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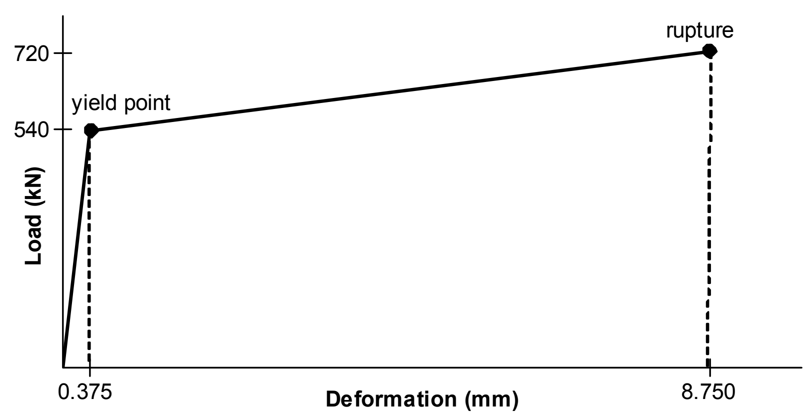
CVG 2141 – CIVIL ENGINEERING MATERIALS

Mid Term Examination (Closed book) **Oct. 25th, 2005**
Dr. B. Martín-Pérez Time: **1 hour & 20 minutes**

QUESTION 1: (25 marks)

A tension test on a specimen made of an elastoplastic material and loaded along its long axis produced the following load-deformation curve. Knowing that the specimen has dimensions of 30 mm × 30 mm × 300 mm, and that deformation was measured using an extensometer with a 125-mm gauge length, estimate the following:



(a) Yield stress

$$\sigma_y = \frac{P_y}{A} = \frac{540 \times 10^3}{30 \times 30} = 600 \text{ MPa}$$

(b) Rupture stress

$$\sigma_f = \frac{P_f}{A} = \frac{720 \times 10^3}{30 \times 30} = 800 \text{ MPa}$$

(c) Modulus of elasticity

$$\varepsilon_y = \frac{\Delta L}{L} = \frac{0.375}{125} = 0.3\%$$

$$E = \frac{\sigma_y}{\varepsilon_y} = \frac{600}{0.003} = 200 \text{ GPa}$$

(d) Modulus of resilience

$$u_r = \frac{1}{2}\sigma_y \varepsilon_y = \frac{600 \times 0.003}{2} = 0.9 \text{ MPa}$$

(e) % elongation of the specimen at rupture

$$\varepsilon_f = \frac{\Delta L}{L} = \frac{8.750}{125} = 7\%$$

(f) If a bar made out of this material is subjected to a tensile load of 600 kN, what would be its minimum cross-sectional area so that the material does not yield under the applied load?;

$$\sigma = \frac{P}{A} = \frac{600 \times 10^3}{A} \le \sigma_y$$

$$\therefore \quad A_{\text{min}} = \frac{600 \times 10^3}{\sigma_y} = \frac{600 \times 10^3}{600} = 1000 \text{ mm}^2$$

(g) Would you classify this material as brittle or ductile? Explain your answer.

This material is ductile, since it undergoes large deformations before failing in tension. Note the strain at failure of 7% compared to the strain corresponding to yielding of 0.3%.

QUESTION 2: (25 marks)

Specify the mix proportions of a concrete to be used in reinforced foundation walls and footings subjected to severe sulphate attack and frequent freezing and thawing in saturated conditions. The 28-day average (not specified) compressive strength required is 35 MPa. The following materials are available:

Cement: Type 10
Relative density = 3.15

Coarse aggregate: 20-mm nominal maximum size
Oven-dry relative density = 2.70
Absorption capacity = 0.4%
Bulk density = 1600 kg/m^3
Coarse aggregate has a moisture content of 0.1%

Fine aggregate: Saturated-surface-dry relative density = 2.60
Absorption capacity = 0.8%
Fine aggregate has a moisture content of 1%

Air entrainer: Wood resin type, ASTM C 260. Recommended dosage is 6.3ml/1% air/100 kg cementing materials

Sieve analysis of the fine aggregate is as follows:

Sieve (mm)	5	2.5	1.25	0.630	0.315	0.160
Percentage of individual fraction passing	97	89	82	82	65	79

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 retained	3	11	18	18	35	21
Cumulative percentage of individual fraction retained	3	14	32	50	85	106
						290

$$FM = \frac{290}{100} = \underline{2.90}$$

2. Slump

- For reinforced foundation walls and footings, the maximum slump that is allowed is 75 mm (see Table 9-6.)

3. Strength

- As specified in the problem statement, the wall is to be exposed to severe sulphate attack and frequent freezing and thawing in a saturated condition. From Tables 8-2 and 9-2, the exposure classes for this environment are F-1 and S-2.
- According to Table 9-1, the minimum 28-day compressive strength is 30 MPa, the maximum *w/c* is 0.50, and the air content category is 1. According to Table 9-2, the minimum specified 56-day compressive strength is 32 MPa, the maximum *w/c* is 0.45, and the air content category is 2.
- Since the 28-day average compressive strength required of 35 MPa (as given in the problem statement) meets both strength requirements, f'_{cr} is 35 MPa.

4. Water-to-cementing materials ratio

- From a durability requirement, the maximum *w/c* allowed for a concrete exposed to an S-2 environment is 0.45 (see Table 9-2).
- From a strength requirement, the recommended *w/c* for a concrete with f'_{cr} of 35 MPa and entrained air (category 1) is 0.39 (Table 9-3). Since the lower *w/c* governs, the mix must be designed for *w/c* = 0.39.

5. Air content

- From Tables 9-1 and 9-2, the category for air content is the most restrictive, which is Category 1.
- For a 20-mm nominal maximum aggregate size and an air content category 1, the recommended range for entrained air is 5-8% (see Table 9-5). The mix proportions will therefore be designed for the maximum allowable of 8%.

6. Amount of mixing water

- For a 20-mm nominal maximum aggregate size and a slump of 75 mm, the recommended amount of mixing water for an air-entrained concrete is 184 kg/m^3 of concrete (see Table 9-5).

7. Amount of cement

- $$\text{mass of cement} = \frac{\text{mass of water}}{w/c} = \frac{184}{0.39} = \underline{472\ \text{kg/m}^3\ \text{of concrete}}$$

8. Amount of coarse aggregates

- The bulk volume of dry-rodded coarse aggregate per unit volume of concrete for a 20-mm nominal maximum aggregate size and a fineness modulus of 2.90 is 0.61 (see Table 9-4).
- mass of coarse agg. $= 1600 \times 0.61 =$ 976 kg/m^3 of concrete (oven-dry mass)

9. Determine the amount of air entrainer

- amount of air entrainer $= 6.3 \times 8 \times \dfrac{472}{100} =$ 238 ml or 238×10^{-6} m^3
- mass of air entrainer $= 238 \times 10^{-6} \times 1.0 \times 1000 =$ 0.238 kg/m^3 of concrete

10. Determine the amount of fine aggregates

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

$$\text{volume of water} = \frac{184}{1.0 \times 1000} = 0.184 \text{ m}^3$$

$$\text{volume of cement} = \frac{472}{3.15 \times 1000} = 0.150 \text{ m}^3$$

$$\text{volume of coarse agg.} = \frac{976}{2.70 \times 1000} = 0.361 \text{ m}^3$$

$$\text{volume of air} = 8\% = 0.08 \text{ m}^3$$

Total volume of known ingredients 0.775 m^3

- volume of fine agg. $= 1.0 - 0.775 = 0.225$ m^3
- mass of fine agg. $= 0.225 \times 2.60 \times 1000 =$ 585 kg/m^3 of concrete (SSD mass)

11. Adjust for aggregate moisture

- So far the mixture has the following proportions:

Water	184 kg
Cement	472 kg
Coarse agg. (OD)	976 kg
Fine agg. (SSD)	585 kg
Air entrainer	0.238 kg

- Since the amount of air entrainer is so small, it will not be considered to be part of the mixing water, and, therefore, the mixing water will not be adjusted accordingly.
- The fine aggregate is wet (i.e., the moisture content is greater than the absorption capacity), and since the above quantity is based on saturated-surface-dry conditions, its weight must be adjusted for the presence of surface moisture on it.

$$\text{mass of fine agg. (1\% MC)} = 585 \times (1.01 - 0.008) = \underline{586 \text{ kg/m}^3 \text{ of concrete}}$$

- The coarse aggregate is actually on the dry side (its moisture content is lower than its absorption capacity, i.e., 0.1% < 0.4%). The above quantity for the coarse aggregate is based on oven-dry conditions, thus its weight still has to be adjusted for the presence of some water in it.

$$\text{mass of coarse agg. (0.1\% MC)} = 976 \times 1.001 = \underline{977 \text{ kg/m}^3 \text{ of concrete}}$$

- The mixing water needs to be adjusted to account for both the water given away by the fine aggregates and that absorbed by the coarse aggregates.

$$\text{mass of water} = 184 + \underbrace{\left[976 \times \left(0.004 - 0.001\right)\right]}_{\text{moisture absorbed by coarse agg.}} - \underbrace{\left[585 \times \left(0.01 - 0.008\right)\right]}_{\text{moisture contributed by fine agg.}} = \underline{186 \text{ kg/m}^3 \text{ of concrete}}$$

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

Water	186 kg
Cement	472 kg
Coarse agg. (0.1%)	977 kg
Fine agg. (1%)	586 kg
Air entrainer	0.238 kg
	2221 kg

The density of the concrete (2221 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

2. 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

3. When does ettringite formation pose a problem in concrete?

   (a) When concrete is hardened (b) When concrete is fresh (c) Using Type 20 cement

   (d) Using Type 50 cement (e) None of the above

4. 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

5. With what cement hydration product does a pozzolan react with?

   (a) Calcium silicate hydrate (b) Calcium hydroxide (c) Ettringite

   (d) Gypsum (e) Tri-calcium aluminate

6. Why is the amount of $CaCl_2$ used as an accelerating admixture limited to 2% by weight of cement?

   (a) To prevent reinforcement corrosion (b) To prevent concrete from freezing

   (c) To delay early hardening (d) To permit early removal of the forms

   (d) None of the above

7. How do water-reducing admixtures function?

   (a) Causing cement particles to flocculate (b) Increasing C-S-H

   (c) Increasing the viscosity (d) Increasing the fluid volume in concrete

   (e) None of the above

8. How do air-entraining agents function?

   (a) Creating air bubbles by chemical reaction (b) Stabilizing air entrapped during mixing

   (c) Causing cement particles to flocculate (d) Plasticizing the concrete

   (e) None of the above

9. Which compound contributes to late strength development in concrete?

(a) C_3S (b) $Ca(OH)_2$ (c) C_2S

(d) Gypsum (e) C_3A

10. Which of the listed improvements in concrete properties can be attributed to the appropriate use of supplementary cementing materials?

(a) Improved long-term strength (b) Reduced permeability

(c) Increased resistance to sulphate-ion penetration (d) Reduced potential for corrosion

(e) All of the above