PAVEMENT TECHNOLOGY ADVISORY
- DESIGNING FOR HEAVILY LOADED VEHICLES -
PTA-D1

WHY DESIGN FOR HEAVILY LOADED VEHICLES?

Most pavements are designed to accommodate a certain number of 18,000-pound Equivalent Single Axle Loads (ESALs) during their lifetime (see *PTA-D2*). The pavement designer usually possesses raw traffic count data, which must then be converted to ESALs in order to design the pavement. This is accomplished by using equivalency factors, such as those presented in Chapter 54 of the Illinois Department of Transportation (IDOT) Bureau of Design and Environment Manual (BDE Manual).

The IDOT design equivalency factors for multiple unit (MU) and single unit (SU) trucks are average values derived from statewide weigh scale studies. These averages represent a mix of fully-loaded, partially-loaded, and empty vehicles; however, there are situations when a road, or even one traffic lane of a road, is utilized mainly by fully-loaded trucks. If the typical SU and MU equivalency factors are used to design the pavement for such a roadway, the pavement may reach the design ESAL count sooner than expected and fail prematurely. This costly problem can be avoided by making design adjustments to account for frequent heavily loaded vehicles.

LOCATIONS TO CONSIDER

Design adjustments for heavily loaded vehicles should be considered for roadways providing current or planned access to:

- Industrial parks
- Mines
- Grain terminals
- Distribution centers
- River ports
- Intermodal facilities
- Landfills
- Businesses that move large quantities of heavy products or materials

In urban areas, current and planned bus routes should be considered when designing pavements for residential and commercial developments. Refuse trucks can also have a large impact, as they are often allowed heavier axle weights by law.

Attention should also be given to locations where size or load restrictions cause heavy trucks to use the roadway on a regular basis. In general, adjustments for heavily loaded vehicles should be considered when they make up 10 percent or more of the design truck traffic.

DESIGN PROCEDURES

Data is collected to determine the average daily traffic and a breakdown of vehicle types. Additional data collection as to the typical weight distribution and axle configuration of the heavily-loaded vehicles is recommended. If only the gross vehicle weight is available, simplifying assumptions can be made to estimate the weight distribution. One of two estimating methods can be used. The two methods should produce reasonably similar results.

1. Legal loading method: The rear axles are assumed to carry the full legal load. The remaining gross load is assumed to be the front steering axle load. The legal load limits for different truck types and axle configurations may be found on the IDOT Designated State Truck Route System map, available upon request by calling (217)782-6271.

2. Equal tire loading method: For each vehicle type, divide the gross weight by the number of tires on the vehicle. The axle load is then determined by multiplying the load per tire by the number of tires on each axle. The legal load limits should be checked to make sure this method does not result in illegal axle loadings which would not be typical of the operation.

TRAFFIC FACTOR

Once the axle loading configuration is determined, the amount of damage sustained from one pass of the vehicle is calculated. This is done by determining the 18,000-pound ESAL contribution of each axle on the vehicle, then the ESALs contributed by each axle are added to find the equivalency factor for that vehicle. Based upon the expected traffic for each vehicle type over the design period, the total number of design ESALs can be calculated. The ESAL contribution for a particular axle load and configuration depends mainly on the pavement type (flexible or rigid). The ESAL contribution values suitable for most flexible and rigid pavements on the state system are given in Table 1 on the following page.

The Traffic Factor (TF) for the normal traffic is found using the appropriate TF equation from Chapter 54 of the BDE Manual (exclude the heavily loaded vehicles from the calculation). The ESALs from the heavily-loaded vehicles are calculated separately, and divided by 1,000,000 to convert them to TF terms. The separate TF values are added to obtain the Design TF.

Example:

A coal mine is to open off of a 2-lane section of highway. Part of the highway will be reconstructed to meet the alignment and safety needs of the larger trucks. A flexible pavement will be used. The 20-year Design Traffic is as follows:

Normal Traffic (Total 2-way Traffic):

PV - 1000 vehicles/day
SU - 400 vehicles/day
MU - 275 vehicles/day

Mine Traffic: The 5-axle MU trucks will weigh 80,000-pounds when fully loaded. The trucks will have 1 steering axle, 1 power tandem axle, and 2 single rear axles (known as a "spread tandem," but actually calculated as 2 axles). A total of 150 fully-loaded trucks per day are expected to leave the mine, and the mine will operate 255 days a year. All of the fully-loaded trucks will take the same route to a nearby major highway.

Step 1- Determine Normal TF:

By IDOT pavement design methodology, this is a Class III road. Based on Equation 54-5.3 in the BDE Manual, the design TF is calculated as follows (assume 50 percent of traffic in the design lane):

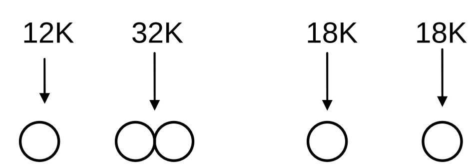
PV: 0.15 x 0.5 x 1000 =	75
SU: 109.14 x 0.5 x 400 =	21,828
MU: 384.35 x 0.5 x 275 =	52,848
Yearly Design Lane ESALs =	74,751

Normal TF = Design Period x (Yearly Design Lane ESALs/1,000,000):

20 x (74,751/1,000,000) = 1.50

Step 2 - Determine Equivalency Factor for Mine Trucks:

For these trucks, assume the typical axle load distribution was found to be:



Flexible Pavement ESAL values (Table 1):

0.19 0.86 1.00 1.00

Equivalency Factor (ESALs/veh) = 3.05

Step 3 - Determine TF for Mine Traffic:

150 fully-loaded trucks per day (single direction traffic) with 3.05 ESALs per truck for 255 working days a year for 20 years:

150 x 3.05 x 255 x 20 = 2,333,000 ESALs

Mine TF: 2,333,000/1,000,000 = 2.33

Step 4 - Determine the Design TF:

Add the Normal TF to the Mine TF to determine the Design TF:

Design TF = 1.50 + 2.33 = 3.83

Step 5 - Check the Minimum TF:

Figure 54-2C of the BDE Manual gives minimum structural design traffic requirements for state routes. For a Class III route, the minimum structural design traffic is 900 MUs and 300 SUs.

SU: 109.14 x 0.5 x 300 = 16,371
MU: 384.35 x 0.5 x 900 = 172,958
Yearly Design Lane ESALs = 189,329

Min. TF = 20 x (189,329/1,000,000) = 3.79

Since the Design TF is greater than the Minimum TF, the Design TF of 3.83 is used in the flexible pavement thickness design procedure.

This basic process can be followed for any number of scenarios to adjust for heavily-loaded vehicles during the design process. If you have any questions, or would like additional information on unique loadings, please contact:

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TABLE 1: EQUIVALENT 18,000-POUND SINGLE AXLE LOAD FACTORS

LOAD, KIPS	FLEXIBLE PAVEMENT		RIGID PAVEMENT	
	AXLE TYPE		AXLE TYPE	
	SINGLE	TANDEM	SINGLE	TANDEM
6	0.01	0.001	0.01	0.002
8	0.03	0.003	0.03	0.005
10	0.09	0.007	0.08	0.013
12	0.19	0.014	0.18	0.026
14	0.36	0.03	0.34	0.05
16	0.62	0.05	0.60	0.08
18	1.00	0.08	1.00	0.13
20	1.51	0.12	1.57	0.21
22	2.18	0.18	2.34	0.31
24	3.03	0.26	3.36	0.44
26	4.09	0.36	4.67	0.62
28	-	0.50	-	0.85
30	-	0.66	-	1.14
32	-	0.86	-	1.49
34	-	1.09	-	1.92
36	-	1.38	-	2.43
38	-	1.70	-	3.03

From AASHTO Guide for Design of Pavement Structures; SN = 5, T = 9, p_t = 2.5
These values are suitable for most flexible and rigid pavements on the state system.