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CVG 2141 – CIVIL ENGINEERING MATERIALS

Mid Term Examination (Closed book) **Oct. 23rd, 2007**
Dr. Adel Bugaldian Time: **1 hour & 20 minutes**

QUESTION 1: (25 marks)

Using the information given, determine the proportions of cement, water, fine aggregate, and coarse aggregate for a concrete subjected to frequent freezing and thawing in a saturated condition. The concrete is to be used for a retaining wall in Ottawa and the specified 28-day compressive strength is 20 MPa. The maximum aggregate size is 20 mm, the dry rodded density of coarse aggregate is 1600 kg/m^3, the specific gravity of both coarse and fine aggregates is 2.60, the absorption capacity of the fine aggregate is 0.7%, and the absorption capacity of the coarse aggregate is 0.5%. The moisture content of the fine and coarse aggregates to be used is respectively 0.7% and 0.2%.

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 retained	2	10	15	20	29	21

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	2	10	15	20	29	21
Cumulative percentage of individual fraction retained	2	12	27	47	76	97
						261

$FM = \frac{261}{100} = 2.61$

2. Slump

- For a retaining wall, 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 frequent freezing and thawing in a saturated condition. From Table 8-2, the exposure class for this environment is F-1.
- 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. Since the minimum strength requirement is greater than what it was specified (20 MPa), the value used for f'_c becomes now 30 MPa.
- Since there is no statistical data available on previous mixes, the average strength required for proportioning is (see Table 9-11): $f_{cr}^{'} = f_c^{'} + 8.5 = 38.5 Mpa$

4. Water-to-cementing materials ratio

- From a durability requirement, the maximum *w/c* allowed for a concrete exposed to an F 1 environment is 0.50 (see Table 9-1).
- From a strength requirement, the recommended *w/c* for a concrete with f'_{cr} of 38.5 MPa and entrained air (category 1) is 0.35 (this value is interpolated from those in Table 9-3). Since the lower *w/c* governs, the mix must be designed for *w/c* = 0.35.

5. ***Air content***

- From Table 9-1, the category for air content for an F-1 exposure condition 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***

- Mass of cement = (mass of water)/(w / c) = $\frac{184}{0.35} = 526 kg/m^3$ 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 2.61 is 0.64 (see Table 9-4).
- mass of coarse agg.=1600×0.64=1024 kg/m^3 of concrete (oven-dry mass)

9. ***Determine the amount of fine aggregates***

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

Volume of water $= \frac{184}{1.0\times1000} = 0.184$ m^3

Volume of cement $= \frac{526}{3.15\times1000} = 0.167$ m^3

Volume of coarse agg. $= \frac{1024}{2.6\times1000} = 0.394$ m^3

Volume of air = 8% = 0.08 m^3

Total volume of know ingredients = 0.825 m^3

Volume of fine agg. = 1.0 - 0.825 = 0.175 m^3

Mass of fine agg.=0.175 × 2.60 x 1000 = 455 kg/m^3 of concrete (oven-dry mass)

10. ***Adjust for aggregate moisture***

- So far the mixture has the following proportions:

Water	184 kg
Cement	526 kg
Coarse agg. (dry)	1024 kg
Fine agg. (dry)	455 kg

- Since the fine aggregate is in the SSD condition (the moisture content is equal to the absorption capacity, i.e., 0.7%) and the above quantity is based on oven-dry conditions, its weight must be adjusted for the presence of water in it.
  Mass of fine agg. (0.7% MC) = 455×1.007=458 kg/m^3 of concrete

- The coarse aggregate is actually on the dry side (its moisture content is lower than its absorption capacity, i.e., 0.2% < 0.5%). 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. However, it will also absorb water until its moisture content reaches that corresponding to SSD conditions. It is for this reason that the mixing water needs to be increased to compensate for the loss of water absorbed by the coarse aggregates.

  Mass of coarse agg. (0.2% MC) =1024×1.002=1026 kg/m^3 of concrete
  Mass of water=184+(1024×0.003)=187 kg/m^3 of concrete

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

Water	187 kg
Cement	526 kg
Coarse agg. (dry)	1026 kg
Fine agg. (dry)	458 kg
	2197 kg

The density of the concrete (2197 kg/m^3) is within normal range.

QUESTION 2: (25 marks)

(a) A tensile load of 220 kN is applied to a round metal bar with a diameter of 16 mm and a gage length of 50 mm. Under this load the bar elastically deforms so that the gage length increases to 50.1686 mm and the diameter decreases to 15.9875 mm. Determine the modulus of elasticity and Poisson's ratio for this metal.

SOLUTION:

P = 220 kN D_o = 16 mm L_o = 50 mm L = 50.1686 mm D = 15.9875 mm **E = ? ν = ?**

$A = 201.06 mm^2$ $\sigma = \frac{P}{A} = \frac{220 \times 10^3}{201.06} = 1094 MPa = 1.094 GPa$

$$\varepsilon_a = \frac{\Delta L}{L} = \frac{(50.1686 - 50)}{50} = 0.00337$$

$$E = \frac{\sigma}{\varepsilon_a} = \frac{1094}{0.00337} = 324630 MPa = 324.630 GPa$$

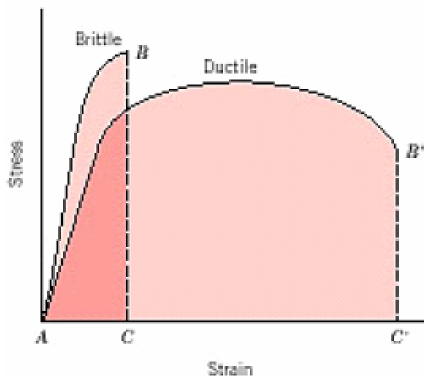
$$\varepsilon_l = \text{change in diameter / diameter} = \frac{15.9875 - 16}{16} = -0.00078$$

$$\nu = \frac{-\varepsilon_l}{\varepsilon_a} = \frac{0.00078}{0.00337} = 0.23$$

(b) Write a short description (3-5 lines) on each of the following. Use a sketch if appropriate.

(1) Brittle and ductile materials.

Brittle materials exhibit little or no yielding at all before failure. On the other hand, ductile materials undergo large strains (well into the plastic range) before failure.



(2) Why gypsum is added in the manufacture of Portland cement.

Gypsum is added to the manufacture of cement to retard the setting time of cement (i.e., to prevent flash set) by controlling the hydration of C_3A. The reaction rate of C_3A with water is very high; however, the resulting hydration products do not contribute to the strength development of the cement paste. The presence of gypsum (a source of sulphate ions) slows down the early rate of hydration of C_3A.

(3) Use of superplasticizers.

Superplasticizers, also called high-range water-reducing admixtures, are added to the concrete mix to improve the workability, reduce the water-to-cement ratio by reducing the amount of mixing water, and/or to increase the strength of concrete, eliminate segregation, and reduce plastic shrinkage cracks.

(4) Similarities and differences between creep and shrinkage of concrete.

Creep and shrinkage are both time-dependent deformations that occur in concrete; creep is due to sustained loading, while shrinkage is due to loss of moisture. When a concrete member is allowed to creep or shrink freely no stresses are induced; however, if the deformation either from creep or shrinkage is controlled or restrained, tensile stresses develop in the concrete, and these can cause cracking if the concrete tensile strength is exceeded.

(5) Methods to reduce corrosion of reinforcing steel in concrete.

Strategies to combat corrosion of reinforcing steel involve restricting the availability of oxygen and moisture at the cathodes and preventing electron flow from the anode to the cathode. This can be achieved by:

(1) Reducing the permeability of concrete: low *w/c*, proper curing, use of mineral admixtures, increasing the concrete cover.
(2) Using protective membranes on the concrete: concrete overlays, surface treatments with water-repellent materials, sealers.
(3) Using protective coatings on the reinforcing steel: epoxy-coated, galvanized, stainless-steel.
(4) Suppressing the electrochemical process: corrosion inhibiting admixtures, cathodic protection.

QUESTION 3: (25 marks)

1. Elastic behaviour means that

(a) Deformation is recoverable (b) Stress is directly proportional to strain

(c) Deformation is not recoverable (d) Stress is not directly proportional to strain

An aggregate sample of 1020 g has the following properties: oven-dried mass = 980 g, saturated surface dry mass = 1000 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 capacity of the aggregate?

(a) 2.04% (b) 4.08%

(c) 20% (d) None of the above

4. For the same volume, an aggregate that has a specific gravity of 1.0

(a) Weighs more than water (b) Weighs less than water

(c) Weighs like water (d) None of the above

5. 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

6. 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

7. 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

8. 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

9. How can concrete be protected from frost damage?
   (a) By specifying a low w/c (b) By using durable aggregates
   (c) By using air entrainers (d) All 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