Name: _____ ID: _____ 18/12/2023

**BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI, PILANI**

**First Semester 2023 – 2024**

**CE G534 (Pavement Material Characterization) Comprehensive (Closed Book)**

**Instructor In-Charge : Dr. Nishant Bhargava**

**Max. Marks : 70** **Duration : 3 hours**

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1. Explain with the help of graphical representations, the two factors affecting the output of a hot mix plant. **[4]**
2. Draw the three-phase diagram for bituminous mixture. Define volume of air voids in a compacted mixture mathematically. Using the volumetric relation, derive the formula for percentage air voids, in terms of specific gravity. **[4]**
3. What is a tender mix? List at least three aggregate, bitumen and construction issues causing mix to become tender. **[6]**
4. What are the overall objectives of mix design? Draw a flow chart representing the mix design methodology adopted in India. **[6]**
5. Use the gradation provided below to explain the step-by-step procedure for aggregate blending using Roth-Futch Method. Determine the trial proportion for 20 mm, 10 mm and S/D. **[10]**

| Sieve Size, mm | Lower Limit | Upper Limit | Cumulative % passing | | |
|---|---|---|---|---|---|
| | | | 20 mm | 10 mm | S/D |
| 19 | 100 | 100 | 100.0 | 100.0 | 100.0 |
| 13.2 | 90 | 100 | 80.0 | 100.0 | 100.0 |
| 9.5 | 70 | 88 | 43.8 | 80.0 | 100.0 |
| 4.75 | 53 | 71 | 18.0 | 50.0 | 100.0 |
| 2.36 | 42 | 58 | 0.0 | 28.5 | 100.0 |
| 1.18 | 34 | 48 | 0.0 | 30.0 | 76.0 |
| 0.6 | 26 | 38 | 0.0 | 23.0 | 60.0 |
| 0.3 | 18 | 28 | 0.0 | 11.0 | 48.0 |
| 0.15 | 12 | 20 | 0.0 | 5.0 | 35.7 |
| 0.075 | 4 | 10 | 0.0 | 0.0 | 17.5 |

6. The results of the experimental investigations conducted for Marshall Mix Design are provided in the table below. The value of $G_{mm}$ at 5.5% bitumen content is 2.533. Bulk specific gravity of aggregates and bitumen is 2.685 and 1.020, respectively.

| Bitumen Content, % by weight of mix | Weight of specimen in air (dry condition), g | Weight of specimen in water, g | Weight of specimen in air (SSD condition), g | Stability, kN | Flow, mm |
|---|---|---|---|---|---|
| 5 | 1250 | 735.0 | 1253 | 12 | 2.5 |
| 5.5 | 1250 | 736.5 | 1252 | 13.5 | 3 |
| 6 | 1250 | 736.0 | 1251 | 13 | 3.8 |
| 6.5 | 1250 | 735.5 | 1251 | 11 | 5.5 |
| 7 | 1250 | 733.0 | 1250.5 | 7.5 | 8 |

Using the data, determine bulk specific gravity of mix, air voids content, void in mineral aggregates and voids filled with bitumen for each bitumen content. Compute the optimum bitumen content (OBC) and all the volumetric and strength properties at OBC. **[20]**

7. Determine the mix proportioning for M50 grade concrete. **[20]**

Stipulations for proportioning are:

a. Grade designation = M 50
b. Type of cement = OPC 53 grade conforming to IS:269
c. Maximum nominal size of aggregate = 9.5 mm
d. Minimum cement content = 360 kg/m$^3$
e. Maximum water-cement ratio = 0.40
f. Workability = 25 mm (slump)
g. Degree of supervision = Good
h. Type of aggregate = Crushed angular aggregate
i. Maximum cement content = 450 kg/m$^3$
j. Chemical admixture (Superplasticizer) = 1.5% by mass of cement (Water content reduction = 25%)
k. Specific gravity of cement = 3.10
l. Specific gravity of coarse aggregate = 2.65
m. Specific gravity of fine aggregate = 2.75
n. Specific gravity of superplasticizer = 1.2

Assume that fine aggregates conform to grading Zone I as per IS-383 and the combined gradation meets the IRC specification limits.

| Nominal Maximum Size of Aggregate, mm | Entrapped Air, as Percentage of Volume of Concrete |
|---|---|
| 9.5 | 1.5 |
| 19 | 1.0 |
| 26.5 | 0.9 |
| 31.5 | 0.8 |

| S. No. | Grade of concrete | Assumed Standard Deviation N/mm² |
|---|---|---|
| 1 | M 30 | 5.0 |
| 2 | M 35 | |
| 3 | M 40 | |
| 4 | M 45 | |
| 5 | M 50 | |
| 6 | M 55 | |
| 7 | M 60 | |
| 8 | M 65 | 6.0 |
| 9 | M 70 | |
| 10 | M 75 | |
| 11 | M 80 | |

Table 4 Value of X

| Sl. No. | Grade of concrete | Value of X N/mm² |
|---|---|---|
| 1 | M 30 | 5.0 |
| 2 | M 35 | |
| 3 | M 40 | 6.5 |
| 4 | M 45 | |
| 5 | M 50 | |
| 6 | M 55 | |
| 7 | M 60 | |
| 8 | M 65 & above | 8.0 |

| Sl. No. | Compressive Strength at 28-Day N/mm² | Approximate Water- Cement/ Cementitious Materials Ratio | |
|---|---|---|---|
| | | OPC-43 Grade | OPC-53 Grade |
| 1 | 32 | 0.47 | 0.50 |
| 2 | 37 | 0.43 | 0.48 |
| 3 | 42 | 0.39 | 0.45 |
| 4 | 48 | 0.36 | 0.42 |
| 5 | 53 | 0.33 | 0.38 |
| 6 | 58 | 0.30 | 0.35 |
| 7 | 65 | 0.27 | 0.32 |
| 8 | 68 | 0.24 | 0.29 |

| Nominal Maximum Size of Aggregate mm | Volume of Coarse Aggregate Per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate | | |
|---|---|---|---|
| | Zone III | Zone II | Zone I |
| 9.5 | 0.48 | 0.46 | 0.44 |
| 19 | 0.64 | 0.62 | 0.60 |
| 26.5 | 0.69 | 0.67 | 0.65 |
| 31.5 | 0.68 | 0.65 | 0.63 |

| Nominal Maximum Size of Aggregate mm | Suggestive Water Content kg/m³ |
|---|---|
| 9.5 | 208 |
| 19 | 186 |
| 31.5 | 165 |