University of Technology

Building & Construction Engineering Department

Final Exam 2012-2013

Division: Structural Engineering Branch

Class: 3rd year

Subject: Highway Engineering

Time: 3 Hours

Examiners: Dr. Rasha H. A., Dr. Samir F. D. & Zena T.

Date: 11/06/2013

Note: Attempt **Four** questions only

Q1/ Marshall test results for five specimens gave the results below.

1. Determine the O.B.C. for a **binder course layer.**
2. Check the suitability of these mixes for the Iraqi Design Specification.

Binder Content (%)	Stability (KN)	Flow (mm)	Density (kg/m^3)	V.T.M. (%)	V.F.B. (%)
3.5	7.4	2.0	2219	10.2	40
4.0	9.6	2.1	2257	7.9	55
4.5	10.6	2.6	2305	6.0	66
5.0	10.1	3.4	2280	4.5	72
5.5	9.1	4.6	2240	3.4	75

(25 Marks)

Q2/

(A) For a rigid pavement slab of **(9 m)** length, **(3.5 m)** width & **(28 cm)** thickness:

1. Calculate the combined stress in the day time for edge loading.
2. What suggestion would you made to reduce **(50 %)** of the warping stress in (1)?

Given that:

- Radius of contact area = **20 cm**
- Wheel load = **3600 kg**
- Modulus of elasticity = $2*10^5$ kg/cm^2
- Poisson's ratio = **0.15**
- Coefficient of thermal expansion = $8*10^{-6}$/ °C
- Modulus of subgrade reaction = 2.8 kg/cm^3
- Temperature difference = 1 °C/cm.

(15 Marks)

(B) Draw a suitable sketch to explain the components of the passing sight distance.

(10 Marks)

Q3/

(A) Calculate the elements and the main stations for a circular horizontal curve which has a chord length of (241 m), radius of (270 m) and Sta. PT at (49 +00). (15 Marks)

(B) A (34 cm) pavement of (7000 kg/cm^2) modulus of elasticity is constructed on a subgrade of (140 kg/cm^2) modulus of elasticity. What is the maximum wheel load that can be carried by this pavement if the maximum allowable deflection is (0.6 cm)? Assume minimum radius of contact area (16 cm). (10 Marks)

Q4/

(A) Use AASHTO method to design a two-lane rural flexible pavement to carry equivalence single axle load (ESAL/day = 4000) in both directions for a design life of (20 years). The pavement should consist of three layers. Given that:

- Reliability = 90 %
- Overall standard deviation = 0.4
- Drainage coefficient = 0.9
- CBR value of subgrade material = 4 %
- Initial serviceability index = 5

Knowing that the materials available for each layer & their properties are as follows:

Layer	Material	Layer Coefficient	Resilient Modulus (psi)
Surface	Asphalt concrete	0.44	400000
Base	Bitumen-treated soil	0.34	35000
Subbase	Sandy gravel	0.11	12000

(15 Marks)

(B) Sketch a section of a 4-lane highway indicating the elements of the highway cross-section. (10 Marks)

Q5/

(A) Determine the thickness of a reinforced concrete slab if the maximum spacing between transverse joints is (6 m) and the width of the slab is (4 m). Given that:

- Unit weight of concrete = 2400 kg/m^3
- Unit weight of steel = 7200 kg/m^3
- Ultimate tensile stress in steel = 1000 kg/cm^2
- Average coefficient of subgrade restraint = 1.5
- Area of steel = 300 mm^2/ m width
- Factor of safety = 2. (15 Marks)

(B) A vertical curve is to be designed to join a (+ 3.5 %) grade with a (- 4 %) grade. Determine the minimum length of the curve that will satisfy all minimum criteria and a design speed of (65 kph). Assume the driver acceleration rate is (2.95 m/sec^2) and the perception & reaction time is (2.5 sec.). (10 Marks)

WISHING YOU ALL THE BEST

Useful Information

The Iraqi Road Mix Design Specification:

Property	Wearing Course	Binder Course	Base
Stability (KN)	8 (min.)	7 (min.)	5 (min.)
Flow (mm)	2-4	2-4	2-5
V.T.M. (%)	3-5	3-7	3-7
V.F.B. (%)	70-85	60-80	

$$\sigma_e = \frac{0.572\,P}{h^2}\left[4\log\left(\frac{\ell}{b}\right) + \log b\right]$$ (Edges are warped upward)

$$\sigma_e = \frac{0.572\,P}{h^2}\left[4\log\left(\frac{\ell}{b}\right) + 0.359\right]$$ (Edges are curled downward)

$$\sigma_i = \frac{0.316\,P}{h^2}\left[4\log\left(\frac{\ell}{b}\right) + 1.069\right]$$

$$\sigma_{xe} = \frac{C_x.E.\rho.t}{2} \qquad \sigma_{xi} = \frac{E.\rho.t}{2}\left[\frac{C_x + \mu.C_y}{1-\mu^2}\right] \qquad \ell = \sqrt[4]{\frac{E.h^3}{12\,(1-\mu^2)\,K}}$$

$b = \sqrt{1.6\,a^2 + h^2} - 0.675\,h$ For $a < 1.724\,h$ $\qquad$ $b = a$ For $a > 1.724\,h$

$$\ell = \frac{2\,\sigma}{w * f} \qquad \ell = \frac{2\,f_s * A_s}{w * f * b * h}$$

$$S = (0.278\,V.t) + \frac{V^2}{254\left(\frac{a}{9.81} \pm g\right)}$$

$L = \frac{A * S^2}{658}$ For S<L $\qquad$ $L = (2 * S) - \frac{658}{A}$ For S>L

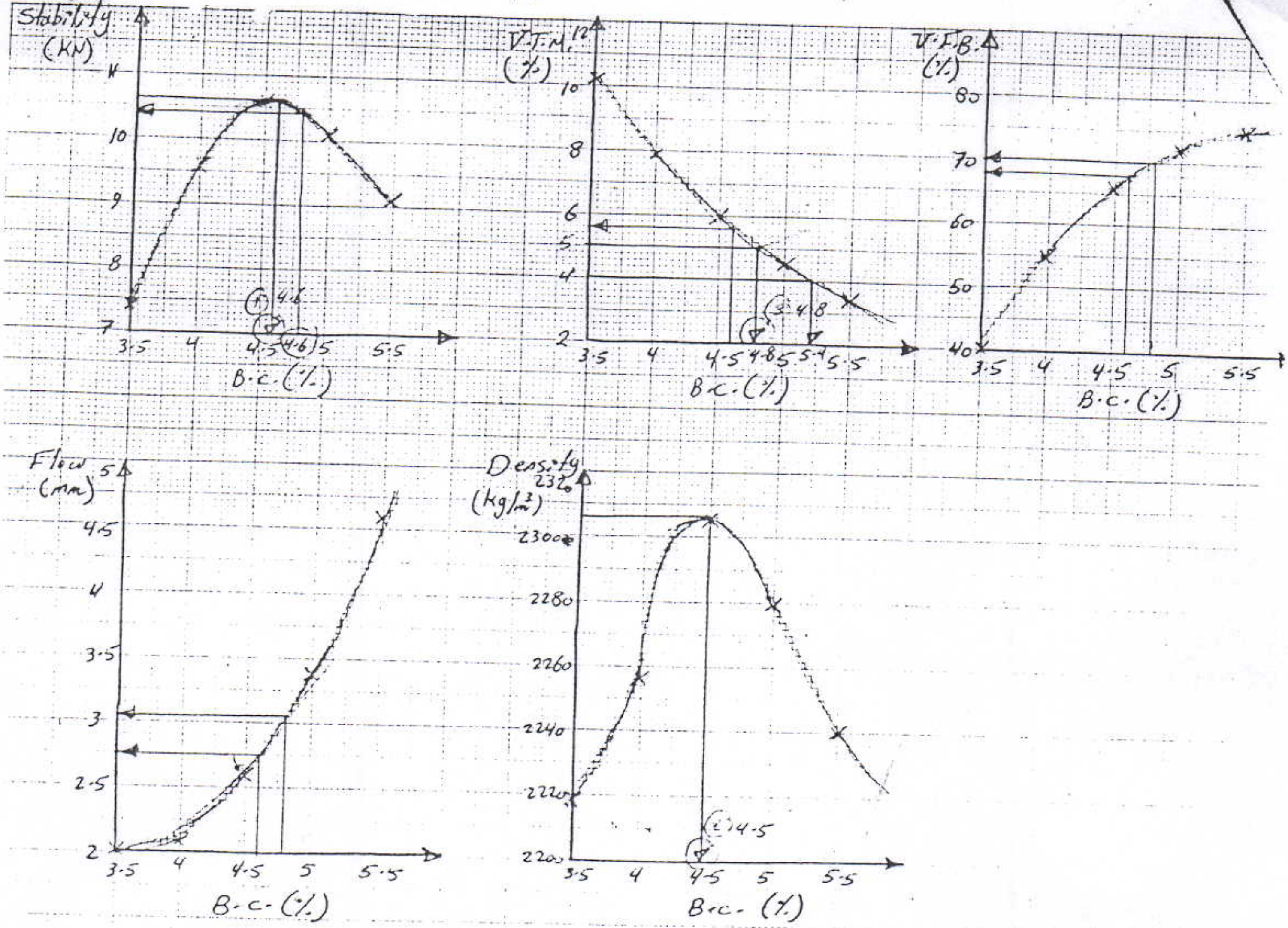
$L = \frac{A * S^2}{120 + (3.5 * S)}$ For S<L $\qquad$ $L = (2 * S) - \frac{120 + (3.5 * S)}{A}$ For S>L

$$T = R * \tan\frac{\Delta}{2} \qquad C = 2R * \sin\frac{\Delta}{2}$$

$$M = R * \left(1 - \cos\frac{\Delta}{2}\right) \qquad E = R * \left(\sec\frac{\Delta}{2} - 1\right)$$

$$L = \frac{2 * \pi * R * \Delta}{360}$$

Q1 / فرع الهندسة الإنشائية / ثالث / هـ. طرق



① $O.B.C. = \frac{4.6 + 4.5 + 4.8}{3} = 4.6\ \%$ for binder course.

② Mix characteristics @ the O.B.C. :-

Stability = 10.6 KN > 7 KN ∴ O.K.

Flow = 2.75 mm (2–4) ∴ O.K.

V.T.M. = 5.6 % (3–7) ∴ O.K.

V.F.B. = 68 % (60–80) ∴ O.K.

∴ The mix with O.B.C. = 4.6 % is suitable to use as binder course layer.

Q2/A ① $\sigma_e = \frac{0.572P}{h^2}\left[4\log\left(\frac{\ell}{b}\right) + 0.359\right]$

$\ell = \sqrt[4]{\frac{Eh^3}{12K(1-\mu^2)}} = \sqrt[4]{\frac{2*10^5(28)^3}{12(2.8)[1-(0.15)^2]}} = 107.5\ cm$

$a = 20\ cm < 1.724(28) = 48.3\ cm$

$\therefore b = \sqrt{1.6a^2+h^2} - 0.675h$

$= \sqrt{1.6(20)^2+(28)^2} - 0.675(28) = 18.84\ cm = b$

$\sigma_e = \frac{0.572(3600)}{(28)^2}\left[4\log\left(\frac{107.5}{18.84}\right) + 0.359\right]$

$= 8.89\ Kg/cm^2 = \sigma_e$

$\sigma_{xe} = \frac{C_x . E . \alpha . t}{2}$

$\frac{L_x}{\ell} = \frac{9(100)}{107.5} = 8.37 \Rightarrow$ from Fig(20-3) $\Rightarrow C_x = 1.07$

$\sigma_{xe} = \frac{1.07(2*10^5)(8*10^{-6})(1*28)}{2} = 23.97\ Kg/cm^2 = \sigma_{xe}$

Combined stress $= \sigma_e + \sigma_{xe} = 8.89 + 23.97 = 32.86\ Kg/cm^2$. comb.

② 50% of warping stress = 50% of $\sigma_{xe} = \frac{23.97}{2} = 11.985\ Kg/cm^2$.

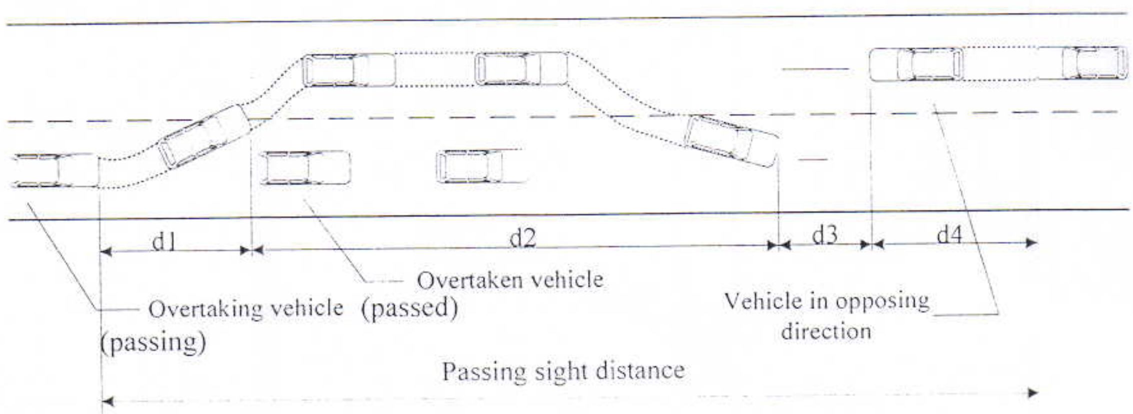
$11.985 = \frac{C_x(2*10^5)(8*10^{-6})(1*28)}{2} \Rightarrow C_x = 0.535$

$C_x = 0.535 \Rightarrow$ from Fig.(20-3) $\Rightarrow \frac{L_x}{\ell} = 4.4$

$\therefore L_x = 4.4\left(\frac{107.5}{100}\right) = 4.73\ m$

i.e. The slab length must be 4.73 m when reducing 50% of the warping stress.

Q2/(B)



Q3/

(A) Chord length$^{(c)}$ = 241 m , R = 270 m , PT = 49+00

$$C = 2R\left(\sin\frac{\Delta}{2}\right) \Rightarrow 241 = 2(270)\left(\sin\frac{\Delta}{2}\right)$$

$$\sin\frac{\Delta}{2} = 0.446 \Rightarrow \frac{\Delta}{2} = 26.51^\circ \Rightarrow \Delta = 53.02^\circ$$

$$T = R\tan\frac{\Delta}{2} = 270\tan(26.51) = 134.68\ m$$

$$L = \frac{2\pi R\Delta}{360} = \frac{2\pi(270)(53.02)}{360} = 249.85\ m$$

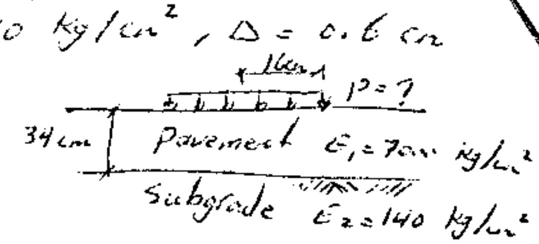
$$E = R\left(\sec\frac{\Delta}{2} - 1\right) = 270\left(\sec(26.51) - 1\right) = 31.72\ m$$

$$M = R\left(1 - \cos\frac{\Delta}{2}\right) = 270\left(1 - \cos(26.51)\right) = 28.39\ m$$

Sta. PC = 49+00 − 2+49.85 = 46+50.15

Sta. PI = 46+50.15 + 1+34.68 = 47+84.83 .

(B) $h = 34\ cm$, $E_1 = 7000\ Kg/cm^2$, $E_2 = 140\ Kg/cm^2$, $\Delta = 0.6\ cm$
$a = 16\ cm$. $P = ?$



Solution :-

$$\Delta = F_w \cdot \frac{1.5\,P\,a}{E_2}$$

$$\left.\begin{array}{l}\frac{E_1}{E_2} = \frac{7000}{140} = 50 \\ \frac{h}{a} = \frac{34}{16} \Rightarrow h = 2.125\,a\end{array}\right\} \Rightarrow \text{From } F_w \text{ chart } F_w = 0.17$$

$$0.6 = 0.17 * \frac{1.5\,P\,(16)}{140} \Rightarrow P = 20.59\ Kg/cm^2$$

Q4/.

(A) $ESAL = \frac{4000}{2(2)} = 1000\ ESAL/day$

$ESAL = 1000 * 365 * 20 = 7.3*10^6\ /design\ life$

$R = 90\%$; $S_o = 0.4$, $m_2 = m_3 = 0.9$, $P_i = 5$, $P_t = 2$ (rural)

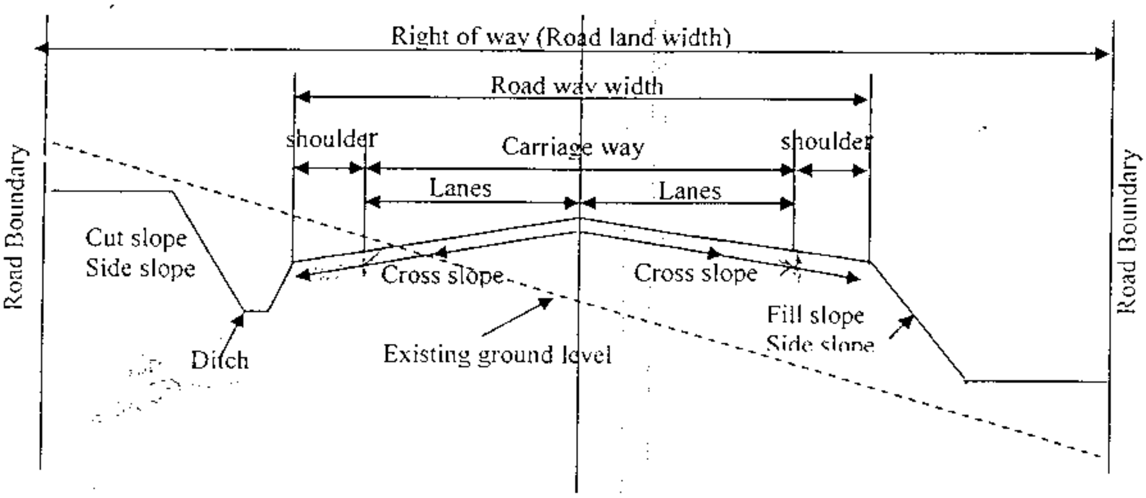
$\Delta PSI = P_i - P_t = 5 - 2 = 3 = \Delta PSI$

Layer	Material	SN_i	a_i	D_i^*	$a_i D_i^* m_i$
Surfacing	Asphalt concrete	/	0.44	6"	2.64
Base	Bitumen-treated soil	2.6	0.34	4"	1.224
Subbase	Sandy gravel	3.7	0.11	5"	0.495
Subgrade	/	4.3	/	/	/

$\Sigma = SN_4^* = 4.359$

Q4/

(B)



Typical cross-section I,cut and fill

Q.5/

(A) $W * \gamma_{av.} * \frac{l}{2} * b * h = f_s A_s \Rightarrow h = \frac{2 f_s A_s}{W \gamma_{av.} l b}$

Allowable tensile stress (f_s) = $\frac{\text{Ultimate stress}}{\text{Safety factor}}$

$= \frac{1000}{2} = 500\ kg/cm^2$

Area of steel = 300 * slab width

$= 300 * 4 = 1200\ mm^2$

$h = \frac{2(500)(1200) * 10^{-2} * 10^{+2}}{2400(1.5)(6)(4)} = 13.89\ cm$

∴ Use 14 cm thickness of concrete slab.

(B)

$$SSD = 0.278\ V t + \frac{V^2}{254(\frac{a}{9.81} \mp g)}$$

$$= 0.278(65)(2.5) + \frac{(65)^2}{254(\frac{2.95}{9.81} + 0.035)}$$

$$= 94.7\ m$$

Assume SSD < L

$$L = \frac{A(SSD)^2}{658}$$

$$= \frac{|-4-(+3.5)|\ (94.7)^2}{658}$$

$$= 102.2\ m > 94.7\ m$$

∴ o.k.