UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: August 2015

Module Number: CE5302 **Module Name: Highway Engineering Design**

[Three Hours]

[Answer all questions. Each question carries **TWELVE** marks]
You may use equations given at the end of this paper with standard notations

Q1. Due to the high traffic flow and low speed conditions in the current AA class highway; a new highway is proposed to be designed between Gampola and Nuwara-Eliya towns. This route is regarded as a scenic highway, with lower speed limits, a dual carriageway (2 lanes in each direction), and with a design speed of 80 km/hr.

a) Enthusiastic member of your team suggest that the team has to leave for Gampola and Nuwara-Eliya immediately to start locating the route "Hands-on". What is your advice on this? Justify your answer in 3 to 5 lines.

[2.0 Marks]

b) First the highway has to be located; as a design team leader you have to explain the highway location process to your team mates. Prepare a write-up naming the main four phases of highway location process; and giving brief description on the activities involved in each of the phases.

[5.0 Marks]

c) Existing road is to be promoted a high speed mobility highway while the new highway as scenic route. Briefly explain three factors that should be considered when designing scenic routes.

[3.0 Marks]

d) Name four factors that should be considered when designing a route through urban area.

[2.0 Marks]

Q2. It is inevitable that there will be many grades along the new highway (stated in Q1). Smooth transition between grades is a must when we considering safety and comfort of the riders. When designing vertical curves "a constant rate of change in the gradient (K given in units of %/m)" is recommended in AASHTO guidelines.

a) If a constant rate of change in the gradient is to be achieved, prove that that vertical curve needs to be a parabola.

[2.0 Marks]

b) At a certain location along the proposed new highway, there are two successive gradient of +2% and +4%. What is the type of vertical curve that should be placed here when referring to Table Q2-1 (*No detail calculations are needed*).

[1.0 Marks]

c) Referring to the Table Q2-1, calculate the desired and absolute minimum crest curve lengths for this dual carriageway highway with a design speed of 80 km/hr where the gradient change from +2% (uphill) to - 4% (downhill).

[2.0 Marks]

d) A 400 m vertical curve is proposed for the curve [in Q2. (c)]. If the elevation of the starting point (T1) of the vertical curve is 876.990 m AMSL and the chainage is 35+766 m, calculate the following (Refer Figure Q2-1):
   i. Elevation of PI
   ii. Elevation of the midpoint of the curve
   iii. Maximum elevation achieved by the curve
   iv. Chain-age of Point T2
   v. Copy the Table Q2-2 and fill it.

[7.0 Marks]

Q3. a) Your institution wants to buy new drilling machines for this project. However, director board is divided over what type of drilling machine to buy. With respect to their drilling action drilling machines can be divided into two types name them and briefly explain those two types and list down two ground related factors that affect the drilling.

[2.00 Mark]

b) In a quarrying operation the bench height is 15m and inclined blast holes having a slope of 1:4 (1 horizontal: 4 vertical) have been planned for the operation. The economically available explosive is ANFO of density 1250 kg/m^3. The site is characterised by a ground factor of 45. Determine the specific charge of the blast hole with a diameter of 120 mm.

[6.0 Marks]

c) Crushed rock samples obtained from a rock query, near the proposed highway between Gampola and Nuwara-Eliya towns, has undergone many tests for the suitability of it as an "ABC". Test observations of the elongation index test are shown in Table Q3-1. State your recommendation based on elongation index only (Project specification states that elongation index cannot exceed 10% for ABC).

[4.0 Marks]

Q4. Pavement of the most portion of the proposed highway between Gampola and Nuwara-Eliya towns (stated in Q1) is going to be designed as a granular road base with surface dressing based on Road Note 29. At a certain stretch CBR value of the existing soil was found to be 5.5%. Estimated AADT and growth factor for the Gampola Nuwara-Eliya Highway by axle load for this stretch is given in Table Q4-1 with their growth factors. Other relevant data are given in Table Q4-2, Table Q4-3, Table Q4-4, Figure Q4-1, and Figure Q4-2.

a) Calculate the equivalent factor for each axle load class given in Table Q4-1.

[2.0 Marks]

b) Calculate the cumulative ESAL if the road is to be designed for 15 years and hence calculate the Traffic Class.

[5.0 Marks]

c) Briefly explain why it is very important to estimate the AADT correctly with respect to the cost of the construction.

[3.0 Marks]

d) If the capping layer is to be introduced in to this design to economize the construction work, calculate the height of the capping layer and draw the modified section

[2.0 Marks]

Q5. First five kilometres of the proposed highway between Gampola and Nuwara-Eliya towns (stated in Q1) is going to be a 6 lane dual carriage way road with flexible pavement with three layers. The consultant of this project recommended to use AASHTO method to design this section of the road.

The ground in the five kilometres of the proposed highway between Gampola and Nuwara-Eliya towns is described in Table Q5-1, The road section is predicted to have 60/40 directional distribution. The data to design the pavement is as follows. Data for the three layers are as foloows.

Layer 1
Reliability is 99%, Overall Standard Deviation is 0.35, estimated total 18- kip equivalent single axis load for entire road is 0.53 ($\times 10^6$esal), Design serviceability loss is 1.0.
Layer coefficient- 0.5

Layer 2
Layer coefficient - 0.15
Drainage modifying factor-0.9
SN - 3.5

Layer 3
Layer coefficient - 0.08
Drainage modifying factor - 0.85
SN - 7.5

a) Calculate the effective roadbed soil resilient modulus using Table Q5-1. You may use the scale given in Figure Q5-1 or use the appropriate equation.

[4.0 Marks]

b) Calculate the Structural number for layer 1. Use the nomograph given in Figure Q5-2 and **attach the nomograph to your answer sheet.**

[2.0 Marks]

c) Calculate the depths of layer 1, 2 and 3.

[6.0 Marks]

Equations, Figures and Tables

Table Q2-1 Design K values for Vertical Alignment

	Design speed (km/hr)					
	120	100	85	70	60	50
Desirable minimum K value – Crest curves (not recommended for single carriageways)	182	100	55	30	17	10
Absolute minimum K value – Crest curves	100	55	30	17	10	6.5
Absolute minimum K value – Sag curves	37	26	20	20	13	9
Full overtaking sight distance (FOSD) K value – Crest curve	–	400	285	200	142	100

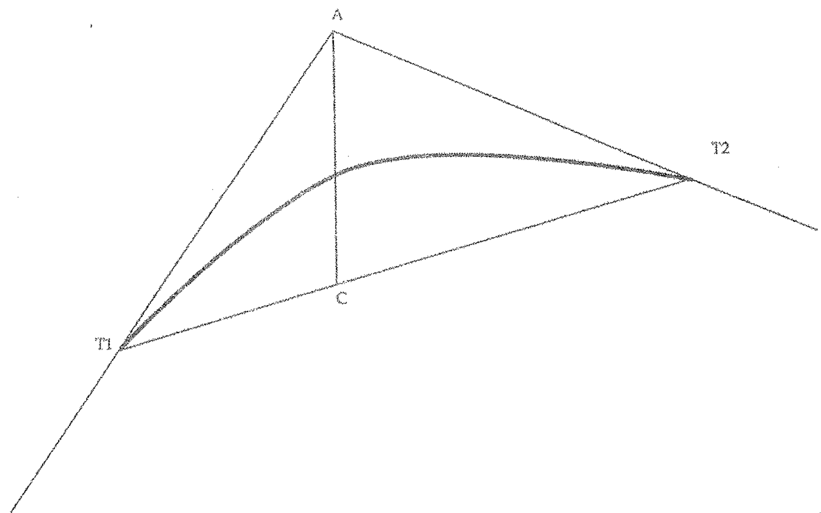

Figure Q2-1 Schematic diagramme of a vertical curve (Not to scale)

Table Q2-2 Setting out table for Vertical curve starting from 35+766

Point	Chainage	Horizontal Length (m)	Elevation (m)
T1	35+766	0	876.99
P1	35+800	34	
P2			
P3			
P_{Max}			
P4			
P5			
P6			
P7			
P8			
P9			
P10			
T2			

Table Q3-1 Observations of Elongation test for the sample from rock query No:5

Sieve Sizes (mm)		Weight Retained (g)	Weight passing through metal length gauge (g)	Weight Retaining on metal length gauge
100% passing	100% retaining			
63	50	120	110	
50	37.5	345	280	65
37.5	28	98.5	54	
28	20	489.3	412	77.3
20	14	358.2	290	68.2
14	10	411.5	385.2	26.3
10	6.3	569.5	516.2	53.3
6.3	5	156.6	116.5	

Table Q4-1 Estimated AADT and growth factor for the New Gampola Nuwara-Eliya Highway

Axle load (1000 kg)	AADT	GF %	EF	ESAL	Yearly ESAL	for 15 years
3.0	301	7				
4.0	305	7				
5.0	550	7				
6.0	350	5				
7.0	190	5				
8.0	150	3				
9.0	76	-3				

Table Q4-2 Directional factor with Directional Distribution

Directional Distribution	Directional factor f_D
50/50	1.00
60/40	0.94
70/30	0.89
80/20	0.83

Table Q4-3: Recommended values for Lane Distribution Factor

Number of Lanes in each direction	Fraction 18-kip ESAL in Design Lane
1	1.00
2	0.80-1.00
3	0.60-0.80
4	0.50-0.75

*use the minimum value of the corresponding factor

Table Q4-4 Traffic and Sub-grade strength classes

(a) Traffic Classes

Traffic Class	10^6 esa Range
T_1	<0.3
T_2	0.3-0.7
T_3	0.7-1.5
T_4	1.5-3.0
T_5	3.0-6.0
T_6	6.0-10.0
T_7	10.0-17.0
T_8	17.0-30.0

(b) Sub-grade Strength Classes

Sub-grade strength class	Range of CBR%
S1	2
S2	3-4
S3	5-7
S4	8-14
S5	15-29
S6	>30

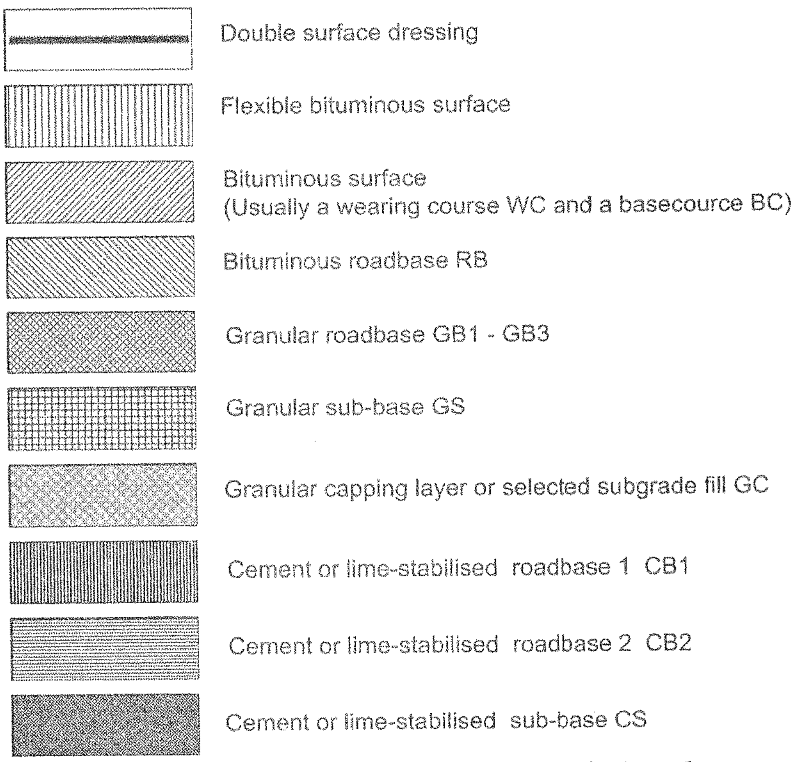

Figure Q4-1 Key for the pavement design charts

	T1	T2	T3	T4	T5	T6	T7
S1	SD 150 175 300	SD 150 225* 300	SD 200 200 300	SD 200 250* 300	SD 200 300* 300	SD 225 325* 300	
S2	SD 150 150 200	SD 150 200 200	SD 200 175 200	SD 200 225* 200	SD 200 275* 200	SD 225 300* 200	
S3	SD 150 200	SD 150 250	SD 200 225	SD 200 275*	SD 200 325*	SD 225 350*	
S4	SD 150 125	SD 150 175	SD 200 150	SD 200 200	SD 200 250	SD 225 275	
S5	SD 150 100	SD 150 100	SD 175 100	SD 200 125	SD 225 150	SD 250 175	
S6	SD 150	SD 150	SD 175	SD 200	SD 225	SD 250	

Notes	1	* Up to 100mm of sub-base may be substituted with selected fill provided the sub-base is not reduced to less than the road base thickness or 200mm whichever is the greater. The substitution ratio of sub-base to selected fill is 25:32.
	2	A cement or lime stabilized sub-base may also be used.
	3	All numbers indicated are in mm unless stated otherwise

Figure Q4-2 Pavement design catalogue for a road granular road base with surface dressing.

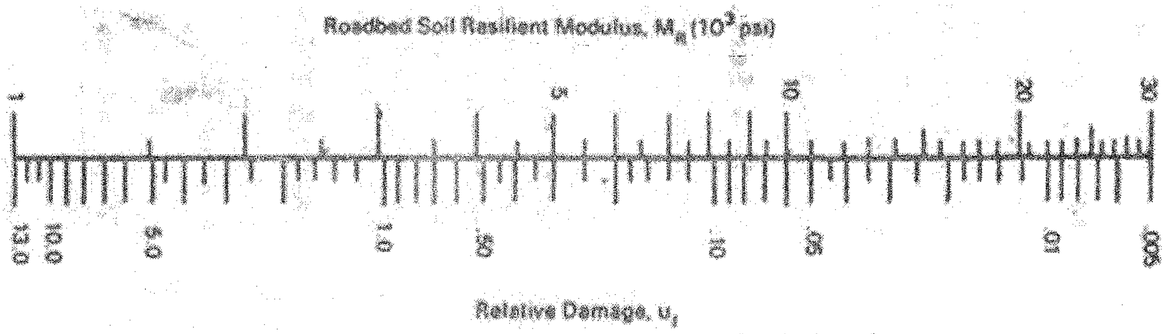

Figure Q5-1 Roadbed resilient modulus and relative damage

Table Q5-1 Roadbed Soil Modulus

Month	Roadbed Soil Modulus MR (psi)
Jan	20000
Feb	15000
Mar	15000
Apr	7500
May	7000
June	4000
July	4000
Aug	4000
Sep	7000
Oct	5000
Nov	5000
Dec	20000

Equations to be used in the calculations

$h_p = H-(h_o+h_b)$

$q_{bk}=3.14/4\times d^2\times P$

$$L = 2d_s - \frac{200\times(\sqrt{h_1}+\sqrt{h_2})^2}{|G_2-G_1|}$$

$q_{pk}=0.5\times q_{bk}$

$$K = \frac{|G_2-G_1|}{L}$$

$Q_b=q_{bk}\times h_b$

$$S_n = \frac{(1+r)^n-1}{r}$$

$Q_p=q_{pk}\times h_p$

$V_{Max}=C\times d$

$Q_{tot}=Q_b+Q_p$

$U=0.3\times V_{Max}$

$q= Q_{tot}/(K\times V\times E)$

$H=(K+u)\times 1.03$

$D_1 \geq SN_1/a_1$

$F=0.05+0.03\times H$

$D_n \geq (SN_n - SN_{n-1}^* \cdots - SN_1^*)/a_n m_n$

$V= V_{Max}-F$

$h_o= V_{Max}$

$E=1.25\times V$

$h_b=1.3\times V_{Max}$

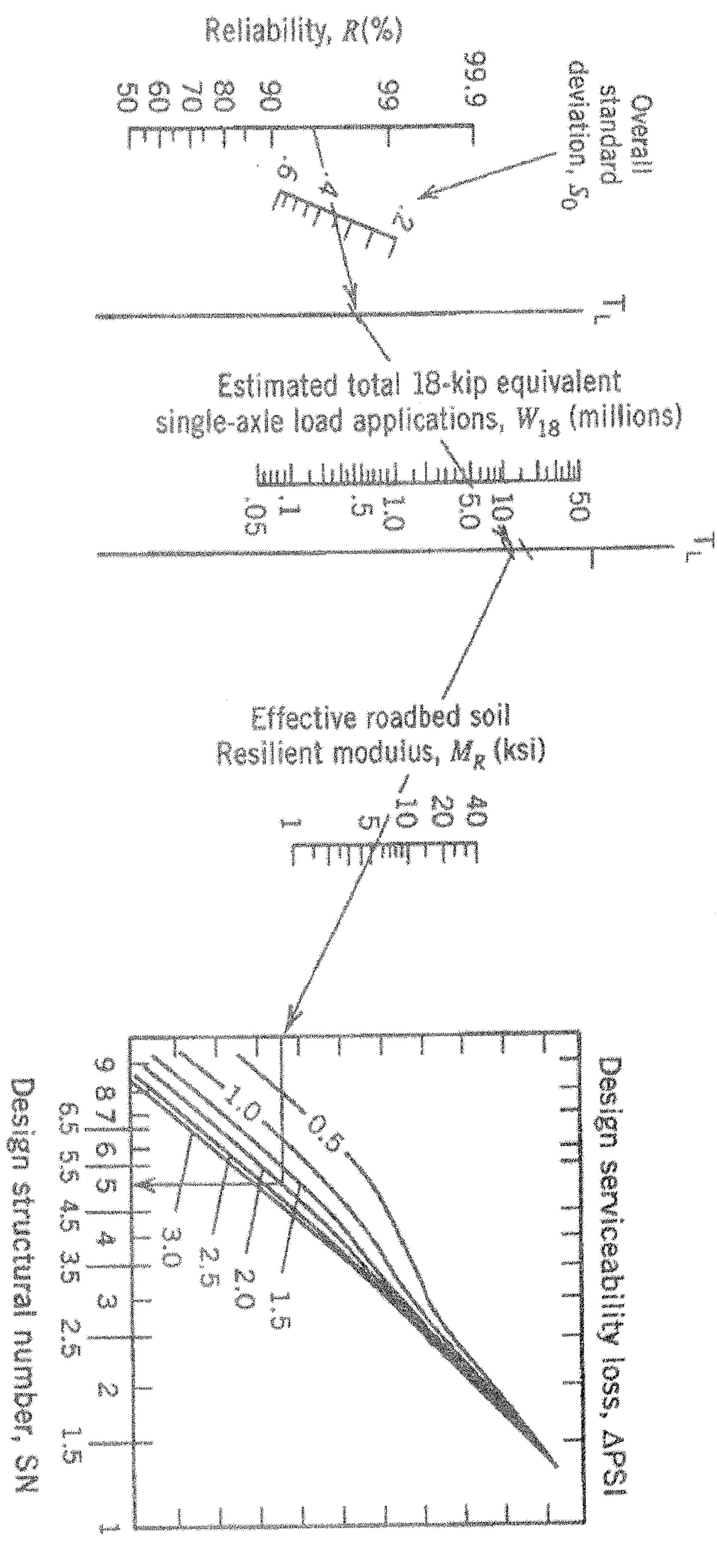

Figure Q5-2 Nomograph