King Saud University
College of Engineering
Civil Engineering Department

CE 431: Highway Engineering
Tutorial Note 4: Chapter 16
Eng. Ibrahim Almohanna

16.1 during the first year of service, a pavement on a rural minor arterial is expected to accommodate the number of vehicles in the classes shown. Estimate the ESAL.

Vehicle type	Number of vehicles	Truck factors	Product
Single unit trucks			
Two-axle, four tire	**72,000**	0.003	216
Two-axle, six tire	**20,500**	0.28	5740
Three-axle	**2,800**	1.06	2968
Tractor semitrailer			
Four-axle	**1,400**	0.62	868
Five-axle	**3,700**	1.05	3885
			ESAL = sum = 13,667

■■■■

16.2 determine the design ESAL for a 25-year design period if the traffic grows at an annual rate of 5 percent.

By equation 16-6 where T_1 = ESAL from previous question:

$$T = \left[\frac{(1+r)^n - 1}{r}\right] T_1 = \left[\frac{(1+0.05)^{25} - 1}{0.05}\right] 13{,}667 = 652{,}746$$

■■■■

16.3 A flexible pavement is to be designed for a rural primary highway by the AASHTO method to carry a design ESAL of 0.5 × 10^6. It is estimated that the pavement base will be exposed to moisture levels approaching 20 percent of the time. The overall quality of drainage is "fair". The following additional information is available:

Resilient modulus of asphalt concrete at 68° F = 400,000 psi.
Resilient modulus of the base – 35,000 psi.
CBR of subgrade material = 3.0
Reliability level = 85 percent.
Standard deviation = 0.45
Initial serviceability index = 4.5
Terminal serviceability index = 2.5

Design a pavement by AASHTO method. Assume that there is no subbase.

From figure 16- 3, for asphalt concrete surface course, M_r = 400,000 and a_1 = 0.41

From figure 16 -5, for base course, M_r = 35,000 and a_2 = 0.155

From table 16-7 take average, for base, drainage coefficient m_2 = 0.9

From Figure 16-11, SN_1 = 1.6

$$D_1 \;=> \frac{SN_1}{a_1} > \frac{1.6}{0.41} = \;3.9, \qquad say\; 4"$$

$$SN^* \;=\; D_1 * a_1 \;=\; 4(0.41) \;=\; 1.64$$

$$D_2 \;>\; (SN_2 \;-\; SN_1^*)/a_2 m_2$$

From Figure 16-11, SN_2 = 2.9

$$D_2 \;>\; (2.9 \;-\; 1.64)/(0.155)(0.9)$$

$$D_2 \;>\; (1.26)/(0.155)(0.9) \;=\; 9.33", \;\; say\; 10"$$

Use 4" surface course, 10" base.

■■■■

16.4 design a full depth asphalt pavement for the conditions give in problem 16 -2 by the asphalt institute method.

By Figure 16-7, thickness of full depth asphalt concrete = 13”.

■■■■

16.5 An axle-weight study on a certain highway produced the following data:

Calculate the truck factor for this highway. For the < 4000 single axle group, use load equivalency factor of 0.0002.

Axle load group single (lb)	**No. of axles per 1000 vehicles**	Load Equivalency factor	Product
< 4000	**775**	0.0002	0.155
4000 – 8000	**268**	0.0104	2.7872
8000 – 12000	**98**	0.0877	8.5946
12000 – 16000	**87**	0.36	31.32
16000 – 20000	**52**	1	52
20000 – 24000	**45**	2.18	98.1
24000 – 28000	**10**	4.09	40.9
28000 – 32000	**8**	6.97	55.76
32000 – 38000	**7**	11.18	78.26
Axle load group tandem (lb)	**No. of axles per 1000 vehicles**	Load Equivalency factor	Product
8000 – 12000	**184**	0.007	1.288
12000 – 18000	**196**	0.037	7.252
18000 – 22000	**133**	0.121	16.093
22000 – 26000	**177**	0.26	46.02
26000 – 34000	**78**	0.658	51.324
34000 – 40000	**49**	1.587	77.763
40000 – 50000	**28**	3.47	97.16
50000 – 60000	**23**	7.725	177.675
> 60000	**0**	0	0
		Total	842.45 per 1000 vehicles

Average truck factor = 842.45 /1000 = 0.84

■■■■

16.6 a four lane highway is to replace an existing two lane facility. The AADT (both directions) can be described by 1543 ESAL. Construction is expected to be completed in four years. If the annual traffic growth rate is 4.5 percent, and the CBR of the subgrade on the new alignment is 6, determine the depth of full-depth asphalt pavement by the asphalt institute method (mean annual air temperature = 75°F). Assume the design life of the pavement is 20 years.

With a growth rate of 4.5%/year, the ESAL at the end of the fourth year would be

T_1 = 1,294 $(1.045)^4$ = 1,543

By equation 16-6, the total traffic during the design period is

$$T = \left[\frac{(1+r)^n - 1}{r}\right] T_1 = \left[\frac{(1+0.045)^{20} - 1}{0.045}\right] 1{,}543 = 48{,}406$$

From Table 16-1, D_D = 0.45, and from Table 16-5, D_L = 0.9. By equation 16-7,

w_{18} = 0.45 X 0.9 X 48,406 = 19,604

By equation 16-2, M_r = 1500 CBR = 1500 X 6 = 9,000

From Figure 16-7, depth of pavement = 5".

■■■■