THE UNIVERSITY OF ZAMBIA

SCHOOL OF ENGINEERING

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

2021/2022 ACADEMIC YEAR

CEE 3111 – CVIL ENGINEERING MATERIALS AND PRACTICES

FINAL EXAM WITH MODEL ANSWERS

TUESDAY 27TH JUNE 2023

DURATION: THREE (3) HOURS **CLOSED BOOK EXAM**

INSTRUCTIONS

1. There are **TWO SECTIONS** with a total of five (5) questions in this Examination Paper
2. **QUESTIONS IN SECTION A (QUESTIONS 1 & 2) ARE BOTH COMPULSORY QUESTIONS**
3. **ANSWER QUESTIONS 1 & 2 AND ANY OTHER TWO (2) QUESTIONS IN SECTION B**
4. **Total Marks =100. The Weight of each Question is indicated in brackets**
5. Remember to clearly number your answers
6. The answer for each question should begin on a new sheet
7. Make sure your computer number is indicated on all booklets including the questions attempted
8. All the relevant information is provided. However, if you feel the information provided is not adequate, make and state your assumptions.
9. Calculations must be clear and logical
10. Marks will be lost for illegible, untidy and unorganised answers
11. All necessary graphs, tables, and equations are given in the appendices

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SECTION A

QUESTION 1 [20 Marks] – COMPULSORY QUESTION

a) Mention any three tests that can be performed on hardened concrete Portland cement concrete to control the quality of the concrete and check specification compliance.

ANS:

i. Compressive Strength Test
ii. Split Tension Test
iii. Flexure Strength Test
iv. Rebound Hammer Test (Schmidt Hammer)
v. Penetration Resistance Test
vi. Ultrasonic Pulse Velocity Test
vii. Maturity Test

[1.5 Marks]

b) What is the difference between tar and asphalt cement? List the four methods used to grade asphalt binders. Which method is used in Zambia?

ANS:

- Tars are produced by the destructive distillation of bituminous coal or by cracking petroleum vapors while asphalts are obtained from Crude Petroleum Residues

- i. Performance grading
  ii. Penetration grading
  iii. Viscosity grading
  iv. Viscosity of aged residue grading

- Penetration Grading

[1 + 4 + 1 Marks]

c) What factors are considered in grading lumber? State any two different imperfections that may be found in lumber, and briefly discuss them.

ANS:

- i. Strength
  ii. Durability
  iii. Workability

- i. Knots: Branch bases that have become incorporated into the wood of the tree trunk or another limb. Knots degrade the mechanical properties of lumber, affecting the tensile and flexural strengths.
  ii. Warp: A distortion of wood from the desired true plane Penetration Grading

[1 + 2 Marks]

d) What is a composite material? List four different advantages of composite materials over conventional materials.

ANS:

- i. These materials usually combine the best properties of their constituents and frequently exhibit qualities that do not even exist in their constituents.

- i. Improved Strength
  ii. Corrosion and Wear Resistance [1 + 2 Marks]

e) Mention three key principles considered in the selection of construction equipment.

ANS:

i. **Technical Efficiency**
ii. **Commercial & Financial Ability**
iii. **Availability** **[1.5 Marks]**

f) Define Formwork with respect to construction. Mention one advantage and one disadvantage of timber and steel formwork.

ANS:

- **Formwork is a mould or box into which wet concrete can be poured and compacted. It contains freshly placed and compacted concrete until it has gained enough strength to be self-supporting.**

Timber Formwork Advantage: More Economical, Easy to handle.
Timber Formwork Advantage: Not enough strength, shrinkage, Leakage.

Steel Formwork Advantage: Able to carry large concrete weight and pressure,
Timber Formwork Advantage: Limited to the shape of the structure.

1 + 2 Marks]

g) What is a Bill of Quantities (BoQ) and what is its principal use?

ANS:

A form of document which sets out the quantities and descriptions of the items of labour, materials and plant required to erect and complete a building or other works in a systematic manner. **[2 Marks]**

QUESTION 2 [40 Marks] – COMPULSORY QUESTION

a) The table below shows the grain size distribution for two aggregates and the specification limits for an asphalt concrete.

Sieve Size (mm)		19	12.5	9.5	4.75	2.36	0.6	0.3	0.15	0.075
Specification Limits (%)		100	80–100	70–90	50–70	35–50	18–29	13–23	8–16	4–10
% Passing	Aggregate A	100	85	55	20	2	0	0	0	0
	Aggregate B	100	100	100	85	67	45	32	19	11

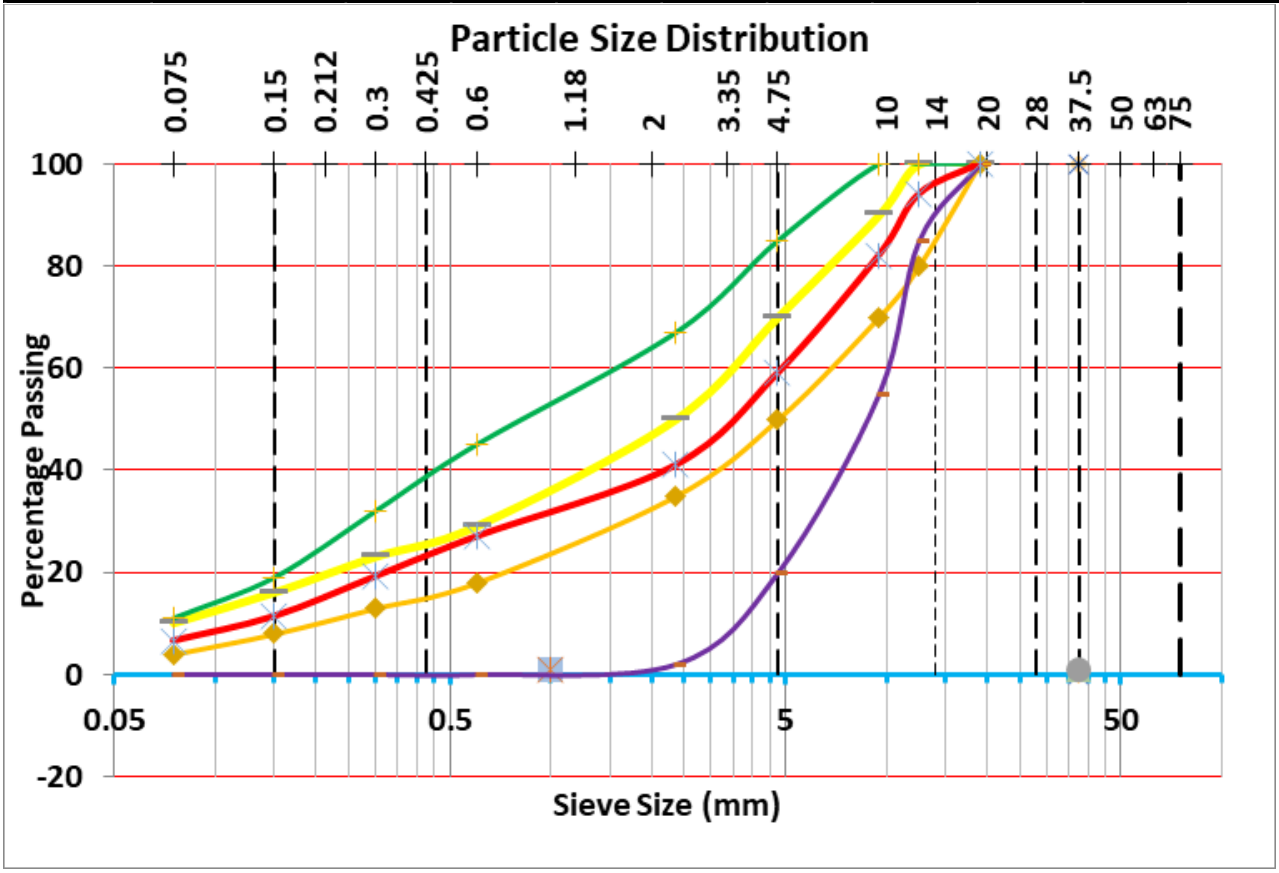
i. Determine the blend proportion required to meet the specification.
ANS:
Any Option that fits is ok (Best Option is 40% Aggregate A & 60 Aggregate B (40/60)

ii. Determine the gradations of the blend.
ANS:
Any Option that fits is ok (Best Option is 40% Aggregate A & 60 Aggregate B (40/60)

Sieve Size (mm)		19	12.5	9.5	4.75	2.36	0.6	0.3	0.15	0.075
Bled Option	Opt. 3: 40/60	100	94	82	59	41	27	19	11	7

iii. On a semilog gradation graph provided, plot the gradations of aggregate A, aggregate B, the selected blend, and the specification limits.
ANS:
See Graph Below

Sieve Size (mm)		19	12.5	9.5	4.75	2.36	0.6	0.3	0.15	0.075
Specification Limits (%)	Upper Limit	100	100	90	70	50	29	23	16	10
	Lower Limit	100	80	70	50	35	18	13	8	4
Target Gradation (Spec Mid Point)		100	90	80	60	42.5	23.5	18	12	7
% Passing	Aggregate A	100	85	55	20	2	0	0	0	0
	Aggregate B	100	100	100	85	67	45	32	19	11
Bled Option	Opt. 1: 50/50	100	93	78	53	35	23	16	10	6
	Opt. 2: 45/55	100	93	80	56	38	25	18	10	6
	Opt. 3: 40/60	100	94	82	59	41	27	19	11	7



[5 + 5 + 20 Marks]

b) Laboratory specific gravity and absorption tests run on the two aggregates in **part a)** had the following results:

Aggregate A: Bulk specific gravity = 2.814; absorption = 0.4,

Aggregate B: Bulk specific gravity = 2.441; absorption = 5.2,

Using the blend proportion calculated in **part a) (i):**

i. Determine the specific gravity of a blend by weight.

ANS: $\boldsymbol{Composite\ SG} = \frac{1}{\frac{P_1}{G_1}+\frac{P_2}{G_2}+\cdots}$ Note: P: decimal fraction used in the blend

$= \frac{1}{\frac{40}{2.814}+\frac{60}{2.441}} =$ **2.578**

ii. What is the absorption of the blend aggregate?

ANS: $\boldsymbol{Composite\ Absorption} = P_1X_1 + P_2X_2 + \cdots$=0.4*0.4+.6*5.2 = 3.28%

[5 + 5 Marks]

SECTION B (ANSWER ANY TWO QUESTIONS)

QUESTION 3 [20 Marks]

The Marshall method of mix design has been widely used by many highway agencies.

a) What are the steps of Marshall mix design?

ANS:

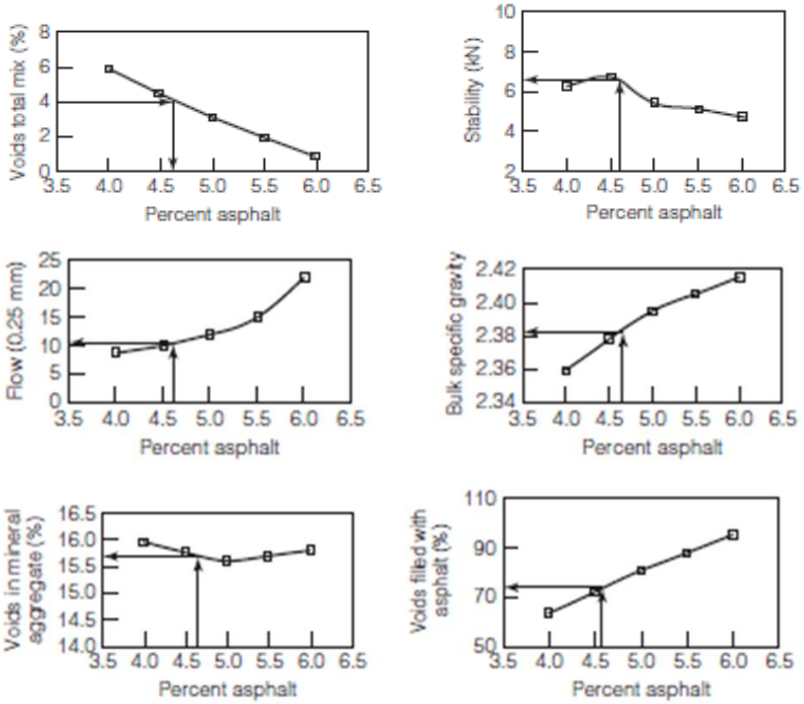
1. **Aggregate Evaluation**
2. **Asphalt Cement Evaluation**
3. **Specimen Preparation**
4. **Marshall Stability and Flow Measurement**
5. **Density and Voids Analysis**
6. **Design Asphalt Content Determination**

b) What parameters are calculated?

ANS:

1. **Marshall Flow**
2. **Stability**
3. **Voids in Total Mix (VTM)**
4. **Voids in Mineral Aggregate (VMA)**
5. **Voids Filled with Asphalt (VFA)**
6. **Asphalt Content**
7. **Bulk Specific Gravity**
8. **Theoretical Maximum Specific Gravity**
9. **Effective Specific Gravity**

c) Show (sketch) the typical graphs that are plotted after tests are completed.



d) What is the purpose of plotting these graphs?

ANS: The graphs are used to determine the Optimum Asphalt Content

[6 + 3 + 9 + 2 Marks]

QUESTION 4 [20 Marks]

a) What do you understand by the term '**Atterberg Limits'? Define** three different types of Atterberg Limits.

ANS:

- **Atterberg Limits : The water content levels at which the soil changes from one state to the other**
- **i. Liquid Limit**
- **ii. Plastic Limit**
- **iii. Shrinkage Limit** **[2 + 3 Marks]**

b) What is Soil Stabilization?

ANS:

Soil Stabilization is the biological, chemical or mechanical modification of soil engineering properties **[2 Marks]**

c) The table shows results obtained from a standard AASHTO compaction test on six samples, 4 in. diameter, of a soil to be used as fill for a highway.

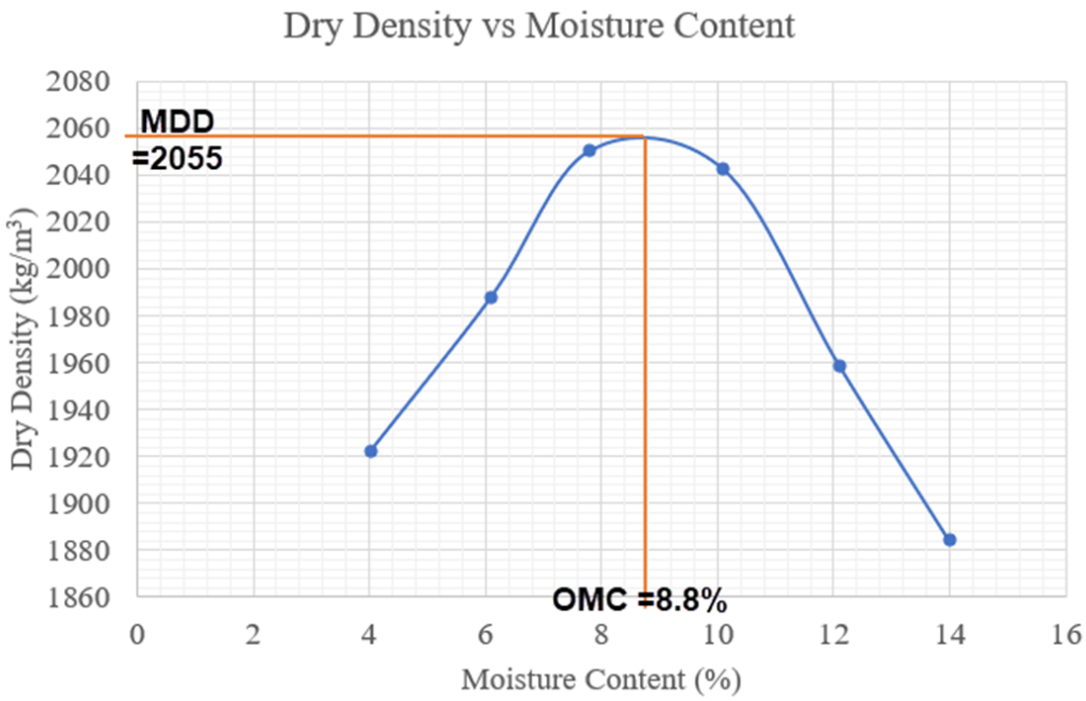
Sample ID	1	2	3	4	5	6
Sample Weight (kg)	1.89	1.99	2.09	2.12	2.07	2.03
Moisture Content (%)	4	6.1	7.8	10.1	12.1	14

The net volume of each sample is 0.0009439 m^3.

i. Determine the Maximum Dry Density and Optimum Moisture Content of this soil **(NB: You do not need to use a graph paper to plot the graph. A neat sketch within your exam booklet will be enough).**

ANS:

Sample ID	Weight (W) (kg)	Volume (V) (m^3)	Bulk Density $\gamma = W/V$ (kg/cm^3)	Moisture Content (%)	Dry Density, $\gamma_d = \gamma/(1+w)$
1	1.89	0.0009439	1999.1	4	1922.21
2	1.99	0.0009439	2109.63	6.1	1988.34
3	2.09	0.0009439	2210.55	7.8	2050.6
4	2.12	0.0009439	2248.99	10.1	2042.68
5	2.07	0.0009439	2196.13	12.1	1959.08
6	2.03	0.0009439	2148.07	14	1884.28



[10 Marks]

ii. This soil was used as imported material in the construction of a hardcore for a multi-story building and the minimum compaction requirement was 98%. Sand Replacement Test found a Field Dry Density of 1998 kg/m³. **Determine the compaction that was achieved on site and discuss its adequacy.**

ANS:

$$\boldsymbol{Compaction} = \frac{\boldsymbol{Field\ Dry\ Density}}{\boldsymbol{Maximum\ Dry\ Density}} * \mathbf{100\%} = \frac{\mathbf{1998}}{\mathbf{2055}} * \mathbf{100\%} = \mathbf{97\%}\ \boldsymbol{Compaction}$$

Comment: Since the Compaction of 97% is less than the 98% requirement, the compaction was not adequate.

[3 Marks]

QUESTION 5 [20 Marks]

a) The table below shows Bill No. 4, the bill for Asphalt Pavement and Seals, of a particular project in Zambia. Based on the quantified items, **calculate the Total Amount of Bill No. 4 that has to be taken to the summary.**

BILL NO. 4: ASPHALT PAVEMENT AND SEALS						
ITEM N0.	PAYMENT REFERS	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT(ZMW)
	4000	SEALS				
	4100	PRIME COAT				
4.1	41.01	Prime coat				
		(c) MC-30 cut-back bitumen at 1.0Ltr/m²	litre	48,714.00	15.00	
	41.02	Aggregate for Blinding	sq.m	Rate only	300.00	
4.2	41.03	Extra over item 41.01 for applying the prime coat in areas accesable only to hand held equipment	litre	Rate only	15.00	
	4200	ASPHALT BASE AND SURFACING				
	42.02	Asphalt surfacing,40mm thick, hot-mix Asphalt Concrete				
		(a) continously graded, 0/12mm	sq.m	38,121.60	165.00	
	42.03	Apply SS60 tack coat at 0.5ltrs/sq.m	sq.m	Rate only	15.00	
	42.06	Trial Section. 30mm thick	sq.m	267.00	150.00	
	42.07	100mm Diameter Cores in Asphalt Paving	N0.	11.00	250.00	
		TOTAL CARRIED TO SUMMARY				-

ANS:

BILL NO. 4: ASPHALT PAVEMENT AND SEALS						
ITEM N0.	PAYMENT REFERS	DESCRIPTION	UNIT	QUANTITY	RATE	AMOUNT(ZMW)
	4000	SEALS				
	4100	PRIME COAT				
4.1	41.01	Prime coat				
		(c) MC-30 cut-back bitumen at 1.0Ltr/m²	litre	48,714.00	15.00	730710
	41.02	Aggregate for Blinding	sq.m	Rate only	300.00	
4.2	41.03	Extra over item 41.01 for applying the prime coat in areas accesable only to hand held equipment	litre	Rate only	15.00	
	4200	ASPHALT BASE AND SURFACING				
	42.02	Asphalt surfacing,40mm thick, hot-mix Asphalt Concrete				
		(a) continously graded, 0/12mm	sq.m	38,121.60	165.00	6290064
	42.03	Apply SS60 tack coat at 0.5ltrs/sq.m	sq.m	Rate only	15.00	
	42.06	Trial Section. 30mm thick	sq.m	267.00	150.00	40050
	42.07	100mm Diameter Cores in Asphalt Paving	N0.	11.00	250.00	2750
		TOTAL CARRIED TO SUMMARY				7063574 -

b) To select an asphalt binder for a specific location, the mean seven-day maximum pavement temperature is estimated at 55°C with a standard deviation of 2.5°C. The mean minimum pavement temperature is -9 °C with standard deviation of 1.5°C. What PG grade asphalt is needed at 98% reliability?

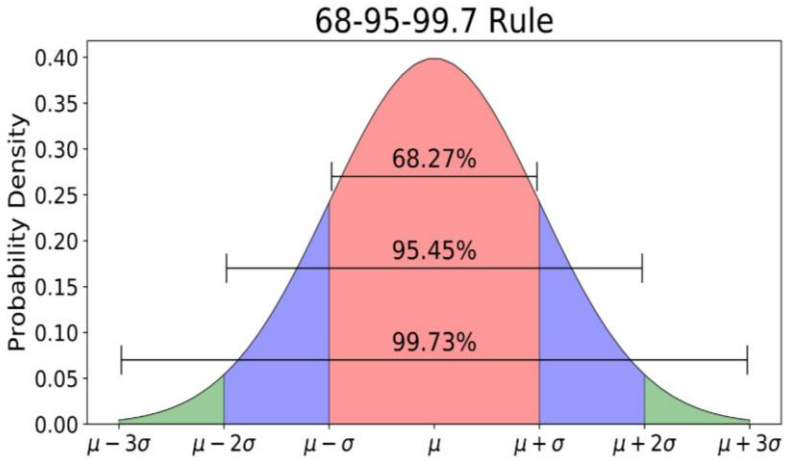
ANS:

At 98 % reliability: Min Temp/Max Temp = Mean∓2 ∗ ***Standard Deviation***

High-temperature grade ≥ 55 + (2*1.5) ≥ 58°C

Low-temperature grade ≤ -9 - (2*1.5) ≤ -12°C

Summary the table provided, the closest standard PG asphalt binder grade that satisfies the two temperature grades is PG 58–16.



Binder Grade Specifications

High Temperature Grades (°C)	Low Temperature Grades (°C)
PG 46	−34, −40, −46
PG 52	−10, −16, −22, −28, −34, −40, −46
PG 58	−16, −22, −28, −34, −40
PG 64	−10, −16, −22, −28, −34, −40
PG 70	−10, −16, −22, −28, −34, −40
PG 76	−10, −16, −22, −28, −34
PG 82	−10, −16, −22, −28, −34

[10 + 10 Marks]