TEXAS DEPARTMENT OF TRANSPORTATION

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Flexible Pavement Design Frequently Asked Questions

What is ESAL?

ESAL is the acronym for equivalent single axle load. ESAL is a concept developed from data collected at the American Association of State Highway Officials (AASHO) Road Test to establish a damage relationship for comparing the effects of axles carrying different loads.

The reference axle load is an 18,000-lb. single axle with dual tires.

What is design ESALs?

Design ESALs is a cumulative traffic load summary statistic. The statistic represents a mixed stream of traffic of different axle loads and axle configurations predicted over the design or analysis period and then converted into an equivalent number of 18,000-lb. single axle loads summed over that period.

Use the following calculations to determine design ESALs:

$$\Sigma\ ESALs = T_f TGDL\,(365)Y$$

Where:

T_f = truck factor

Use the following calculation to determine T_f:

$$T_f = \left(\sum_{i=1}^{m} p_i\, F_i\right) A$$

Where:

p_i = percentage of total repetitions for the *i*th load group

F_i = equivalent axle load factor for the *i*th load group

A = average number of axles per truck.

T = percentage of trucks in average daily traffic (ADT)

G = growth factor

Use the following calculation to determine G:

$$G = \frac{(1+g)^n - 1}{g}$$

Where:

g = annual growth rate

n = analysis period in years

D = directional distribution factor

L = lane distribution factor

Y = design period in years

For more information, refer to Appendix D of *AASHTO Guide for Design of Pavement Structures* (1993).

When can I use a lane distribution factor?

Lane distribution factors are used to reduce the estimated one-direction cumulative ESALs for sections that have three or more lanes in one direction. For these sections, truck traffic will tend to use the inner lanes more often than the two-lane scenario, thus reducing the accumulation of loads on any one lane. The following distribution factors can be used as a multiplier to the one-direction cumulative ESALs to establish the design traffic:

3 lanes	0.7
4 or more lanes	0.6

How do I get the ESAL information?

Transportation Planning and Programming Division (TP&P), Traffic Analysis Section provides beginning and ending two-direction average daily traffic (ADT) statistics for the beginning and ending year of the analysis period, directional distribution, percentage trucks in the ADT, the average ten heaviest wheel loads daily (ATHWLD) statistic, the percent tandem axles in the ATHWLD, and one-direction cumulative ESALs for both flexible and rigid pavement design. Further summary statistics are provided for the percent trucks in terms of percent medium duty and heavy duty.

A request for a traffic study should include the following information:

- geographic limits
- base year and design year for the project (base year should be tied to the projected opening date to traffic)
- current land use maps for the area surrounding the proposed project
- location and type of major traffic generators
- past and current traffic counts for an existing facility
- major cross streets
- map giving general project alignment
- identification of proposed facility type
- one or two way operation
- number of lanes (for facilities with frontage roads, the designer should also specify requirements for mainlanes and frontage roads separately)
- preliminary schematic or straight-line map
- length (in ft.) for each link of the proposed facility (new location projects only).

Requests for traffic projections should be coordinated with the District Director of Transportation Planning & Development (TP&D).

For more information, refer to “1430: Obtain Traffic Data” in the *Project Development Process Manual*.

What traffic data should I use if my analysis period is not 20 years?

You must always input the 20-year cumulative one-direction ESALs in FPS-19 (Texas Flexible Pavement Design System). Note that ESALs stated in the traffic report are cumulative one-direction ESALs. If you want to consider an analysis period other than 20 years, adjust the “analysis period” input accordingly. The program will automatically calculate the appropriate cumulative ESALs and ending ADT for the new analysis period.

What is the computer program that I can use for flexible pavement design?

For flexible pavement designs, FPS-19W (Texas Flexible Pavement Design System [Windows]) or AASHTO Design Procedure, DARWin 3.1, may be used. FPS-19W is the preferred method.

What back-calculated layer moduli should I expect when running the MODULUS program?

Falling weight deflectometer (FWD) deflection data and accurate pavement layer thickness data must be processed through MODULUS to provide back-calculated layer moduli.

Values similar to the one presented in Table 1 should be expected for layer moduli.

Table 1. Typical Back-Calculated Values for Moduli of Pavement Layers

Material	Elastic Modulus, (ksi)		
	Good	Fair	Poor
Dense-Graded Hot Mix Asphalt Concrete (HMAC)[1]	500		
Performance Design HMAC[1]	650 - 800		
Flexible Base[2]	75	50	25
Cement Stabilized Base	350	150	75
Lime Stabilized Base	75-200	40-75	less than 40
Cement Stabilized Subgrade	50		
Lime Stabilized Subgrade	50		
Subgrade Soils	12-16	8-12	4-8

[1]HMAC is a visco-elastic material; the modulus is temperature sensitive and will vary according to the temperature at the time of testing.

[2]The flexible base modulus will vary depending on the quality of the material (toughness, particle angularity, percent fines - especially clayey fines), the overall thickness, and the support provided by the subgrade.

What layer moduli should I use for designing a flexible pavement?

For existing pavements, FWD deflection data and accurate pavement layer thickness data must be processed through MODULUS to provide back-calculated layer moduli. Back-calculated layer moduli are needed for FPS-19W.

For a new construction, the recommended values shown in Table 2 may be used.

Table 2. Typical Design Values for Moduli of Pavement Layers

Material	Elastic Modulus, (ksi)
Dense-Graded HMAC	500
Performance HMAC	650 - 800
Flexible Base[1]	40-70
Cement Stabilized Base[2]	120-150
Lime Stabilized Base[2]	60-75
Cement Stabilized Subgrade[3]	35-45
Lime Stabilized Subgrade[3]	35-45
Subgrade Soils	12-4

[1]The flexible base modulus will vary depending on the quality of the material (toughness, particle angularity, percent fines - especially clayey fines), the overall thickness, and the support provided by the subgrade.

[2]For lime and cement stabilized base material, the current version of FPS-19 will likely under-design the structure for modulus values > 250 ksi. Minimum thickness of 8 in. Also, laboratory evaluation of the proposed material should be made to insure a target unconfined compressive strength of 300 psi is attained, with 85% of this strength retained after 10-day capillary rise. Over-stabilization is not encouraged as it may lead to shrinkage cracking, reflecting through the surface.

[3]Lime or cement series should be run to insure optimal stabilizer type and content is used.

Other sophisticated techniques, both destructive and non-destructive, are available to determine valuable pavement layer information. These techniques are not common practice but may be discussed with CST/M&P personnel.

Which design type should I use when designing with FPS-19W?

Use the design type appropriate for the proposed structure:

Type 1 - HMAC over flexible base on subgrade. This option should be used when no stabilized layers are anticipated, including when a minimum amount of stabilizer is used in the prepared subgrade to function as a working surface. This design type will tie the base modulus to the subgrade modulus using an algorithm that includes the effect of support offered by the subgrade. However, based on engineering judgment, the designer may override the calculated base modulus. This option can also be used to design two course surface treatments on top of a flexible base or on top of a light stabilized base.

Type 2 - HMAC over asphalt stabilized base on subgrade. This option should be used for full-depth bituminous structures on non-stabilized subgrade.

Type 3 - HMAC over asphalt stabilized base on flexible base on subgrade. This option can be used as presented, or other materials such as stabilized subgrade or another bituminous layer may be substituted for the flexible base layer. If used as stated, the flexible base modulus will be tied to the subgrade modulus using an internal algorithm.

Type 4 - HMAC over flexible base over stabilized subgrade over subgrade. This option can be used as stated or for HMAC or surface treatments over light stabilized bases over stabilized subgrade over subgrade.

Type 5 - HMAC overlay on an existing flexible structure. Use this option to design a structural overlay. The thickness of all existing layers must be fixed at the maximum thickness of each layer. This design type is not to be used for design of HMAC overlay on an existing rigid structure.

There are many situations in which the existing or desired number of distinct structural layers exceeds the layers allowed by the above options. When this is the case, layers may be consolidated or ignored to allow use of the software. Consolidation should be considered for materials with similar stiffness properties only. Considerations for determining the governing layer should be based on which layer contributes the most to the overall structure.

What depth to bedrock should I use?

The depth to bedrock that is computed in the MODULUS program should also be used in the FPS design. Alternatively, if no other information is available, the default values in FPS may be used.

Which generated design should I use? (in case of several outputs from FPS-19W)

In case of several outputs from FPS-19W, each design should be evaluated by using the Design Check option of the FPS-19W. All selected designs must be checked using the Modified Texas Triaxial Check (referenced in the TTI Report 1869-2).

The following guidelines should be considered when selecting the best design:

- The design *should* pass the Texas Triaxial Design Check. Engineering judgment can be used as justification to override the outcome of this check if performance of similar structures (under similar traffic, subgrade, etc.) in the district have proven viable.
- constructability of proposed materials at the suggested layer thickness
- compatibility with the existing structure (widening), including considerations for positive (internal) drainage
- number of performance periods - minimum initial performance period of eight years before an overlay is required
- performance time
- life cycle cost as well as initial (capital) costs - inputs such as traffic information, layer information, detour, etc. impact the life cycle cost of the project. Therefore, inputting accurate information is very critical in design selection.

Which design check should I use?

The proposed design should pass the Texas Triaxial Design Check module of FPS-19W. The Mechanistic Design Check option is not required at this time, but can be used to evaluate potential early failure in fatigue and full-depth rutting.

Exceptions to use of the Texas Triaxial Design Check may be granted by the State Pavement Engineer/Flexible Pavement Branch if the district has a successful history using the same material and design with the same traffic levels.

When can I use full depth asphalt pavement?

Full depth asphalt pavements are an option for any section, but cost will often restrict their use to sections that require rapid return to traffic or have high traffic levels.

New or "bottom-up" construction for facilities with a projected 20-year one direction cumulative loading of more than 30 million ESALs will be designed as a "perpetual pavement" which essentially is full depth asphalt pavement design. Perpetual pavement consists of the following layers: subgrade, rich bottom layer (RBL), stiff rut resistant hot mix asphalt (HMA) base, and stone matrix asphalt (SMA), permeable friction course (PFC), or Superpave as the surface layer. These structures must be built on a firm foundation that is not subject to swelling/settling. As such, the subgrade must be suitable or prepared in such a way to ensure a permanent stable foundation. Failure to address this may result in eventual rough ride.

The list of high use truck routes is available in the Pavement Design Manual.

What is a pavement design report?

A pavement design report is a formal engineering document that presents all analyses, data, policies, and other considerations used to design a pavement. Guidelines for the information that must be included in a pavement design report are discussed under "Guidelines for the Development of a Pavement Design Report" in the *Pavement Design Manual*.

For the special cases that do not require a pavement design report, the documentation should include a brief description of the criteria, engineering considerations, and/or district policy used in the decision process. For other reporting requirements, contact the district pavement engineer for guidance.

What is the process of pavement design?

Pavement design and documentation is the responsibility of the engineer of record and must be reviewed and approved by the district pavement engineer.

The pavement design report must be signed and dated by the district pavement engineer and must include his or her serial number (reference "Procedures for Sealing Engineering Documents" of the *Project Development Policy Manual*). A copy of the pavement design report should be sent to the director of CST/M&P for review and archiving.

Where can I get more information about pavement design in Texas?

For more information about Texas pavement design, go to the *Pavement Design Manual* at http://manuals.dot.state.tx.us/dynaweb/coldesig/pdm or contact Joe Leidy, P.E. 512/506-5848 or Magdy Mikhail, P.E. (512)506-5838