CEE (22)

M. Sc. Engg. (CE) 12 May, 2023, Friday, (10 AM–1 PM)

# ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)
## DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

TERM : FINAL EXAMINATION SUMMER SEMESTER: 2021-2022
COURSE NO. : CEE 6109 TIME : 3 Hours
COURSE TITLE: Advance Concrete Technology FULL MARKS: 150

**There are 8 (EIGHT) questions. Answer ALL questions. Programmable calculators are not allowed. Do not write on this question paper. The figures in the right margin indicate full marks. The Symbols have their usual meaning.**

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**1** Concrete mix design is required for a commercial building project based on the following data: 30

Volume ratio of sand to total aggregate = 0.40
Cement Type: CEM Type I
Air Content = 1 % (air-entraining admixture is not used)
Specific gravity of cement = 3.1 (for CEM Type I cement)
Specific gravity of sand (SSD) = 2.60
Specific gravity of coarse aggregate (SSD) = 2.70
Design compressive strength (28 days) = 5000 psi
Minimum required slump = 175 mm
Maximum aggregate size = ¾ inch. Aggregate type = Stone chips
Dosage of superplasticizer = 8 ml/kg of cement if W/C is less than 0.45.
FM of Coarse Aggregate = 6.6, FM for Fine Aggregate = 2.6

The following graphs are provided :

- Variation of compressive strength (28 days) with W/C (**Fig. 1**),
- Variation of cement content with compressive strength (28 days) for different aggregate size and slump value (**Fig. 2**).

(i) Calculate the unit contents.
(ii) Prepare a mixture proportion table. Typical form of mixture proportion table is attached.
(iii) Calculate the volume ratio of the mix. Assume unit weights of cement, sand (SSD), and coarse aggregate (SSD) with void are 1300 kg/m$^3$, 1350 kg/m$^3$ and 1450 kg/m$^3$, respectively.
(iv) Calculate the cost of concrete for one cubic meter. Assume the cost of 1 bag cement is Tk. 400, cost of 1 cft sand is Tk. 30, and cost of 1 cft stone chips is Tk. 130.
(v) Assume 3% surplus water in sand over SSD condition and the amount of bulking of sand is 10%. What adjustments are necessary in the mix design?
(vi) Calculate the compaction factor of the mix.
(vii) If s/a is changed to 0.48, what changes will occur in fresh and hardened

properties of concrete? (no calculation is required)

(viii) If CEM Type II B-M cement is used instead of CEM Type I cement, what changes will occur in fresh and hardened properties of concrete at the early stage and after a long term?

(ix) If specific gravity of coarse aggregate changes from 2.7 to 2.5; what will be the unit content of the coarse aggregate?

(x) Write the steps for the mix design of concrete as per ACI 211.

**2** The specified FM of fine aggregate of a bridge project is 2.6. The sieve analysis data of a fine aggregate sample collected for the bridge project are summarized below: 20

| ASTM Sieve | Materials Retained (g) |
|---|---|
| 3 inch | 0 |
| 1.5 inch | 0 |
| 1.0 inch | 0 |
| ¾ inch | 0 |
| ½ inch | 0 |
| 3/8 inch | 0 |
| #4 | 40 |
| #8 | 70 |
| #12 | 60 |
| #16 | 30 |
| #30 | 50 |
| #40 | 0 |
| #50 | 0 |
| #100 | 40 |
| #200 | 20 |
| Pan | 90 |

(i) Calculate the FM of the sample.

(ii) Draw the grading curve of the sample.

(iii) Make a brief discussion on the FM, sieve analysis data, and grading curve.

(iv) What measures are necessary to improve the grading of the sand sample?

(v) In what ratio the sand sample is to be mixed with another sand sample of FM 2.0 to obtain the required fineness modulus of 2.6?

Sieve openings for ASTM sieves are provided in **Table 1**.

3 The following data (carbonation depth with time) were recorded for a structure in Dhaka City: 20

| Time (Year) | Carbonation Depth (mm) |
|---|---|
| 0 | 0 |
| 5 | 13 |
| 10 | 18 |
| 15 | 21 |
| 20 | 25 |
| 30 | 30 |
| 40 | 35 |
| 50 | 40 |

(i) Draw the depth of carbonation versus square root of time curve in a plain graph paper.
(ii) Determine the carbonation coefficient of concrete.
(iii) If cover concrete depth = 25 mm, make a brief discussion on the status of corrosion of steel bars inside concrete after 15 years.
(iv) Determine the time necessary to break down the passivation film over the steel bars inside concrete.
(v) "The exposure condition of Bangladesh is favorable for carbonation of concrete" – Discuss briefly.
(vi) How will you reduce the carbonation coefficient of concrete during planning and construction of a structure in Dhaka City?

4 Concrete samples were collected to determine chloride profile in concrete after 15 years of exposure in seawater. Mixture proportion of concrete and data associated with the chloride profile are given in **Table 2** and **Table 3**. 30

i) Draw chloride profiles (for chloride concentration in $kg/m^3$ and also for chloride concentration in % of cement mass).
ii) Write the steps for calculation of the apparent diffusion coefficient.
iii) Write the steps for calculation of time of initiation of chloride induced corrosion.

If the cover concrete depth is 40 mm, briefly explain the status of chloride induced corrosion of steel bars inside concrete after 15 years of exposure.

5 If 110 g of water is added with 200 g of cement, calculate the following for 0%, 50%, and 100% of hydration: 20

(i) Amount of water chemically bonded,
(ii) Amount of water in gel pores of cement,
(iii) Amount of free water in capillary,
(iv) Volume of empty capillary,
(v) Volume of cement gel, and

(vi) Gel-to-space ratio.

Make a brief discussion on the results.

**6(a)** Briefly explain the effect of W/C on compressive strength, permeability, and durability of concrete. 5

**(b)** "Concrete industries pollute our environment significantly" – Justify. Explain the countermeasures that can be taken to reduce this pollution. 5

**7(a)** Discuss the cathodic protection of steel from corrosion in marine environment by (i) discrete anode system, and (ii) impressed current. 5

**(b)** Write the name of the materials that are recommended to be used in cement in addition to clinker and gypsum as per **BDS EN 197-1 2003**. Also, discuss the function of these materials in cement. 5

**8(a)** "Durability design of concrete structures and recycling of concrete are two key factors related to sustainability of concrete construction works" – Explain. 5

**(b)** Write short notes on (i) high performance concrete, (ii) lightweight concrete, and (iv) self-compacting concrete. 5

**Table** | Traditional American and British Sieve Sizes

| *Aperture mm or μm* | *Approximate Imperial equivalent in.* | *Previous designation of nearest size* | |
|---|---|---|---|
| | | *BS* | *ASTM* |
| 125 mm | 5 | — | 5 in. |
| 106 mm | 4.24 | 4 in. | 4.24 in. |
| 90 mm | 3.5 | $3\frac{1}{2}$ in. | $3\frac{1}{2}$ in. |
| 75 mm | 3 | 3 in. | 3 in. |
| 63 mm | 2.5 | $2\frac{1}{2}$ in. | $2\frac{1}{2}$ in. |
| 53 mm | 2.12 | 2 in. | 2.12 |
| 45 mm | 1.75 | $1\frac{3}{4}$ in. | $1\frac{3}{4}$ in. |
| 37.5 mm | 1.50 | $1\frac{1}{2}$ in. | $1\frac{1}{2}$ in. |
| 31.5 mm | 1.25 | $1\frac{1}{4}$ in. | $1\frac{1}{4}$ in. |
| 26.5 mm | 1.06 | 1 in. | 1.06 |
| 22.4 mm | 0.875 | $\frac{7}{8}$ in. | $\frac{7}{8}$ in. |
| 19.0 mm | 0.750 | $\frac{3}{4}$ in. | $\frac{3}{4}$ in. |
| 16.0 mm | 0.625 | $\frac{5}{8}$ in. | $\frac{5}{8}$ in. |
| 13.2 mm | 0.530 | $\frac{1}{2}$ in. | 0.530 in. |
| 11.2 mm | 0.438 | — | $\frac{7}{16}$ in. |
| 9.5 mm | 0.375 | $\frac{3}{8}$ in. | $\frac{3}{8}$ in. |
| 8.0 mm | 0.312 | $\frac{5}{16}$ in. | $\frac{5}{16}$ in. |
| 6.7 mm | 0.265 | $\frac{1}{4}$ in. | 0.265 in. |
| 5.6 mm | 0.223 | — | No. $3\frac{1}{2}$ |
| 4.75 mm | 0.187 | $\frac{3}{16}$ in. | No. 4 |
| 4.00 mm | 0.157 | — | No. 5 |
| 3.35 mm | 0.132 | No. 5 | No. 6 |
| 2.80 mm | 0.111 | No. 6 | No. 7 |
| 2.36 mm | 0.0937 | No. 7 | No. 8 |
| 2.00 mm | 0.0787 | No. 8 | No. 10 |
| 1.70 mm | 0.0661 | No. 10 | No. 12 |
| 1.40 mm | 0.0555 | No. 12 | No. 14 |
| 1.18 mm | 0.0469 | No. 14 | No. 16 |
| 1.00 mm | 0.0394 | No. 16 | No. 18 |
| 850 μm | 0.0331 | No. 18 | No. 20 |
| 710 μm | 0.0278 | No. 22 | No. 25 |
| 600 μm | 0.0234 | No. 25 | No. 30 |
| 500 μm | 0.0197 | No. 30 | No. 35 |
| 425 μm | 0.0165 | No. 36 | No. 40 |
| 355 μm | 0.0139 | No. 44 | No. 45 |
| 300 μm | 0.0117 | No. 52 | No. 50 |
| 250 μm | 0.0098 | No. 60 | No. 60 |
| 212 μm | 0.0083 | No. 72 | No. 70 |
| 180 μm | 0.0070 | No. 85 | No. 80 |
| 150 μm | 0.0059 | No. 100 | No. 100 |
| 125 μm | 0.0049 | No. 120 | No. 120 |
| 106 μm | 0.0041 | No. 150 | No. 140 |
| 90 μm | 0.0035 | No. 170 | No. 170 |
| 75 μm | 0.0029 | No. 200 | No. 200 |
| 63 μm | 0.0025 | No. 240 | No. 230 |
| 53 μm | 0.0021 | No. 300 | No. 270 |
| 45 μm | 0.0017 | No. 350 | No. 325 |
| 38 μm | 0.0015 | — | No. 400 |
| 32 μm | 0.0012 | — | No. 450 |

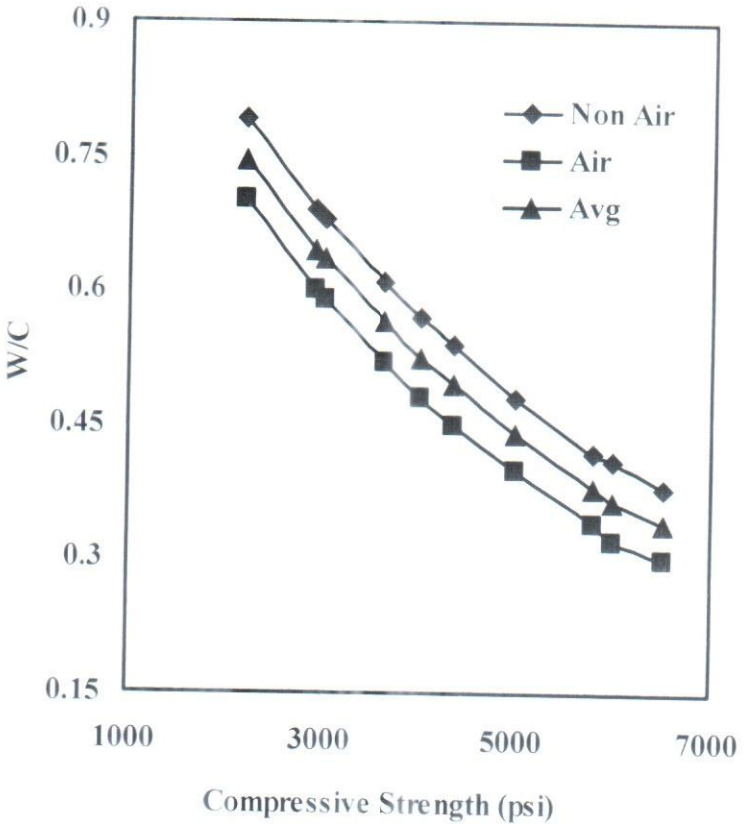


Fig. 1 W/C versus Compressive Strength (aggregate type = stone chips)

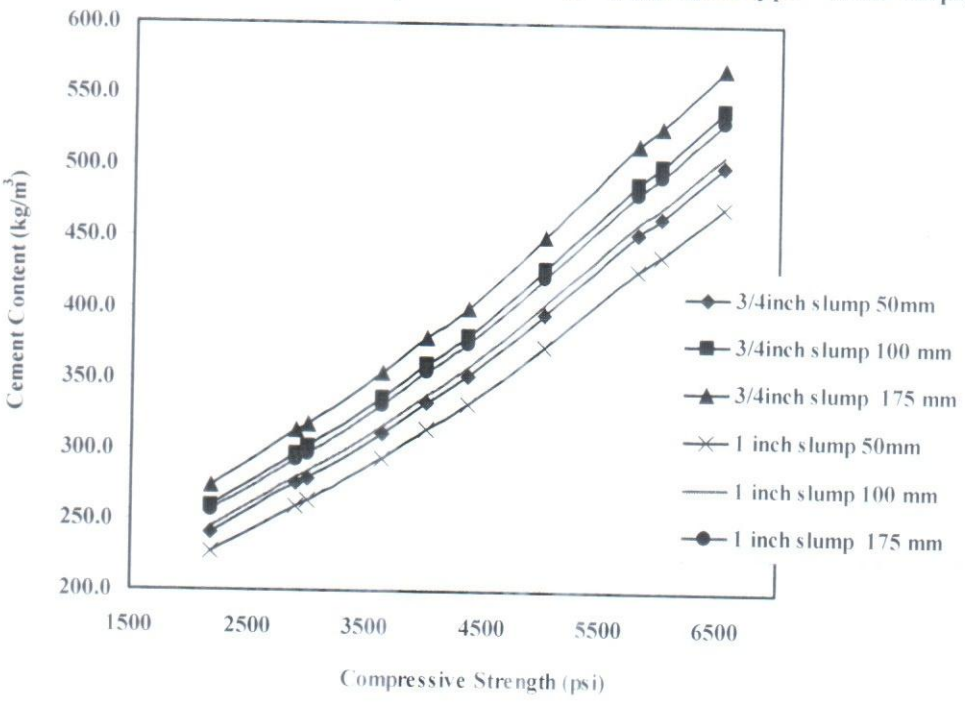


Fig. 2 Cement Content versus Compressive Strength (aggregate type = stone chips)

**Table 2 - Mixture Proportion of Concrete**

| Max. Aggregate Size (mm) | s/a (%) | W/C (%) | Air (%) | Slump (cm) | Unit Contents ($kg/m^3$) | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Cement | Water | Sand | Coarse Aggregate |
| 20 | 40 | 50 | 1~2 | 6~10 | 375 | 150 | 700 | 1100 |

**Table 3 - Chloride Analysis Data**

| Average Sample Depth (mm) | Amount of Concrete Powdered Sample (g) | Amount of Water Used to Dissolve Chloride into Water (ml) | Volume of Filtered Water Used for Titration (g) | Volume of $AgNO_3$ Solution Used for Titration (ml) |
|---|---|---|---|---|
| 2.5 | 10 | 100 | 2 | 6 |
| 10 | 10 | 100 | 4 | 5 |
| 20 | 10 | 100 | 6 | 4 |
| 40 | 20 | 100 | 9 | 3 |
| 50 | 40 | 100 | 20 | 2 |

Concentration of $AgNO_3$ solution is N/200.