Homework # 4

Question # 1

ESWL stands for **E**quivalent **S**ingle **W**heel **L**oad. It is defined as the load on single tire that will cause an equal magnitude of pre-selected parameter (stress, strain, deflection, or distress) at a given location within specific system to that resulting from multiple-wheel load at the same location within the pavement structure.

ESAL stands for **E**quivalent **S**tandard **A**xle **L**oad. It is defined as the Number of Standard Axle load repletion which causes the same damage effect of the applied load.

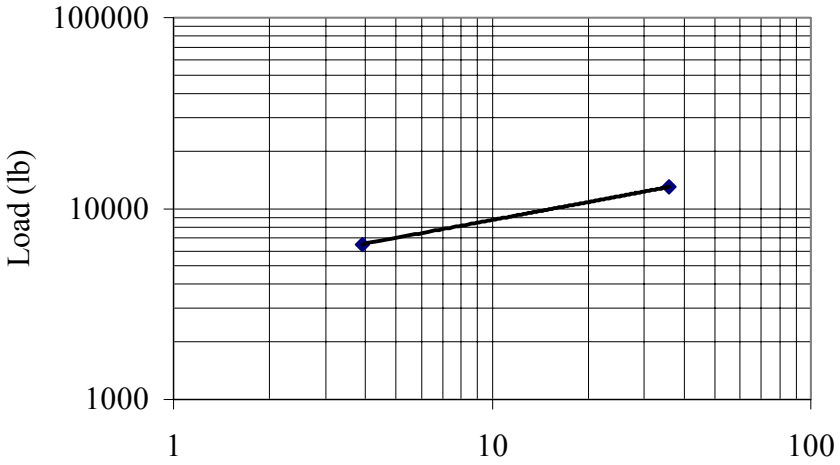
ESWL usually used for airport while ESAL is used for highway because the damage in airport usually caused by the excessive load while the damage in the highway caused by the high number of load repetition.

Question # 2

$$p = 80\ psi, \qquad load\ \ per\ \ wheel = \frac{26000}{4} = 6500\,lb$$

$$a = \sqrt{\frac{6500}{\pi * 80}} = 5.09\,in$$

$$d = d_{\min} = S_d - 2 * a = 18 - 2 * 5.09 = 7.83\,in \Rightarrow \frac{d}{2} = 3.91$$



From the upper figure, P_e = 2*7000 = 14000 lb = 14 kips

Question # 3

LCN method:

$$Contact\ area = \frac{P}{p} = \frac{6500}{80} = 81.25 in^2\ \ per\ \ wheel$$

$$Total\ \ contact\ \ area = 162.5 in^2$$

$$from\ \ fig.4.9 \Rightarrow Reduction\ \ factor = 1.3$$

$$ESWL = \frac{Total\ \ Load}{Reduction\ \ factor} = \frac{26000}{1.3} = 20000 lb = 20 kips$$

FAA method:

$$l = \sqrt[4]{\frac{Eh^3}{12(1-\mu^2)k}}$$

$$for\ \ E = 4*10^6\ psi,\ \mu = 0.15,\ k = 100\ pci,\ and\ \ h = 4 \Rightarrow l = 21.6 in$$

$$then\ \frac{s}{l} = \frac{18}{21.6} = 0.83$$

$$\frac{A}{l^2} = \frac{162.5}{21.6} = 0.35$$

$$from\ \ fig.\ 4.11 \Rightarrow \frac{Total\ \ gear\ \ Load}{ESWL} = 1.29 \Rightarrow ESWL = \frac{26}{1.29} = 20.2 kips$$

Question # 4

From the one layer theory: $\sigma_z = p*(A+B)$

For wheel # 1:

$$a_1 = \sqrt{\frac{4000}{\pi * 50}} = 5.05\,in, \quad r_1 = 8\,in,\ z = 10\,in$$

$$then\ \ from\ table\ \#\ 2.2 \Rightarrow A = 0.0603,\ \ B = 0.0543 \Rightarrow \sigma_{z1} = 5.886\ psi$$

For wheel # 2:

$$a_2 = \sqrt{\frac{6000}{\pi * 50}} = 6.18\,in, \quad r_2 = 12\,in,\ z = 10\,in$$

$$then\ \ from\ table\ \#\ 2.2 \Rightarrow A = 0.05278,\ \ B = 0.02211 \Rightarrow \sigma_{z2} = 3.744\ psi$$

$$the\ total\ \ stress = \sigma_{z1} + \sigma_{z2} = 9.63\ psi$$

Now for P_e we have: $\frac{z}{a} = \frac{10}{a}, \qquad \frac{r}{a} = \frac{0}{a} = 0, \qquad p_e = 50\ \ psi, \quad \sigma = 9.63\,psi$

Therefore: $A + B = \frac{\sigma}{p} = \frac{9.63}{50} = 0.193$

From table 2.2 (by interpolation) we get $\frac{z}{a} = 2.565 \Rightarrow a = 3.9\,in$

$$P_e = \pi * a^2 * p = \pi * 3.9^2 * 50 = 2389\ lb = 2.4\ kips$$

Question # 5

Axle Load	Single Axle per day			Tandem Axle per day		
	N	F	N*F	N	F	N*F
2	4000	0.0002	0.8			
6	500	0.01	5.0			
8	450	0.03	13.5			
10	250	0.08	20.0			
12	280	0.18	50.4	400	0.01	4.0
14				300	0.03	9.0
18				250	0.08	20.0
20				200	0.12	24.0
24				100	0.25	25.0
Total			89.7			82.0

The total daily EAL on the road = 89.7+82 = 171.7

EAL_o = 171.7*0.7*0.5 = 60.1 *per lane per day*

For 20 years life: *n = 20,* *i = 0.07*

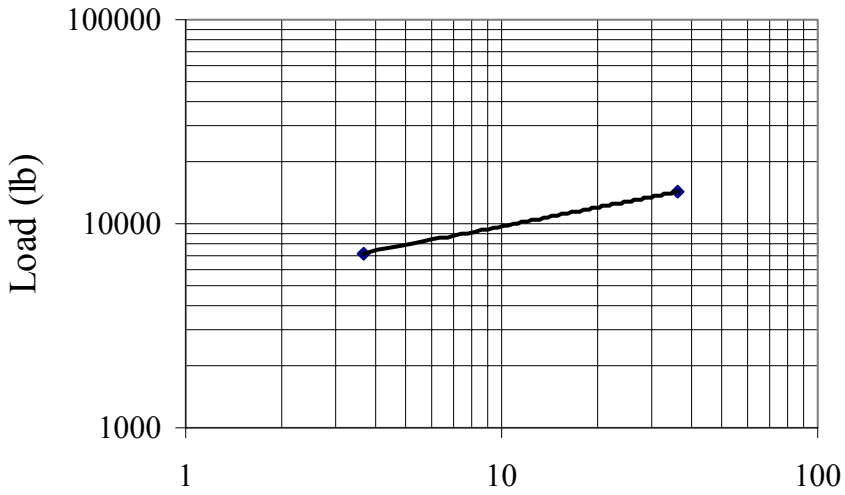
$$\sum_{0}^{20} EAL = \frac{EAL_o * 365}{\ln(1+i)} * \left[(1+i)^n - 1\right] = 930640$$

Question # 6

$$p = 80\ psi \qquad load\ \ per\ \ wheel = \frac{13 * 2204.62}{4} = 7165\,lb$$

$$\Rightarrow a = \sqrt{\frac{7165}{\pi * 80}} = 5.34\,in$$

$$d = d_{\min} = 18 - 2 * 5.34 = 7.32\,in \Rightarrow \frac{d}{2} = 3.66\,in$$



From the upper figure: ESWL = P_e = 8000*2 = 16000 lb = 16 kips

Question # 7

$$p = 80\ psi, \qquad load\ \ per\ \ wheel = P_k = \frac{13 * 2204.62}{4} = 7165\,lb \Rightarrow a = 5.34in$$

$$P_e = \frac{P_k * \sum F_{i\max}}{F_e}$$

$$\frac{z}{a} = 0.75 \Rightarrow F_e = \frac{1.5}{\left(1 + \left(\frac{z}{a}\right)^2\right)^{0.5}} = \frac{1.5}{\left(1 + 0.75^2\right)^{0.5}} = 1.2$$

If we neglect the deflection in the pavement layer, then the maximum deflection = the interface deflection.

$$\frac{r}{a} = \frac{9}{5.34} = 1.69,\ \frac{z}{a} = \frac{4}{5.34} = 0.75 \Rightarrow F_1 = F_2 = 0.48 \quad (from\ \ fig.\ 4.5)$$

$$\Rightarrow ESWL = P_e = 2 * 7165 * \frac{(0.48 + 0.48)}{1.2} = 11464\,lb = 11.5kips$$

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