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CVG 2141 – CIVIL ENGINEERING MATERIALS

Mid Term Examination (Closed book) **Oct. 27th, 2009**
Dr. Adel Bugaldian **Time: 1 hour & 20 minutes**

QUESTION 1: (25 marks)

(a) A cylindrical rod with a length of 380 mm and a diameter of 10 mm is to be subjected to a tensile load of 30 kN. The rod must not experience plastic deformation or an increase in length of more than 0.9 mm when the load is applied. Which of the four materials listed below are possible candidates? Justify your answer.

Material	Elastic Modulus (GPa)	Yield Strength (MPa)
Copper	110	248
Aluminum alloy	70	225
Steel	200	448
Brass alloy	101	345

SOLUTION:

In choosing the material from the list provided, there are two requirements that must be fulfilled:

1. The rod must not experience plastic deformation, i.e., it must not yield. Upon the application of a tensile load of 30 kN, the stress in the rod is:
   $$\sigma = \frac{p}{A} = \frac{30\times 10^3}{\pi \times \frac{10^2}{4}} = \underline{\mathbf{382\ MPa}}$$
   The only material that does not yield at that stress level is steel. However, one must still ensure that the second requirement is met.

2. The rod must not experience an increase in length of more than 0.9 mm when the load is applied. The strain and change of deformation corresponding to a stress of 382 MPa are:
   $$\sigma = E\,\varepsilon \Rightarrow \varepsilon = \frac{\sigma}{E} = \frac{382}{200\times 10^3} = \underline{\mathbf{1.91x10^{-3}}}$$

$$\varepsilon = \frac{\Delta L}{L} \Rightarrow \Delta L = \varepsilon \times L = 1.91 \times 10^{-3} \times 380 = \underline{\mathbf{0.73\ mm}}$$

A rod made out of steel indeed does not deform more than 0.9 mm when subjected to the tensile load of 30 kN. Steel is therefore the only material to fulfill both requirements.

(b) A brass alloy has a yield strength of 280 MPa, a tensile strength of 390 MPa, and an elastic modulus of 105 GPa. A cylindrical specimen of this alloy, 12.7 mm in diameter and 250 mm long, is stressed in tension and found to elongate 7.6 mm. Calculate the magnitude of the load that is necessary to produce this change in length.

SOLUTION:

$$\varepsilon = \frac{\Delta L}{L} = \frac{7.6}{250} = 0.0304 \text{ or } 3.04\%$$

$$\sigma = E\,\varepsilon = 105 \times 10^3 \times 0.0304 = 3192 >> \sigma_y$$

The stress calculated using Hooke's law is much higher than the yield strength. This means that the material is already experiencing plastic deformation, and we cannot use the theory of elasticity to calculate the load necessary to produce such deformation.

QUESTION 2: (25 marks)

Using the information given, determine the proportions of cement, water, fine aggregate, and coarse aggregate for a concrete subjected to a mild sulphate environment and exposed to de-icing chemicals. The concrete is to be used in an underground parking slab on grade and the 28 day specified compressive strength is to be 20 MPa. The maximum aggregate size is 14 mm, the dry rodded density of coarse aggregate is 1600 kg/m^3, the specific gravity of both coarse and fine aggregates is 2.65, the absorption capacity of the fine aggregate is 0.7%, and the absorption capacity of the coarse aggregate is 0.5%. All aggregates are saturated surface dry.

Cement: Type MS
Relative density = 3.15

Sieve analysis of the fine aggregate is as follows:

Sieve (mm)	5	2.5	1.75	0.630	0.315	0.160
percentage of individual fraction passing	97	87	82	82	75	82

SOLUTION:

1. Fineness modulus

The fineness modulus of the fine aggregate is calculated as follows:

Sieve (mm)	5	2.5	1.25	0.630	0.315	0.160
Percentage of individual fraction passing	97	87	82	82	75	82
Percentage of individual fraction retained	3	13	18	18	25	18
Cumulative percentage of individual fraction retained	3	16	34	52	77	95
						277

$$\text{FM} = \frac{277}{100} = \underline{2.77}$$

2. Slump

- For an underground parking slab on grade, the maximum slump that is allowed is 75 mm (see Table 9-6.)

3. Strength

- From Tables 8-2 and 9-1, the exposure class for an underground parking slab on grade is C-4 (minimum 28 day compressive strength of 25 MPa, $w/c \leq 0.55$, air content category 2). Since the concrete is also to be exposed to a moderate sulphate environment, Table 9-2 identifies the level of exposure to sulphates as S-3 (minimum 56 day compressive strength of 30 MPa, $w/c \leq 0.50$, air entrainment not required).
- According to Table 9-1, the minimum strength requirement for a concrete in C-4 exposure condition is 25 MPa. Since this minimum strength requirement is greater than what it was specified, the value used for f'_c becomes now 25 MPa.
- Since there is no statistical data available on previous mixes, the average strength required for proportioning is (see Table 9-11): $f'_{cr} = f'_c + 8.5 = \underline{33.5 \text{ MPa}}$

4. Water-to-cementing materials ratio

- From a durability requirement, the maximum *w/c* allowed for a concrete exposed to a C-4 environment is 0.55 (see Table 9-1), and the maximum *w/c* allowed for a concrete exposed to an S-3 environment is 0.50 (see Table 9-2). Therefore, the value of 0.50 governs from a durability point of view.
- From a strength requirement, the recommended *w/c* for a concrete with f'_{cr} of 33.5 MPa and air-entrained (category 2) is 0.41 (this value is interpolated from those in Table 9-3). Since the lower *w/c* governs, the mix must be designed for $\underline{w/c = 0.41}$.

5. Air content

- From Table 9-1, the category for air content for a C-4 exposure condition is Category 2.
- For a 14-mm nominal maximum aggregate size and an air content category 2, the recommended range for entrained air is 4-7% (see Table 9-5). The mix proportions will therefore be designed for the maximum allowable of 7%.

6. Amount of mixing water

- For a 14-mm nominal maximum aggregate size and a slump of 75 mm, the recommended amount of mixing water for an air-entrained concrete is 193 kg/m^3 of concrete (see Table 9-5).

7. Amount of cement

- $\text{mass of cement} = \dfrac{\text{mass of water}}{w/c} = \dfrac{193}{0.41} = \underline{471\ \text{kg/m}^3\ \text{of concrete}}$
- The requirement that concrete to be used in flatwork should contain at least 350 kg/m^3 of cementing materials for a 14-mm nominal maximum size of aggregate is satisfied by the previous value (see Table 9-7).

8. Amount of coarse aggregates

- The bulk volume of dry-rodded coarse aggregate per unit volume of concrete for a 14-mm nominal maximum aggregate size and a fineness modulus of 2.77 is 0.55 (interpolated from values of Table 9-4).
- $\text{mass of coarse agg.} = 1600 \times 0.55 = \underline{880\ \text{kg/m}^3\ \text{of concrete}}$ (oven-dry mass)

9. Determine the amount of fine aggregates

- Let's calculate first the absolute volume of the known ingredients:

$$\text{volume of water} = \frac{193}{1.0 \times 1000} = 0.193\ \text{m}^3$$

$$\text{volume of cement} = \frac{471}{3.15 \times 1000} = 0.149\ \text{m}^3$$

$$\text{volume of coarse agg.} = \frac{880}{2.65 \times 1000} = 0.332\ \text{m}^3$$

$$\text{volume of air} = 7\% = 0.07\ \text{m}^3$$

Total volume of known ingredients 0.744 m^3

- $\text{volume of fine agg.} = 1.0 - 0.744 = 0.256\ \text{m}^3$
- $\text{mass of fine agg.} = 0.256 \times 2.65 \times 1000 = \underline{678\ \text{kg/m}^3\ \text{of concrete}}$ (oven-dry mass)

10. Adjust for aggregate moisture

- So far the mixture has the following proportions:

Water	193 kg
Cement	471 kg
Coarse agg. (OD)	880 kg
Fine agg. (OD)	678 kg

- Since the aggregates are in the SSD condition and the above quantities are based on oven-dry conditions, their weight must be adjusted for the presence of water in them.

mass of coarse agg. (0.5% MC) $= 880 \times 1.005 =$ 884 kg/m^3 of concrete

mass of fine agg. (0.7% MC) $= 678 \times 1.007 = 683$ kg/m^3 of concrete

The revised batch quantities for 1 m^3 of concrete are:

Water	193 kg
Cement	471 kg
Coarse agg. (0.5%)	884 kg
Fine agg. (0.7%)	683 kg
	2231 kg

The density of the concrete (2231 kg/m^3) is within normal range.

QUESTION 3: (25 MARKS)

1. An aggregate sample of 1000 g has the following properties: oven-dried mass = 970 g and saturated surface dry mass = 1007 g. What is the effective absorption capacity of the aggregate?

(a) 3.1%
(b) 3.8%
(c) 0.7%
(d) 2.5%
(e) None of the above

An aggregate sample of 830 g has the following properties: oven-dried mass = 821 g, saturated surface dry mass = 840 g, and submerged mass = 522 g. Based on this information answer questions 2 and 3.

2. What is the moisture condition of the aggregate?

(a) Air dry
(b) Saturated surface dry
(c) Wet
(d) None of the above

3. What is the absorption of the aggregate?

(a) 2.26%
(b) 2.31%
(c) 3.8%
(d) None of the above

4. What type of Portland cement is often used to produce high strength at early ages?
   (a) Type 20 (b) Type 30 (c) Type 40
   (d) Type 50 (d) None of the above

5. What component occupies the highest proportion in a unit volume of concrete?
   (a) Cement (b) Air
   (c) Water (d) None of the above

6. Hydration is referred as the chemical reaction between:
   (a) C_3S and water (b) C_2S and water
   (c) C_3A and water (d) all of the above

7. Segregation occurs in:
   (a) Very wet mixes (b) Very dry mixes
   (c) Mixes with a great amount of fine particles (d) None of the above

8. Bleeding is reduced by:
   (a) Increasing the fineness of the cement (b) Decreasing the w/c
   (c) Using air-entraining admixtures (d) All of the above

9. In which of the cases listed would you most likely use a set retarding admixture in concrete?
   (a) To increase productivity (b) In cold weather (c) In hot weather
   (d) To open a concrete pavement early for service (e) None of the above

10. Which of the following distresses in concrete are not due to reinforcement corrosion?
    (a) Longitudinal cracking (b) Map cracking
    (c) Spalling (d) Delamination

11. Alkali-aggregate reaction occurs in concrete structures that:
    (a) Have low-alkali cement (b) Are dry
    (c) Have non-reactive aggregates (d) None of the above

12. Durable concrete is achieved by:
    (a) Decreasing the w/c (b) Using mineral admixtures
    (c) Promoting proper curing (d) All of the above