THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF CIVIL ENGINEERING

FIRST SEMESTER EXAMINATIONS – 2022

CE 313- ROAD AND PAVEMENT ENGINEERING

THIRD YEAR CIVIL ENGINEERING

TUESDAY 7th JUNE 2022 – 12:50 PM

VENUE: SLT

TIME ALLOWED: 3 HOURS

INSTRUCTIONS FOR STUDENTS:

1. **WRITE YOUR NAME AND ID NUMBER CLEARLY ON THE FRONT PAGE OF THE ANSWER SHEET.**
2. You have 10 minutes to read this exam paper. You must not begin writing during this time.
3. All answers must be written on the answer booklet provided. No other written material will be accepted.
4. Calculator only is allowed in the examination room. Notes and handouts are not allowed. MOBILE PHONE is not allowed.
5. Maximum Marks: 60.
6. Answer **ALL** questions. All questions carry equal marks.
7. Number of pages is 8 including Cover page and Appendix.

QUESTION 1 [10 marks]

Determine thicknesses of layers of a pavement structure of a 7m wide two-lane road (two-way, one lane each direction). The structure will consist of unbound granular base with a thin asphalt surfacing. Design traffic is $1x10^7$ ESA. The subgrade has design CBR of 5%. The pavement will be composed of all of the following materials:

1. Granular materials with CBR of 86%
2. Quarry materials with CBR of 45%
3. Quarry materials with CBR of 20%

Note: The final answer is a sketch with labels and dimensions of the layers.

QUESTION 2 [10 marks]

a) Sketch a cross section of a pavement structure showing layers and subsurface drains applied in lowering underground water table in cut zones with permeable subgrades. Also show on the cross-section locations of geotextiles for filtration purposes. **[5 marks]**

b) Sketch a cross section of a pavement structure showing layers and a drainage blanket applied in lowering underground water table in cut zones. Also show on the cross-section locations of geotextiles for filtration purposes. **[5 marks]**

QUESTION 3 [10 marks]

A metropolitan planning organization has projected that a new 4-lane motorway will have an AADT of 10,000vpd. Each direction will carry 50% of the AADT. Moreover, 10% of each direction's traffic is heavy vehicles. In each direction, heavy vehicle traffic splits into percentages shown in the table below. Australian vehicle classes and axle loads are shown in the table below.

Vehicle class	%HV Class	Front axle	Rear single axle	Middle tandem	Rear tandem
3	30	26.7 kN	44.5kN		
4	50	35.6 kN			97.8kN
8	20	53.3 kN		178 kN	178 kN

Additional information

- All heavy vehicles use left lanes in each direction
- AADTs of all vehicle types grow at 2% per year
- Design life is 20 years

Calculate

a) Total ESA/day for the design lane in the first year of service **[8 marks]**
b) ESA/year in the first year of service **[1 mark]**
c) DESA for the design lane over the service life **[1 mark]**

QUESTION 4 [10 marks]

The table below presents gradations of two loads of aggregates and the required limits and points of gradation of resulting mix of the two loads of aggregates. Determine suitable blending proportions/percentages for blending the two loads of aggregates to obtain an acceptable mix of combined aggregates.

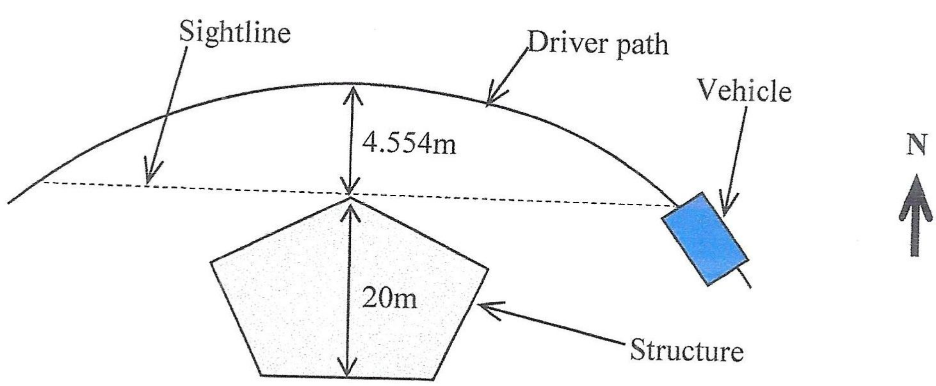
Passing Sieve size	Retained on Sieve size	Percent by Weight		
		Aggregate A	Aggregate B	Required mix
19.000 mm	9.500 mm	20	22	15 to 25
9.500 mm	4.250 mm	30	31	25 to 35
4.250 mm	2.000 mm	7	12	5 to 15
2.000 mm	0.425 mm	23	5	11.75
0.425 mm	0.075 mm	16	22	15 to 25
0.075 mm	0.000 mm	4	8	6.50

QUESTION 5 [10 marks]

Considering safety criterion, a design engineer provided a minimum length of 200m vertical curve to join a G_1=-2% grade to a G_2=+3% grade. What design speed did she use to obtain the 200m length? Ignore comfort, appearance, and drainage criteria.

QUESTION 6 [10 marks]

The diagram bellow shows a 3m tall roadside structure located on the inside of a simple curve of a two lane road. The structure is located 4.554m from the middle of the curved driver path of the sharper lane. The radius of the driver path in the sharper lane is 330m. The intersection angle of the curve is $38^{o}33'52.08''$. The design speed is 80kph. The vehicle (in the diagram) is traveling from East to West on a 3% grade. Determine the radius required to make the minimum available sight distance equal to stopping sight distance. Horizontal tangents should not change.



NB: Top view, not to scale

---- End of Exam----

APPENDIX

FORMULAE, TABLES, AND CHARTS.

A. PAVEMENT LOADING

For an axle group type, $ESA/day = AADT \times DF \times \frac{\%HV}{100} \times \frac{\%HVCLASS}{100} \times LDF \times ESA_{ij}$

Where:

DF = Direction distribution factor

%HV = Percentage of heavy vehicles in the AADT

%HVCLASS = Percentage of a vehicle class within heavy vehicle traffic

LDF = Lane distribution factor (fraction of heavy vehicles in a design lane)

ESA_{ij} = Equivalent standard axles for a passage of axle group type i and load Lij

$ESA_{ij} \equiv$ LEFij=Load equivalent factor for a passage of axle group type i and load Lij

$$ESA_{ij} = \left(\frac{L_{ij}}{SL_{ij}}\right)^4 \text{...AGPT03(36, A13, A26)}$$

$L_{ij} = j^{th}$ load magnitude for axle group type i

$SL_{ij} = j^{th}$ standard load for axle group type i (Table 7.7 and 7.8)

Table 7.7: Loads on axle groups with dual tyres which cause same damage as a Standard Axle

Axle group type	Load (kN)
Single axle with dual tyres (SADT)	80
Tandem axle with dual tyres (TADT)	135
Triaxle with dual tyres (TRDT)	182
Quad-axle with dual tyres (QADT)	226

Table 7.8: Loads on axle groups with single tyres which cause same damage as a Standard Axle

Axle group type	Nominal tyre section width	Load (kN)
Single axle with single tyres (SAST)	Less than 375 mm	53
	At least 375 mm but less than 450 mm	58
	450 mm or more	71
Tandem axle with single tyres (TAST)	Less than 375 mm	89
	At least 375 mm but less than 450 mm	98
	450 mm or more	119
Triaxle with single tyres (TRST)	Less than 375 mm	121
	At least 375 mm but less than 450 mm	132
	450 mm or more	162
Quad-axle with single tyres (QAST)	Less than 375 mm	150
	At least 375 mm but less than 450 mm	164
	450 mm or more	201

B. EMPIRICAL PAVEMENT DESIGN

Figure 8.4: Design chart for granular pavements with thin bituminous surfacing

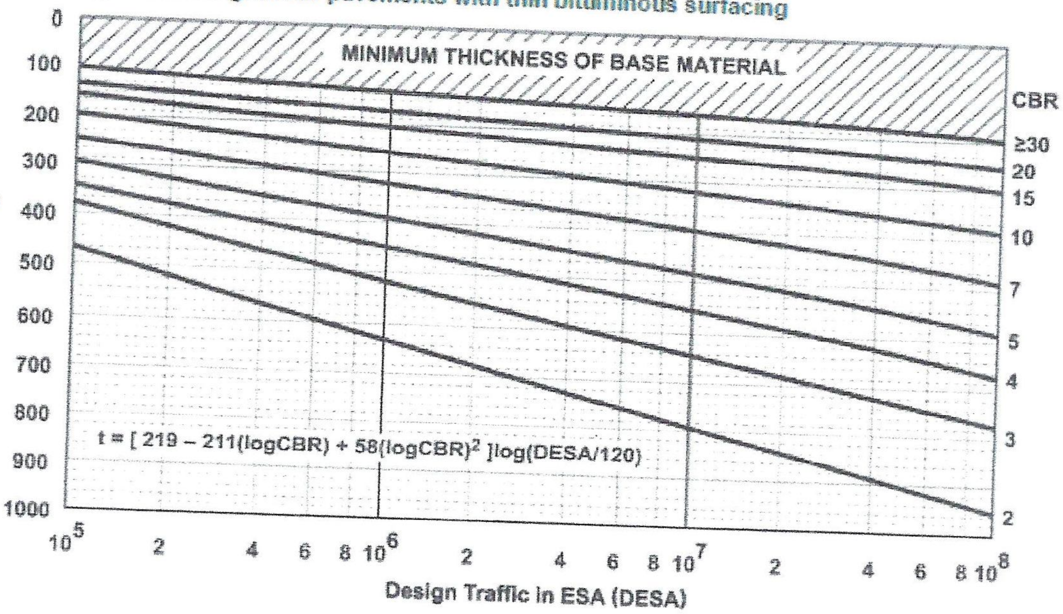
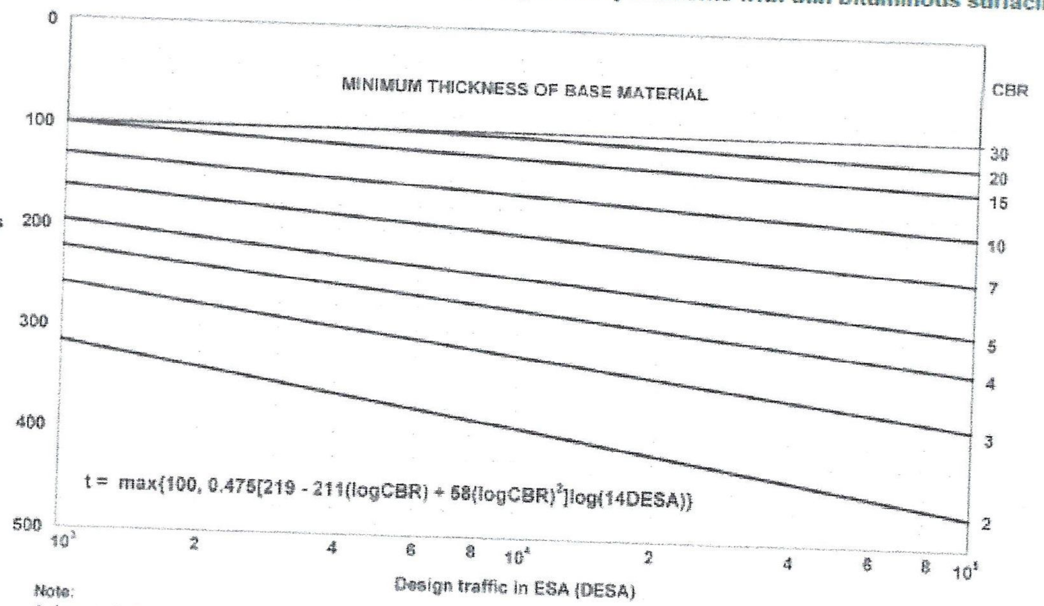


Figure 12.2: Example design chart for lightly-trafficked granular pavements with thin bituminous surfacings



Note:

1. Appropriate local conditions, environmental and drainage issues must be considered in using these design curves.
2. Thin asphalt surfacings may be included in total granular thickness. However, the minimum thickness of the granular base is 100 mm.

C. AGGREGATE BLENDING AND GRADATION

A_{ij} be the percent of aggregate from source i passing a sieve size j and retained on j+1,
B_i be proportions of source i=1, 2, 3,...
$\sum B_i = 100\%$; for sources i=1,2,...
$\sum 0.01 B_i A_{ij} = P_j$
P_j is the percentage of aggregate size j after combination
$\sum P_j = 100\%$
$\sum 0.01 B_i A_{ij} = B_i$ sum over all j=1,2,... for each source i

D. SIGHT DISTANCE

$$S = 0.278 \times V.R_T + \frac{V^2}{254.275\left(\frac{a}{g} \pm \frac{G}{100}\right)}$$

Where

S is stopping sight distance (in meters)
V is design or operating speed in Km/h or Kph
R_T is reaction time, 2.5s for emergency stopping
a is deceleration, $3.4 m/s^2$
g is acceleration due to gravity, $9.81 m/s^2$
G is gradient or slope in percentage %

$$O_{des} = R\left[1 - \cos\left(\frac{28.65 \times S_{des}}{R}\right)\right] \quad \text{for } S \leq L$$

Where

O is offset to roadside obstruction to sightline (in meters)
R radius of driver path on the inside lane (in meters)
L is length of curve (in meters)

$$O_{des} = R\left[1 - \cos\left(\frac{I}{2}\right)\right] + 0.5(S_{des} - L)\sin\left(\frac{I}{2}\right) \quad \text{for } S > L$$

Where

I is the intersection or deflection angle between tangents (in degrees)

E. HORIZONTAL CURVES

$$R_{min} = \frac{V^2}{127\left(\frac{e_{max}}{100} + f_{max}\right)}$$

Where

Rmin is minimum radius (in meters)

V is design or operating speed in Km/h or Kph
e is superelevation in percentage %
f is side friction factor, unitless.

Tangent length $T = R.\tan\left(\frac{I}{2}\right)$

External distance $E = R\left(\sec\left(\frac{I}{2}\right) - 1\right)$

Middle ordinate $M = R\left(1 - \cos\left(\frac{I}{2}\right)\right)$

Long chord $C = 2R.\sin\left(\frac{I}{2}\right)$

F. SIDE FRICTION FACTORS

Table 7.5: Recommended side friction factors for cars and trucks

Operating speed (km/h)	f			
	Cars		Trucks	
	Des max	Abs max	Des max	Abs max
40	0.30	0.35	0.21	–
50	0.30	0.35	0.21	0.25
60	0.24	0.33	0.17	0.24
70	0.19	0.31	0.14	0.23
80	0.16	0.26	0.13	0.20
90	0.13	0.20	0.12	0.15
100	0.12	0.16	0.12	0.12
110	0.12	0.12	0.12	0.12
120	0.11	0.11	0.11	0.11
130	0.11	0.11	0.11	–

G. MAXIMUM SUPERELEVATION

Table 7.8: Maximum values of superelevation to be used for different road types

Road type	Speed range (km/h)	Maximum superelevation (emax)
Urban	All speeds	5%
High speed rural	Greater than 90	6%
Intermediate speed rural	Between 70 and 89	7%
Low speed rural	Less than 70	10%

H. SETTING OUT OF HORIZONTAL CURVES

Initial deflection angle $0.5\delta_1 = 0.5 \times \frac{360 l_1}{2\pi R}$

Initial chord length $c_1 = 2R\sin(0.5\delta_1)$

Intermediate additional angle $0.5D$

Intermediate chord length $C_D = 2R\sin(0.5D)$

Final additional deflection angle $0.5\delta_2 = 0.5 \times \frac{360 l_2}{2\pi R}$

Final chord length $c_2 = 2R\sin(0.5\delta_2)$

Normal offset from tangent $y = R \pm \sqrt{R^2 - x^2}$

Normal offset from long chord $y = -b \pm \sqrt{R^2 - (x-a)^2}$

Where $a = R\sin(0.5I)$ and $b = R\cos(0.5I)$

I. VERTICAL CURVES

All curves

$E = \frac{G_2 - G_1}{200L} x^2 + \frac{G_1}{100} x + E_{BVC}$, with G_1 and G_2 in %

Where

E is elevation above mean sea level (in meters)

G_1 is approach grade in percentage %

G_2 is departure grade in percentage %

Crest curves

$$L_{min} = \frac{AS^2}{448} \quad if\ S \le L$$

$$L_{min} = 2S - \frac{448}{A} \quad if\ S > L$$

Where

A is absolute algebraic difference of grades (in %)

$A = |G_2 - G_1|$

Open sag curves

$$L_{min} = \frac{AS^2}{130 + 3.5S} \quad if\ S < L$$

$$L_{min} = 2S - \frac{130 + 3.5S}{A} \quad if\ S > L$$

Comfort criterion $L_{min} = \frac{AV^2}{635}$

Sag curves with overhead obstruction

$$L_{max} = \frac{AS^2}{800(C - 1.5)} \quad if\ S \le L$$

$$L_{max} = 2S - \frac{800(C - 1.5)}{A} \quad if\ S > L$$

Where

C is minimum clearance (in meters)