: No binder substitution is allowed. Item 344, surface layer criteria apply. The allowable ratio of recycled binder to total binder should not exceed 15%.

## HDP Design Catalogue

HDP design is impacted by many factors. The development of HDP design catalogue considers four factors (Figure 2): (1) project scope (new & re-construction or rehabilitation), (2) base material, (3) traffic condition, and (4) subgrade condition. Tables 2, 3, and 4 list the design catalogues for different scenarios.

**Table 2. Design Catalogue for HDP with New or Re-construction with ASB Base Layer**

<b>Subgrade condition</b>	<b>Layer No.</b>	<b>Layer material</b>	<b>Layer Thickness (in.) for &gt;60M ESAL</b>	<b>Layer Thickness (in.) for 35M-60M ESAL</b>	<b>Layer Thickness (in.) for 20M-35M ESAL</b>	<b>Layer Thickness (in.) for &lt;20M ESAL</b>
Poor Subgrade (E=4-8 ksi)	6	SMA-D	2.0	2.0	2.0	1.5
	5	SP-B	8.5	7.0	5.0	3.5
	4	SP-C	3.0	3.0	2.0	2.0
	3	ASB	4.0	4.0	4.0	4.0
	2	LTS	6.0	6.0	6.0	6.0
	1	Subgrade	-	-	-	-
Fair Subgrade (E=8-12 ksi)	6	SMA-D	2.0	2.0	2.0	1.5
	5	SP-B	7.5	6.0	3.5	2.5
	4	SP-C	3.0	3.0	2.0	2.0
	3	ASB	4.0	4.0	4.0	4.0
	2	LTS	6.0	6.0	6.0	6.0
	1	Subgrade	-	-	-	-
Good Subgrade (E>12 ksi)	6	SMA-D	2.0	2.0	2.0	1.5
	5	SP-B	6.5	5.0	2.5	2.5
	4	SP-C	3.0	3.0	2.0	1.5
	3	ASB	4.0	4.0	4.0	4.0
	2	LTS	6.0	6.0	6.0	6.0
	1	Subgrade	-	-	-	-

**Table 3. Design Catalogue for HDP with New or Re-construction with CTB Base Layer**

<b>Subgrade condition</b>	<b>Layer No.</b>	<b>Layer material</b>	<b>Layer Thickness (in.) for &gt;60M ESAL</b>	<b>Layer Thickness (in.) for 35M-60M ESAL</b>	<b>Layer Thickness (in.) for 20M-35M ESAL</b>	<b>Layer Thickness (in.) for &lt;20M ESAL</b>
Poor Subgrade (E=4-8 ksi)	6	SMA-D	2.0	2.0	2.0	1.5
	5	SP-B	8.5	7.0	5.5	4.0
	4	SP-C	3.0	3.0	3.0	2.0
	3	CTB	8.0	8.0	8.0	8.0
	2	LTS	6.0	6.0	6.0	6.0
	1	Subgrade	-	-	-	-
Fair Subgrade (E=8-12 ksi)	6	SMA-D	2.0	2.0	2.0	1.5
	5	SP-B	7.5	6.0	4.5	3.5
	4	SP-C	3.0	3.0	3.0	2.0
	3	CTB	8.0	8.0	8.0	8.0
	2	LTS	6.0	6.0	6.0	6.0
	1	Subgrade	-	-	-	-
Good Subgrade (E>12 ksi)	6	SMA-D	2.0	2.0	2.0	1.5
	5	SP-B	7.0	5.5	4.0	3.0
	4	SP-C	3.0	3.0	3.0	2.0
	3	CTB	8.0	8.0	8.0	8.0
	2	LTS	6.0	6.0	6.0	6.0
	1	Subgrade	-	-	-	-

**Table 4. Design Catalogue for HDP with Rehabilitation with FDR**

Subgrade condition	Layer No.	Layer material	Layer Thickness (in.) for >60M ESAL	Layer Thickness (in.) for 35M-60M ESAL	Layer Thickness (in.) for 20M-35M ESAL	Layer Thickness (in.) for <20M ESAL
Poor Subgrade (E=4-8 ksi)	6	SMA-D	2.0	2.0	2.0	1.5
	5	SP-B	7.0	5.5	4.0	3.0
	4	SP-C	3.0	3.0	2.0	2.0
	3	FDR	8.0	8.0	8.0	8.0
	2	Existing layer	2.0	2.0	2.0	2.0
	1	Subgrade	-	-	-	-
Fair Subgrade (E=8-12 ksi)	6	SMA-D	2.0	2.0	2.0	1.5
	5	SP-B	6.0	4.0	3.5	3.0
	4	SP-C	3.0	3.0	2.0	1.5
	3	FDR	8.0	8.0	8.0	8.0
	2	Existing layer	2.0	2.0	2.0	2.0
	1	Subgrade	-	-	-	-
Good Subgrade (E>12 ksi)	6	SMA-D	2.0	2.0	2.0	1.5
	5	SP-B	5.5	3.5	3.0	2.5
	4	SP-C	3.0	2.5	2.0	1.5
	3	FDR	8.0	8.0	8.0	8.0
	2	Existing layer	2.0	2.0	2.0	2.0
	1	Subgrade	-	-	-	-

## Intersections and Slow-Moving Traffic Considerations

Although the current guidance for the design of HDP focuses on long-term performance under high volumes of heavy traffic, it is recommended to have additional considerations for locations such as intersections and roadway segments that are exposed to constant slow-moving traffic. In general, these locations include intersections, turn lanes, climbing lanes, and border crossings. In addition to heavy traffic, these locations are also prone to braking, stopping, deceleration, acceleration, and slow-turning movements of heavy truck traffic that produce high shear stresses and consequently cause deep rutting on the pavement surface. The same principles and design catalogue for HDP are applicable for intersections and slow-moving traffic sections. However, the pavement engineer must consider a different binder selection for the top 4-6 inches of the HDP (Layer A and C in Table 1). To improve rutting-resistant properties, higher asphalt grades are recommended. High-Performance Grade (HPG) binders are recommended for the surface layer (Layer A) and for the layer immediately under the surface layer, one or two grade bumping is recommended. TxDOT is currently collaborating with industry and universities conducting research to refine these recommendations.

## HDP Design using TxME

TxME is an advanced pavement design and analysis tool that allows pavement engineers to fully consider the impact of pavement materials, environment, and traffic (ESALs or load spectra) on

pavement life in terms of rutting and cracking. It automatically calculates initial construction cost of each pavement design candidate. Accordingly, pavement engineers can optimize the pavement design based on performance (rutting and cracking) requirements (or failure criteria) and initial construction cost. It allows the evaluation of alternative cost saving items such as the use of RAP in rutting resistant layer and the impact of using district preferred mix types and binders. Also, TxME allows pavement engineers to choose specific performance requirements (or failure criteria) suitable for different pavement types.

TxME design process for heavy duty asphalt pavement is outlined in 6 steps:

*Step 1: Develop Trial Pavement Structure and Layer Material*

- Pavement type: select "perpetual"
- Design/analysis life (years): enter 30 years for HDP
- Project location: select project District and County
- Trial pavement structure: select based on HDP design catalogue

*Step 2: Specify Climate*

- Select the weather station closest to the project location

*Step 3: Define Traffic (use of TxDOT's pWIM system is mandatory for HDP)*

Choose one of the following two options:

- ESALs: (1) tire pressure, (2) ADT-Beginning, (3) ADT-End, (4) 18-kip ESALs 20 YR, and (5) operational speed. This option can be used for an initial analysis while pWIM data becomes available.
- Load spectra (from pWIM data)
  - General information
  - Axle configuration
  - Vehicle class distribution
  - Axle load distribution
  - Monthly adjustment factors
  - Axle per truck

*Step 4: Choose Pavement Failure Criteria and Reliability Input*

- Pavement failure criteria for HDP:
  - Fatigue cracking (% of wheel path area): 15
  - Rutting (inch): 0.35
  - Thermal cracking (ft/mile): 1056; (alternatively, transverse cracking space: >60ft)
  - If CTB is used, CTB fatigue cracking (% of wheel path area): 15
- Reliability: 95%

*Step 5: Run TxME to predict the performance of the trial pavement structure and associated materials*

- Adjust the trial pavement structure and/or layer materials until the predicted performance meets the pavement failure criteria.

*Step 6: Document and incorporate into Pavement Design Report*

Please contact the Maintenance Division at [pavementdesign@txdot.gov](mailto:pavementdesign@txdot.gov) for support.