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University of Asia Pacific
Department of Civil Engineering
Final Examination Spring 2013
Program: B.Sc. Engineering (Civil)

Course Title: Transportation Engineering II: Highway Design & Railways Course Code: CE 451
Time: 3 Hours Full Marks: 150

There are EIGHT (8) questions. Answer any SIX (6)

1. (a) Write the categories of the common gauges with their usual dimension. Why is it desirable to use uniform gauges in a country? (4 +10)
   (b) What are the functions of rail? (6)
   (c) What is coning of wheel? If a rail section is used of 52 kg/m, what will be the maximum axle load? (3+2)

2. (a) What are the requirements of ideal sleeper? (10)
   (b) Define turn out and tongue rail. What does it mean by calling-on signal and repeater signal? (4+5)
   (c) What are the functions of ballast? (6)

3. (a) Briefly differentiate between cant deficiency and cant excess. (5)
   (b) What should be the equilibrium cant on a M.G. curve of 4^0 for an average speed of 60 kmph? What will be the maximum permissible speed after allowing the maximum cant deficiency? (9)
   (c) Define interlocking. Name the functional classification of station. Write short note on Marshalling Yard. (2+3+6)

4. (a) Define pavement. Sketch different layers of the Rigid and Flexible pavement. (2+3)
   (b) What is ESAL? Briefly describe the factors which are considered in pavement design. Write down the difference between tar and asphalt. (2+6+3)
   (c) Name the laboratory test for determining consistency of the bituminous material. From a California Bearing Ratio (CBR) test the load against the penetration of 0.1 in. and 0.2 in. was found to be 200 lb and 250 lb respectively. If the diameter of the penetrating piston is 1.95 in. then calculate the CBR value for the sub-grade soil sample. (3+6)

5. (a) Why low cost road is important? Which materials are required for bituminous soil stabilized road and cement stabilized road? (10)
   (b) Establish a relationship between degree of curvature and versine of a curve. (7)
   (c) What is crossing? Define Reliability in AASHTO method. What are the design criteria in PCA method? (2+3+3)

6. (a) Draw the qualitative curves found from the Marshall method of design. (9)
   (b) If the percentage by weight for both coarse aggregate and fine aggregate is 48 and bulk specific gravity is 2.7 and 2.6 respectively, what is the bulk specific gravity of the aggregate? If the maximum specific gravity of the paving mix is 2.5 and specific gravity of Asphalt cement is 1.03, Calculate the effective specific gravity of aggregate. (6)

(c) What are the considerations for erosion analysis? What are stress ratio factor, ADT and ADTT? If the ADT and ADTT is 10000 and 20% respectively, find out the total number of the trucks for a 4 lane rural interstate highway with projection factor of 1.6 for 20 years. Assume value if required. (3+3+4)

7. (a) During the first year of service, a pavement on a Rural Interstate highway is expected to accommodate the following numbers of vehicles in the design lane. (20)

No. of Vehicles	Truck Factor
24000	0.21
10000	0.60
7500	1.10
30000	1.20

Design a minimum thickness of flexible pavement (i.e. thickness of different layers) for this traffic condition.
Given:
Sub grade soil CBR value is 1
Design life is 20 years
Traffic growth rate is 4% per annum
Reliability is 90%
Overall standard deviation is 0.45
Design serviceability loss is 2.0
Available material:

- Hot mix asphalt surface concrete ($a_1 = 0.44$)
- Crushed stone base course ($a_2 = 0.14$, $m_2 = 0.4$ and $E_2 = 30$ ksi)
- Crushed stone sub base ($a_3 = 0.11$, $m_3 = 0.9$ and $E_3 = 14.5$ ksi)

Note: Use attached figure.

(b) What is pavement serviceability concept? (5)

8. (a) Determine the minimum thickness of a lane of cement concrete rigid pavement in a rural interstate highway which can be used to carry the following expected loading of heavy vehicle over the design period of 20 years. Combined k of the subgrade and 4 in untreated subbase was taken to be 130 lb/in^3. The modulus of rupture of the concrete is 650 lb/in^2. Assume doweled joints and no concrete shoulder. Consider reasonable values for the missing data if any. (LSF =1.2, consider fatigue analysis only) (18)
Note: Use attached figure and table.

Axle load, kips		Expected repetitions
Single axles	30	8,000
	28	10,000
	26	30,000
	24	55,000
	22	75,000
Tandem axles	52	20,000
	48	40,000
	44	60,000

(b) Describe the factors for concrete pavement design by the PCA method (7)

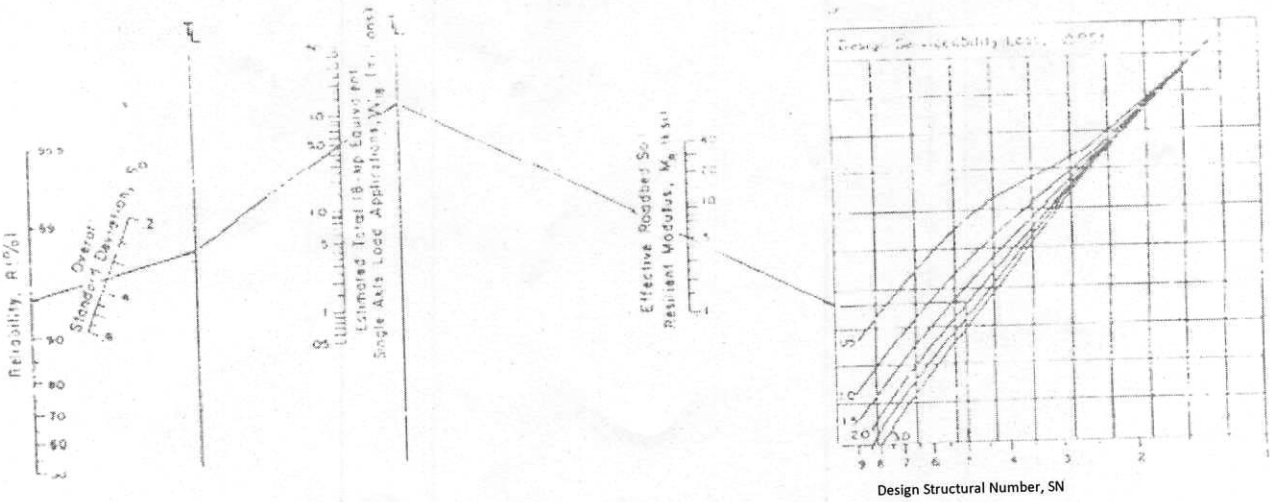

Figure: AASHTO design chart for flexible pavements

Table 6a. Equivalent Stress — No Concrete Shoulder (Single Axle/Tandem Axle)

Slab thickness, in	k of subgrade-subbase, pci						
	50	100	150	200	300	500	700
4	825/679	726/585	671/542	634/516	584/486	523/457	484/443
4.5	699/586	616/500	571/460	540/435	498/406	448/376	417/361
5	602/516	531/436	493/399	467/376	432/349	390/321	363/307
5.5	526/461	464/387	431/353	409/331	379/305	343/278	320/264
6	469/416	411/348	382/316	362/296	336/271	304/246	285/232
6.5	417/380	367/317	341/286	324/267	300/244	273/220	256/207
7	375/349	331/290	307/262	292/244	271/222	246/199	231/186
7.5	340/323	300/268	279/241	265/224	246/203	224/181	210/169
8	311/300	274/249	255/223	242/208	225/188	205/167	192/155
8.5	285/281	252/232	234/208	222/193	206/174	188/154	177/143
9	264/264	232/218	216/195	205/181	190/163	174/144	163/133
9.5	245/249	215/205	200/180	190/170	176/153	161/134	151/124
10	228/235	200/193	186/173	177/160	164/144	150/126	141/117
10.5	213/222	187/183	174/164	165/151	153/136	140/119	132/110
11	200/211	175/174	163/155	154/143	144/129	131/113	123/104
11.5	188/201	165/165	153/148	145/136	135/122	123/107	116/98
12	177/192	155/158	144/141	137/130	127/116	116/102	109/93
12.5	168/183	147/151	136/135	129/124	120/111	109/97	103/89
13	159/176	139/144	129/129	122/119	113/106	103/93	97/85
13.5	152/168	132/138	122/123	116/114	107/102	98/89	92/81
14	144/162	125/133	116/118	110/109	102/98	93/85	88/78

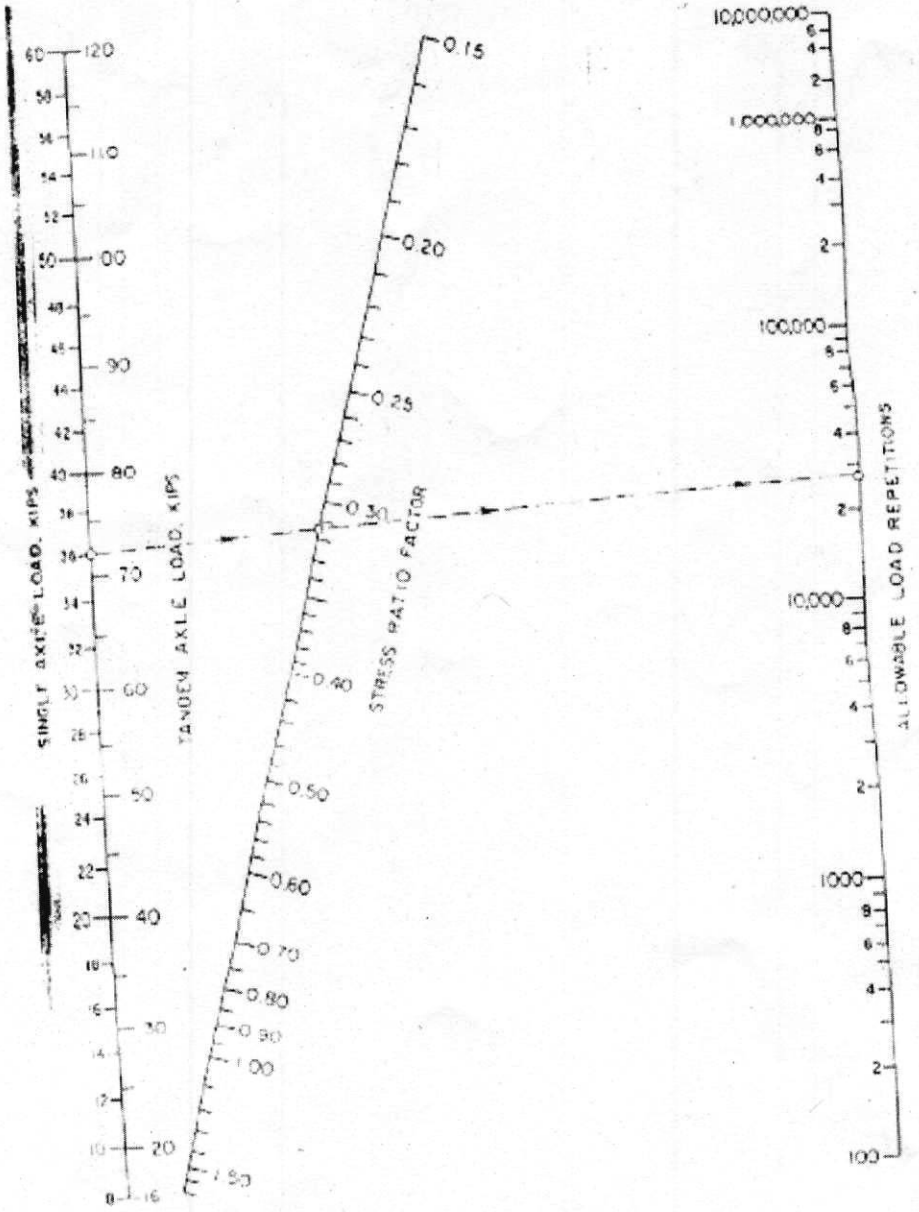

Fig. 5 **Fatigue analysis** - allowable load repetitions based on stress ratio factor (with and without concrete shoulder)

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Section I

Answer any 3 (three) from the following 4 (four) questions.

Assume any reasonable value, if at all required.

1. a) Write down the principal differences between a Flexible and a Rigid Pavement. Which Pavement is more suitable in the climatic condition of Bangladesh and why? (7)

   b) Define resistance to wear of materials. Describe commonly accepted investigations for the hardness of aggregates. (5)

   c) The dry mass of a sample of aggregate is 1206.0 gm. The mass in a saturated surface dry condition is 1226.8 gm. The volume of the aggregates, excluding the volume of absorbed water, is 440.6 cm^3. Find the apparent specific gravity, the bulk specific gravity and the percentage of absorption. (8)

2. a) Briefly discuss CBR and Resilient Modulus. (6)

   b) What do you understand by Pavement Serviceability Concept and its use in Road Maintenance? (6)

   c) Calculate Equivalent 18000-lb Standard Axle Load Applications during the first year of service of a pavement, the pavement is expected to accommodate the following number of vehicles in the classes shown below: (8)

Vehicle Type	Number of Vehicles	Truck Factor
Two-axle, four-tire	87,600	0.02
Two-axle, six-tire	23,600	0.19
Three-axle or more	4,400	0.56
Three-axles	2,100	0.51
Four axle	7,300	0.62
Four-axle or more	50,200	0.94

Also Determine Design ESAL for 20 Year Design Period if the traffic using the pavement grows at an annual rate of 4%.

3. a) What are the stresses induced by volume changes in concrete pavements? Explain Warping Stresses. (4)

b) A pavement for a four-lane regional divided highway is to be designed to last 25 years. During the first year, the estimated two-way equivalent single-axle applications are 144,000. The expected traffic growth rate is 3.5%. The design reliability is 95%, and the overall standard deviation is 0.35. The initial serviceability, P_0, is expected to be 4.5, and the terminal serviceability, P_t, is 2.5. (16)

The PCC pavement is to be laid on a granular subbase material. Using the standard laboratory test on 28-day specimens, the average compressive strength $f'_c = 4{,}900$, and the average modulus of rupture for third-point loadings was 600 psi.

The drainage was judged to be fair and will be subject to moisture levels approaching saturation 10% of time. The pavement is being designed with jointed reinforced concrete with untied asphalt shoulders. The effective modulus of subgrade reaction (corrected for loss of support) k = 110 psi.

Determine the design thickness.
(Please Use the Tables, Equations and Nomograph attached with this question paper and attach the graphs with your answer sheet).

4. a) What is a Pozzolan? "Cement without fly ash is more effective for soil-cement or concrete", explain your views about this statement. (5)

b) What are the cracks that occur in cement treated layers? How the cracking can be controlled during design of pavements with cement treated layers? (8)

c) Discuss Work Program Development and Scheduling for highway maintenance and rehabilitation works. (7)

Section II

Answer any 3 (three) from the following 4 (four) questions.

5. a) What are the differences between roadways and railways? (5)

b) Why is uniformity of gauges important for a particular country? (7)

c) A locomotive with 8 driving axles is required to haul a train at 80 km/hour, the axle load of the driving wheels of the engine is 25 tonnes. The train is to run on a straight level track. Find the maximum permissible train load that the engine can pull. (8)

6. a) Show different types of rails in sketches. What are the advantages of flat footed rails? (7)

   b) What are the materials for cross-sleeper? Mention the important features of timber sleepers. What are the advantages and disadvantages of Concrete sleepers? (8)

   c) Determine the suitable rail section for a locomotive to carry axle load of 22.5 tonnes. (5)

7. a) State the requirements of an ideal material for ballast. (4)

   b) What are the materials normally used as ballast? Sketch three sections showing packing of ballast. (6)

   c) Calculate the width of actual expansion gap to be provided for a rail of 12.80 m length. The maximum rail temperature is 60°C and the temperature at the time of linking is 30°C. Use, $e = L \alpha t \times 10^3$, where the parameters have their usual meaning and $\alpha = 1.2 \times 10^{-5}$ per degree centigrade. (10)
   Also find out: number of rails, sleepers, fish-plates, fish-bolts, bearing-plates and dog-spikes per km of rail track, where rail is of 45 kg type and sleeper density is 15.8.

8. a) What are the advantages of good railway track maintenance? Discuss maintenance of railway bridges. (6)

   b) Curves of a railway track should be avoided in which locations? (4)

   c) A transition curve is to be used to join the ends of a 3.94° circular curve with the straight. The length of the transition curve is 120 m. Work out the shift and offsets at every 30 m interval. How will you set this transition cure? (10)
   $Y = X^3/6RL$, $S = L^2/24R$, where, the symbols have their usual meanings.

Equations:

1. $$T = \frac{(1+r)^n - 1}{r} \times T_1$$

2. $$W_{18} = D_D \times D_L \times \hat{w}_{18}$$

The parameters have their usual meanings

TABLE 20-10 Recommended Load-Transfer Coefficients for Various Pavement Type and Design Conditions

Shoulder	*Asphalt*		*Tied PCC*	
Load transfer devices	*Yes*	*No*	*Yes*	*No*
Pavement type				
1. Plain jointed and jointed reinforced	3.2	3.8–4.4	2.5–3.1	3.6–4.2
2. Continuously reinforced concrete pavement	2.9–3.2	N/A	2.3–2.9	N.A.

Source: AASHTO Guide for Design of Pavement Structures, American Association of State Highway and Transportation Officials, Washington, D.C. (1993).

TABLE 20-11 Recommended Values of Drainage Coefficient, C_d, for Rigid Pavement Design

	Percent of Time Pavement Structure Is Exposed to Moisture Levels Approaching Saturation			
Quality of Drainage	*Less Than 1%*	*1–5%*	*5–25%*	*Greater T 25%*
Excellent	1.25–1.20	1.20–1.15	1.15–1.10	1.10
Good	1.20–1.15	1.15–1.10	1.10–1.00	1.00
Fair	1.15–1.10	1.10–1.00	1.00–0.90	0.90
Poor	1.10–1.00	1.00–0.90	0.90–0.80	0.80
Very poor	1.00–0.90	0.90–0.80	0.80–0.70	0.70

Source: AASHTO Guide for Design of Pavement Structures, American Association of State Highway and Transportation Officials, Washington, D.C. (1993).

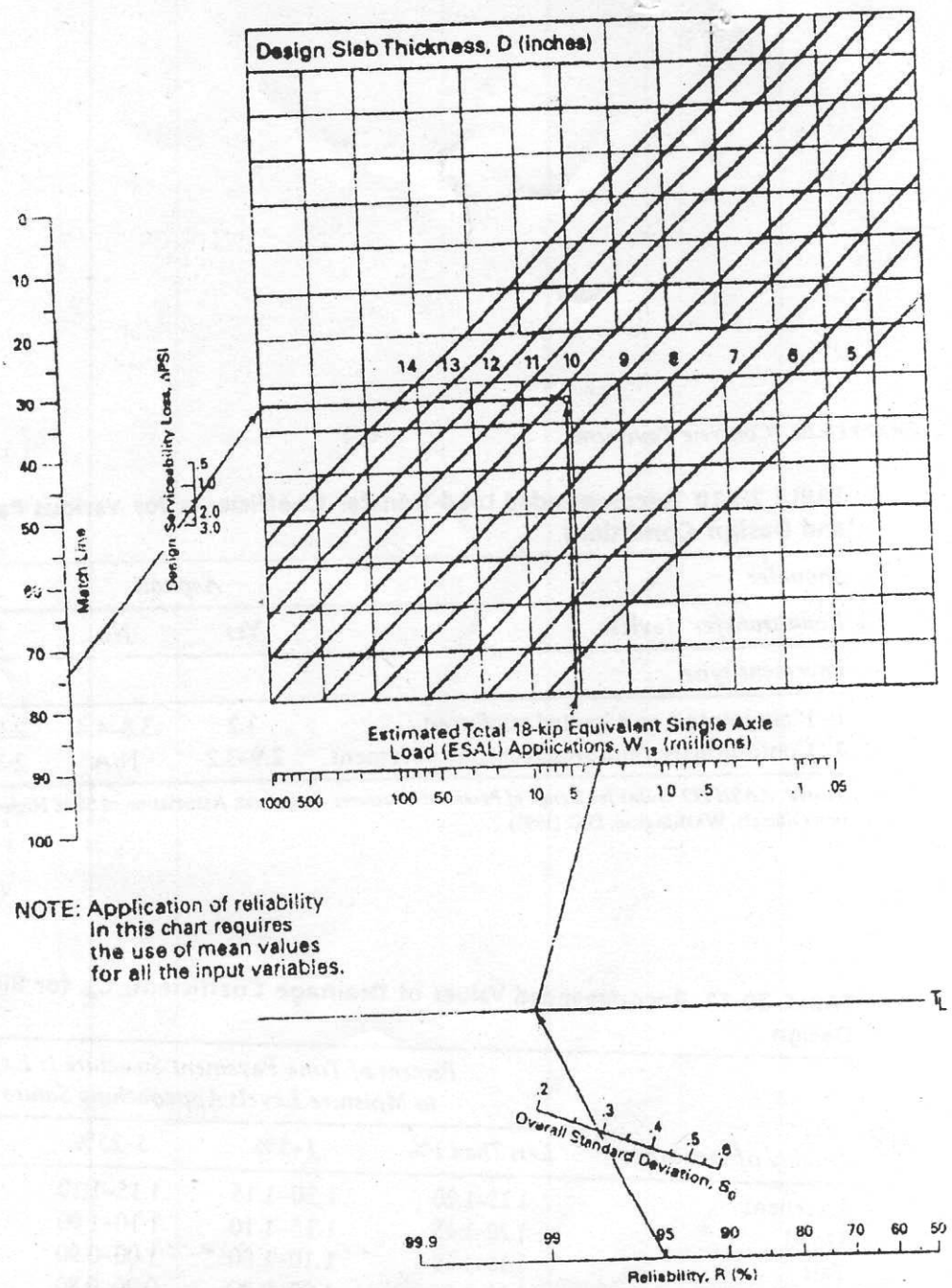

FIGURE 20-13 (Cont.) Design chart for rigid pavement design based on using mean values for each input variable, Segment 2. (Courtesy American Association of State Highway and Transportation Officials.)