UNIVERSITY OF JOHANNESBURG

PROGRAM	:	NATIONAL DIPLOMA ENGINEERING: CIVIL
SUBJECT	:	**TRANSPORTATION ENGINEERING III**
CODE	:	**CET 3211**
DATE	:	November 2019
DURATION	:	(SESSION)
WEIGHT	:	40:60
TOTAL MARKS	:	100

ASSESSOR	:	MR HOSANA H NDLOVU (M-TECH: CIVIL ENGINEERING)
MODERATOR	:	MRS TJ RIKHOTSO (M-TECH: CIVIL ENGINEERING)
NUMBER OF PAGES	:	4 PAGES

INSTRUCTIONS	:	ONLY ONE POCKET CALCULATOR PER CANDIDATE ANSWER ALL QUESTIONS
REQUIREMENTS	:	

MAIN EXAMINATION

Scenario

You have been appointed as a consulting engineer for the City of Tshwane Metropolitan Municipality in Gauteng Province. As the project engineer in a roads project, you must oversee the planning, design and construction of a 3km road that links Meyerspark and Die Wilgers. The road will serve as a link between the two suburbs and will also ensure safe travel for commuters and school children who travel from Meyerspark to attend school in Die Wilgers. Furthermore, the road is used by trucks which travel from Meyerspark to collect newly built cars from Ford SA in Silverton and deliver them to a storage warehouse in Die Wilgers. The vehicle plant and all related economic activities within Meyerspark and Silverton are the main source of employment for many of the residents in the area. The project area is not environmentally sensitive.

The common truck that is used by the freight company to transport the newly built cars is the Mercedes Benz Actros 2837 (30 tons). You must prepare a written report to the Divisional Head (Mr Thabo Lebepe) of the Roads & Transport Department in the municipality explaining some aspects of the design and construction.

The known technical information that you have collected thus far is shown below:

Distance of Road	3km	**Average Daily temperature**	33ºC
Annual Rainfall	612mm	**Available Material Quality**	G8
Mercedes Benz Actros	34 000kg carried on 4 axles	**Pedestrian Traffic volumes**	1500 people/per day
distribution mass on truck	25%:25%:25%:25%	**Annual Traffic Increase**	4%
Design life of road	20	**Geology**	Silverton Shale
n	4	**Peak surface flow**	$2.51m^3/s$
CBR value (in-situ)	6	**Road Width**	8.5m
CBR value (Base)	80	**CBR value (Subbase)**	40
g	$9,81m/s^2$	**CBR value (Selected)**	20

Question 1 **/25/**

1.1 With the aid of a sketch, illustrate to the Divisional Head the typical pavement structure of the flexible pavement that you have designed. (05)
1.2 Briefly explain to Mr Lebepe the methodology that you will use when preparing for the roadbed on site during construction. (06)
1.3 What are the factors that you will consider when conducting the road design pavement? (06)
1.4 Explain to the Divisional Head what empirical designs are. (08)

Question 2 **/25/**

2.1 Briefly explain to the Divisional Head the functions of a sub-base. (05)
2.2 Explain in detail, to the Divisional Head, what a reinforced concrete pavement is. (08)
2.3 Describe to the Mr Lebepe the concept of "*Pavement Structural Balance".* (10)
2.4 Explain to the Divisional Head why a road surface is wetted before placing concrete. (02)

Question 3 **/25/**

3.1 Illustrate to the Divisional Head the correct axle loads in KN by drawing a neat basic sketch of the design truck. (05)
3.2 Compute the number of equivalent E80 axle loads on each axle of the truck and the equivalent E80s for the whole truck thereof. (07)
3.3 There will be 10 such trucks each doing 2 trips per hour per direction on the new 3km section of road. A working day is 12 hours. Calculate the daily equivalent traffic (E80s) at the start of operations ($AADE_{INITIAL}$). (04)

3.4 Calculate the design equivalent traffic for the road and state its design traffic class, road category, and climatic region and draw the timeline of the traffic. (09)

Question 4 **/25/**

4.1 The Divisional Head wants to use Cape Seal for surfacing the new road; however, you are the opinion that Hot Mix Asphalt is a better option. List and describe to the Divisional Head any four (04) types of hot mix asphalt. (12)

4.2 Cement stabilisation is used in the sub-base, explain to the Divisional Head the factors that affect strength development in soils that are treated with cement. (08)

4.3 List any 4 of some common stabilising agents in the industry and recommend one that you think is suitable for your design. (05)

TOTAL = 100 Marks

USEFUL FORMULAE

- $F = \left(\frac{P}{80}\right)^n$ $\qquad F = \frac{\left(\frac{P_{\text{lower limit}}}{80}\right)^n + \left(\frac{P_{\text{upper limit}}}{80}\right)^n}{2}$
- $g_x = \left(1+\frac{i}{100}\right)^x$ $\qquad r = [\left(\frac{AADE_n}{AADE_1}\right)^{\frac{1}{n}} - 1] * 100$
- $ADE = ADT \cdot F$ $\qquad AADE = ADE \cdot Be$
- $E80_{INITIAL} = AADE \cdot g_x$ $\qquad E80_{TOTAL} = E80_{INITIAL} \cdot f_y$
- $fy = \frac{365*\left(1+\frac{i}{100}\right)*\left[\left(1+\frac{i}{100}\right)^y - 1\right]}{\frac{i}{100}}$ $\qquad BF = \frac{BD}{LD}$ $\quad CF = \frac{LD}{CD}$ $\quad SF = \frac{BD}{CD}$ $\quad CF = \frac{CV}{LV}$ $\quad BF = \frac{LV}{BV}$ $\quad SF = \frac{CV}{BV}$
- $J = \frac{P}{W A}$ $\qquad$ J = Distributor speed (m/s) $\qquad$ W = Width sprayed (m)
- $PWOC = C + M_1 (1+r)^{-x_1} + M_2 (1+r)^{-x_2} \ldots\ldots - S(1+r)^{-z}$
- $M_B = \frac{M_A * P_B}{100 - P_B}$ $\qquad M_{ADJ} = \frac{h_A * M_1}{h_B}$

$S = S_F * CF$ $\qquad CF = 965\, h^{-1.655}$ $\qquad ADE = \sum tj * Fj$ $\qquad E80_{TOTAL} = \frac{AADE_{END}}{g_x} * f_y$

- $F = C' - A$ $\qquad Q = \frac{F}{S}$
- $W_{ABS} = 100 \times \frac{M_2 - M_4}{M_4}$ $\qquad BD_{MIX} = \left(\frac{(\rho_W - M_4)}{(M_{2EF} - M_{3EF}) - 1000\, \frac{(M_{2EF} - M_{3EF})}{BD_{EF}}}\right)$

TABLE 4

Classification of pavements and traffic for structural design purposes

Pavement class*	Pavement design bearing capacity (million 80 kN axles/lane)	Volume and type of traffic** — Approximate v.p.d. per lane***	Volume and type of traffic** — Description
ES0.003	< 0,003	< 3	Very lightly trafficked roads; very few heavy vehicles. These roads could include the transition from gravel to paved roads and may incorporate semi-permanent and / or all weather surfacings.
ES0.01	0,003 - 0,01	3 - 10	
ES0.03	0,01 - 0,03	10 - 20	
ES0.1	0,03 - 0,10	20 - 75	
ES0.3	0,10 - 0,30	75 - 220	
ES1	0,3 - 1	220 - 700	Lightly trafficked roads, mainly cars, light delivery and agriculture vehicles; very few heavy vehicles.
ES3	1 - 3	> 700	Medium volume of traffic; few heavy vehicles.
ES10	3 - 10	> 700****	High volume of traffic and / or many heavy vehicles.
ES30	10 - 30	> 2200****	Very high volume of traffic and / or a high proportion of fully laden heavy vehicles.
ES100	30 - 100	> 6500****	

TABLE 16

Subgrade CBR classification for structural design

Class	Subgrade CBR (%)
SG1	> 15
SG2	7 to 15
SG3	3 to 7
SG4	< 3*

TABLE 10

Current typical ranges of total E80 growth rates for different road categories (modified from TRH16, 1991)

Road Category	A	B	C	D
Range of growth rates (%)	2 - 12	2 - 12	2 - 10	2 - 15
Typical growth rates (%)	4	4	4	—*

TABLE 9

Design factors for distribution of total traffic and equivalent traffic among lanes and shoulders

Total number of traffic lanes (Both directions)	Design distribution factor, B_e or B			
	Surfaced slow shoulder	Lane 1*	Lane 2	Lane 3
(a) Equivalent traffic (E80s) Factor B_e				
2	1,00	1,00	—	—
4	0,95**	0,95	0,30	—
6	0,70**	0,70	0,60	0,25
(b) Traffic (total axles e.v.u)***Factor B				
2	1,00	1,00	—	—
4	0,70**	0,70	0,50	—
6	0,30**	0,30	0,50	0,40

TABLE 22

Preparation of subgrade/roadbed and required selected layers for the different subgrade design CBRs (Categories A, B, C and D)

Subgrade CBR Class	SG4	SG3	SG2	SG1
Design CBR of subgrade	< 3	3 - 7	7 - 15	> 15
Add selected layers: Upper Lower	Not applicable	150 mm G7 150 mm G9*	150 mm G7 —	— —
Treatment of in situ subgrade	Special treatment required	Rip and re-compact to 150 mm G10	Rip and re-compact to 150 mm G9	Rip and re-compact to 150 mm G7

* If the in situ subgrade is expected to be very wet, or in wet regions (Section 6), an additional 150 mm layer of G9 or a pioneer layer (CSRA, 1987) could be used.

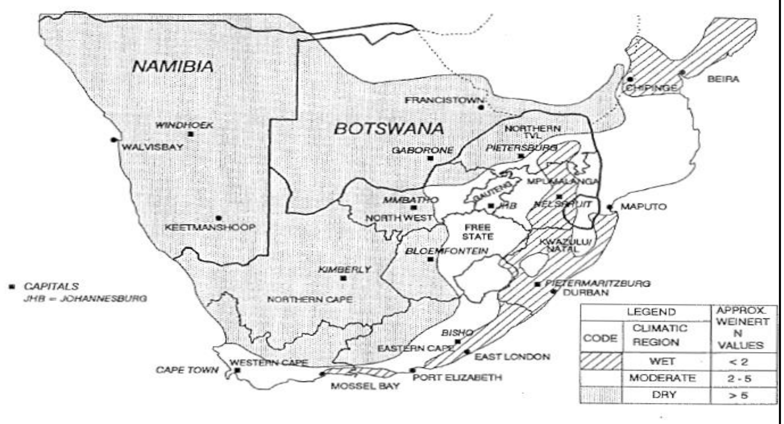

FIGURE 4: MACRO CLIMATIC REGIONS OF SOUTHERN AFRICA
(Adapted from Weinert, 1980)

TABLE 19

Suggested flexible and semi-rigid pavement types for different road categories and traffic classes

Pavement types: Base	Pavement types: Subbase	A: ES100	A: ES3	B: ES10	B: ES3	B: ES1	C and D: ES3	C and D: ES1	C and D: <ES0.3	Brief reasons why listed pavement types are **not** recommended for the given road category and traffic class
Granular	Granular	×	✓**	✓**	✓*	✓	✓	✓	✓	Uncertain behaviour
	Cemented	✓*	✓	✓	✓	✓	✓	✓	✓	—
Hot-mix asphalt	Granular	✓	✓	✓	✓	×	✓	×	×	Cost effectiveness
	Cemented	✓	✓	✓	✓	×	✓	×	×	Cost effectiveness
Cemented	Granular	×	×	×	×	×	×	×	✓	Fatigue cracking, crushing, pumping and rocking blocks
	Cemented	×	×	✓	✓	✓	✓	✓	✓	Shrinkage cracks unacceptable

* Not recommended for wet regions without special provision for drainage.

** Only where experience has proved this to be adequate[89].

✓ = Recommended × = Not recommended