Highway/Traffic/Transportation Engineering

Classifications of highways

1. Principal arterials
2. Minor arterials
3. Major collectors
4. Minor collectors
5. Local roads and streets

Design speed

-selected speed to determine the various geometric features of the roadway

Table. Minimum Design Speed for Rural Collector Roads

Type of Terrain	Design Speed (kph) for Specified Design Volume (Vehicles / day)		
	0 - 400	400 to 2000	Over 2000
Level	64.39	80.49	96.59
Rolling	48.29	64.39	80.49
Mountainous	32.20	48.29	64.39

Glossary

Design speed
-selected speed to determine the various geometric features of the roadway

Design vehicle
-vehicle selected to represent all vehicles on the highway in order to establish geometric standards of the highway

-largest that is likely to use the highway with considerable frequency

Guidelines in the selection of design vehicle

- Passenger car is selected when the parking lot or series of parking lots are the main traffic generators
- A single unit truck maybe chosen for the design of intersections at local streets and park roads
- A city transit bus maybe selected for the design of intersections of state highways and city streets that serve buses with relatively few large trucks
- Either an 84-passenger larger school bus 12.20 m long or a 65-passenger conventional bus 10.98 m long may be selected

  The minimum size of the design vehicle should be WB-20 at intersection of freeway ramp terminals and arterial crossroads and at intersection s of state highways and industrialized streets that carry high volumes of traffic.

ACRONYMS

AADT- Annual average daily traffic
ADT- Average Daily Traffic
CBR- California Bearing Ratio
DHV- Design hourly volume

“Cross section elements” is on page 680 of reference text.

Design of Flexible Pavement

$ESAL_i = f_d \times G_{jt} \times AADT_i \times 365 \times N_i \times F_{Ei}$

= equivalent accumulated 18,000 lb (80 kN) single-axle load for the axle category i
f_d = design lane factor
G_{jt} = growth factor for a given growth rate j and design period t
$AADT_i$ = first year annual average daily traffic for axle category i
N_i = number of axles on each vehicle in category i
F_{Ei} = load equivalency factor for axle category i

Excerpt from Table 20.3 p 965 Load Equivalency Factors

Gross Axle Load		Load Equivalency Factors
kN	lb	For Single Axles
4.45	1000	0.00002
8.9	2000	0.00018
17.8	4000	0.00209
26.7	6000	0.01043
35.6	8000	0.0343
44.5	10000	0.0877
53.4	12000	0.189

For design lane factor see Table 20.7

Table 20.7 p 970 Percentage of Total Truck Traffic on Design Lane

Number of Traffic Lanes	Percentage of Trucks in Design Lane
2	50
4	45(35-48)
6 or more	40(25-48)

For growth factor for given growth rate and design period see Table 20.6

Excerpt of Table 20.6 p 970 Growth Factors

Design Period, years (n)	Annual Growth Rate, Percent (r)		
	No Growth	2	4
15	15	17.29	20.02
20	20	24.30	29.78
25	25	32.03	41.65
30	30	40.57	56.08
35	35	49.99	73.65

Example pp 971

An eight lane divided highway is to be constructed on a new alignment. Traffic volume forecasts indicate that the average annual daily traffic (AADT) in both directions during the first year of operation will be 12,000, with the following vehicle mix and axle loads.

Passenger cars (1000 lb/ axle) = 50 percent
2-axle single unit trucks (6000 lb/axle) = 33 percent
3- axle single unit trucks (10000 lb/axle) = 17 percent

The vehicle mix is expected to remain the same throughout the design life of the pavement. If the expected annual traffic growth rate is 4 percent for all vehicles, determine the design ESAL, given a design period of 20 years.
Growth factor = 29.78
Percent truck volume on design lane = 45
= Design lane factor (in decimal equivalence)

Load Equivalency factors
Passenger cars (1000 lb per axle) = 0.00002 (negligible)
2-axle single unit trucks (6000 lb/axle) = 0.01043
3-axle single unit trucks (10000 lb/axle) = 0.0877

Solution
ESAL for
2 axle single unit trucks
= 0.45 (29.78) (12,000)(365)(.33) (2) (0.01043)
= 0.4041×10^6

ESAL for
3 axle single unit trucks
= 0.45 (29.78)(12000) (365)(0.17) (3) (0.0877)
= 2.6253×10^6

ESAL for passenger cars = negligible

Total ESAL = 3.0294×10^6

Main engineering property required of subgrade is resilient modulus. When resilient modulus is less than 30,000 lb/in^2, the relationship between CBR and M_r (equivalent resilient modulus) is
M_r in MPa

= 10.342 CBR

When resilient modulus is of higher value, direct measurement is recommended.

Example

A full depth asphalt pavement is to be constructed to carry an ESAL of 2,172,042. If the subgrade 's CBR is 10 and the Mean Annual Air Temperature (MAAT) is 60^0 F, determine the depth required for the asphalt layer.

M_r = 10.342 CBR

= 10.342 (10)

= 103.42 MPa or 15,000 psi

ESAL = 2.172042×10^6

Using the graphical way of determining thickness (using Figure 20.5 , p 976),

depth required for full depth asphalt layer is 22.86 cm(9 inches).

Design of Rigid Pavement

Equations developed by Westergaard

For different loading conditions

1. Edge loading when the edges of the slab are warp upward at night

$$\sigma_e = (0.572\,P)/h^2 [\,4 \log_{10}(l/b) + \log_{10} b]$$

2. Edge loading when the slab is unwarped or when the edge of the slab is curled downward in the daytime

$$\sigma_e = (0.572\,P)/h^2 [\,4 \log_{10}(l/b) + 0.359]$$

3. Interior loading

$$\sigma_i = (0.316P)/h^2 [\,4 \log_{10} (l/b) + 1.069]$$

Where

σ_e = maximum stress (in psi) induced in the bottom of the slab, directly under the load P and applied at the edge and in a direction parallel to the edge

σ_i = maximum tensile stress (in psi) induced at the bottom of the slab directly under the load P applied at the interior of the slab

P = applied load (in pounds), including allowance for impact

h = thickness of slab (in inches)

l = radius of relative stiffness

$= \{E_c h^3/[12(1 - \mu^2)k]\}^{1/4}$

E_c = modulus of elasticity of concrete (in psi)

μ =Poisson ratio of concrete = 0.15

k = subgrade modulus (in $lb/in.^3$)

b = radius of equivalent distribution of pressure (in inches)

$= (1.6\, a^2 + h^2)^{1/2} - 0.675\, h$ (for $a < 1.724\, h$)

$= a$ (for $a > 1.724\, h$)

a = radius of contact area of load (in inches) (Contact area is usually assumed as circular for interior and corner loadings and semicircular for edge loading).

Problem solving

Example 21.1 p 1029

Determine the tensile stress imposed by a semicircular wheel load of 900 lb imposed during the day and located at the edge of the concrete pavement with the following dimensions and properties by using the Westergaard equations.

Pavement thickness = 6 in.

$\mu = 0.15$

$E_c = 5 \times 10^6$ lb/in.^{2}

$k = 130$ lb/in.^{3}

radius of loaded area = 3 in.

Solution

$a < 1.724\ h$, then with $h = 6$in.

$$b = (1.6\ a^2 + h^2)^{1/2} - 0.675\ h$$

$$= [(1.6)(3^2) + 6^2]^{1/2} - 0.675\ (6)$$

$$= 3.05 \text{ in.}$$

$$l = \{ E_c\ h^3 / [12\ (1-\mu^2)\ k]\}^{1/4}$$

$$= \{ 5\text{x}10^6\ (6)^3/[12(1-0.15^2)\ 130]\}^{1/4}$$

$$= 29.0 \text{ in.}$$

$$\sigma_e = (0.572\ P)/h^2[4 \log_{10} (l/b) + 0.359]$$

$$= [(0.572)\ (900)]/(6)^2\ [\ 4 \log_{10}(29/3.05) + 0.359]$$

$$= 61.07 \text{ lb/in.}^2$$

Reference

Garber,N & Hoel, L. (2002). Traffic and Highway Engineering (3rd ed).
California: Thomson Learning Inc.