Université d'Ottawa
Faculté de génie

Département de
génie civil

uOttawa

L'Université canadienne
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University of Ottawa
Faculty of Engineering

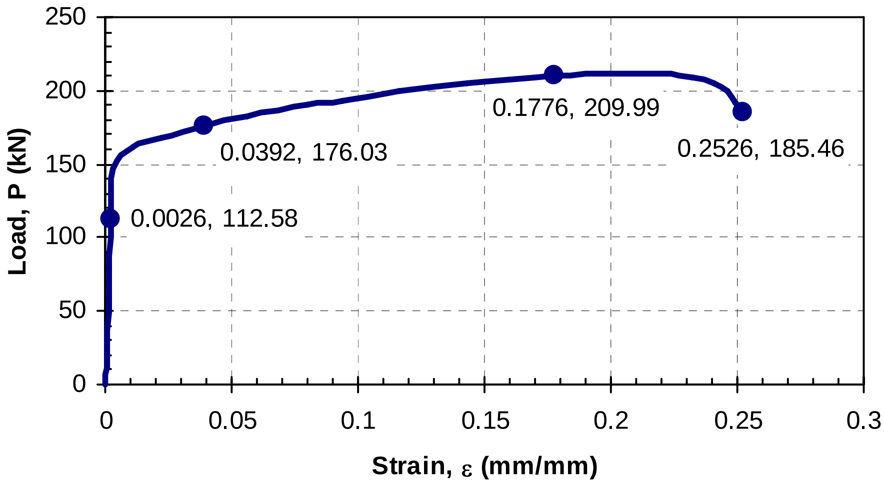
Department of
Civil Engineering

CVG 2141 – CIVIL ENGINEERING MATERIALS

Mid Term Examination (Closed book) — **Oct. 21st, 2008**
Dr. Adel Bugaldian — Time: **1 hour & 20 minutes**

QUESTION 1: (25 marks)

The load-strain curve of a tension test performed on a 12 mm × 12 mm square metal alloy is shown in the figure. Also shown in the figure are the corresponding values of some of the points on the load-strain curve. Knowing that the specimen had a gauge length of 50 mm, estimate the following:



(a) Yield stress at 0.2% offset;

At 0.2% offset, σ_y is approximately given by $\sigma_y = \frac{P_y}{A} = \frac{155\times10^3}{12\times12} = 1076MPa$

(b) Ultimate stress;

$$\sigma_u = \frac{P_u}{A} = \frac{209.99\times10^3}{12\times12} = 1458MPa$$

(c) Rupture stress;

$$\sigma_f = \frac{P_f}{A} = \frac{185.46 \times 10^3}{12 \times 12} = 1288MPa$$

(d) Modulus of elasticity;

The modulus of elasticity is the slope of the linear elastic portion of the stress-strain curve,

$$i.e., E = \frac{\sigma}{\varepsilon} = \frac{\left(112.58 \times 10^3 / 12 \times 12\right)}{0.0026} = 301GPa$$

(e) A cylindrical specimen of this alloy 12-mm in diameter and 250-mm long is stressed in tension and found to elongate 9.8 mm. Compute the magnitude of the load necessary to produce this change in length;

$$\varepsilon = \frac{\Delta L}{L} = \frac{9.8}{250} = 0.0392 = 3.92\%$$

The stress corresponding to a strain of 3.92% is $\sigma_y = \frac{P}{A} = \frac{176.03 \times 10^3}{12 \times 12} = 1222MPa$

Therefore, the load to induce that stress is $P = \sigma \times A = \sigma \times \frac{\pi d^2}{4} = 1222 \times \frac{\pi \times 12^2}{4} = 138kN$

(f) 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, 25.26%, is 42 times the strain corresponding to yielding, which is approximately 0.6%.

QUESTION 2: (25 marks)

Using the information given, specify the mix proportions of a concrete to be subjected to frequent freezing and thawing in an unsaturated condition. The concrete is to be used for an exterior reinforced concrete wall in Ottawa, and the specified 28-day compressive strength required is 27 MPa. Statistical data indicate a standard deviation of compressive strength of 2.1 MPa is expected (more than 30 samples have been tested). The following materials are available:

Cement: Type GU
Relative density = 3.15

Coarse aggregate: 20-mm nominal maximum size
Bulk oven-dry specific gravity = 2.55
Absorption capacity = 1.5%
Bulk oven-dry rodded density = 1761 kg/m^3
Coarse aggregate has a moisture content of 0.8%

Fine aggregate: Bulk oven-dry specific gravity = 2.66
Absorption capacity = 0.5%
Fine aggregate has a moisture content of 2%

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
Cumulative percentage passing	98	87	65	45	22	3

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
Cumulative Percentage Passing	98	87	65	45	22	3
Cumulative Percentage retained	2	13	35	55	78	97
						280

$$FM = \frac{280}{100} = 2.80$$

2. Slump

- For reinforced walls, the maximum slump that is allowed is 100 mm (see Table 9-6.)

3. Strength

- As specified in the problem statement, the exterior wall is to be exposed to frequent freezing and thawing in an unsaturated condition. From Table 8-2, the exposure class for this environment is F-2.
- According to Table 9-1, the minimum 28-day compressive strength is 25 MPa, the maximum *w/c* is 0.55, and the air content category is 2.
- Since the specified 28-day compressive strength of 27 MPa (as given in the problem statement) meets the strength requirements set in Table 9-1, the mix will be designed for a specified strength of 27 MPa.
- The average strength required for proportioning is the greater of:

  $f_{cr}^{'} = f_c^{'} + 1.4S = 27 + (1.4 \times 2.1) = 29.9MPa$

  $f_{cr}^{'} = f_c^{'} + 2.4S - 3.5MPa = 27 + (2.4 \times 2.1) - 3.5 = 28.5MPa$

4. Water-to-cementing materials ratio

- From a durability requirement, the maximum *w/c* allowed for a concrete exposed to an F-2 environment is 0.55 (see Table 9-1).
- From a strength requirement, the recommended *w/c* for a concrete with $f_{cr}^{'}$ of **29.9** MPa and entrained air (category 2) is 0.45 (Table 9-3). Since the lower *w/c* governs, the mix must be designed for *w/c* = 0.45.

5. Air content

- From Table 9-1, the category for air content is Category 2.
- For a 20-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 20-mm nominal maximum aggregate size and a slump of 100 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/$w\ /c$) = $\dfrac{184}{0.45} = 409 kg\ /\ m^3$ 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 2.80 is 0.62 (see Table 9-4).
- Mass of coarse agg. $= 1761 \times 0.62 = 1092 kg\ /\ m^3$ of concrete (oven-dry mass)

9. Determine the amount of air entrainer

- Amount of air entrainer $= 6.3 \times 7 \times \dfrac{409}{100} = 180$ ml or $180 \times 10^{-6} m^3$
- Mass of air entrainer $180 \times 10^{-6} \times 1.0 \times 1000 = 0.18 kg\ /\ m^3$ of concrete

10. Determine the amount of fine aggregates

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

  Volume of water = $\dfrac{184}{1.0 \times 1000}$ = 0.184 m^3

  Volume of cement = $\dfrac{409}{3.15 \times 1000}$ = 0.130 m^3

  Volume of coarse agg. = $\dfrac{1092}{2.55 \times 1000}$ = 0.428 m^3

  Volume of air = 7% = 0.07 m^3

  Total volume of know ingredients = 0.812 m^3

  Volume of fine agg. = 1.0 - 0.812 = 0.188 m^3

  Mass of fine agg.=0.188 × 2.66 x 1000 = 500 kg/m^3 of concrete (oven-dry mass)

11. Adjust for aggregate moisture

- So far the mixture has the following proportions:

Water	184 kg
Cement	409 kg
Coarse agg. (OD)	1092 kg
Fine agg. (OD)	500 kg
Air entrainer	0.180 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 oven-dry conditions, its weight must be adjusted for the presence of moisture on it.
  Mass of fine agg. (2% MC) = 500 ×1.02= 510 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., 0.8% < 1.5%). 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.
  Mass of Coarse agg. (0.8% MC) = 1092 ×1.008= 1101 kg/m^3 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.

$$\text{Mass of water} = 184 + \underbrace{\left[1092 \times \left(0.015 - 0.008\right)\right]}_{\text{moisture absorbed by coarse agg.}} - \underbrace{\left[500 \times \left(0.02 - 0.005\right)\right]}_{\text{moisture contributed by fine agg.}} \approx 184 kg / m^3 \text{ of concrete}$$

(Note that the amount of water absorbed by the coarse aggregates is almost the same as that supplied by the fine aggregates.)

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

Water	184 kg
Cement	409 kg
Coarse agg. (0.1%)	1101 kg
Fine agg. (1%)	510 kg
Air entrainer	0.180 kg
	2204 kg

The density of the concrete (2204 kg/m^3) is within normal range.

QUESTION 3: (25 marks)

A fine aggregate sample of 521.0 g has the following properties: oven-dried mass = 491.6 g, absorption = 2.5%. Based on this information, answer questions 1 and 2.

1. What is the moisture content of the aggregate?
   - (a) 5.6%
   - (b) 5.9%
   - (c) 2.5%
   - (d) 3.4%
   - (e) None of the above
2. What is the free moisture content of the aggregate?
   - (a) 5.6%
   - (b) 5.9%
   - (c) 2.5%
   - (d) 3.4%
   - (e) None of the above
3. Which of these phases is not a clinker compound?
   - (a) C3S
   - (b) Gypsum
   - (c) C4AF
   - (d) None of the above
4. When is a low-heat-of-hydration Portland cement (Type LH) used?
   - (a) To produce low-permeable concrete
   - (b) In massive concrete structures
   - (c) When forms need to be removed quickly
   - (d) When concrete is exposed to sulphates
   - (d) All of the above
5. 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
6. In which of the cases listed would you most likely use a set accelerating admixture in concrete?
   - (a) To increase time for proper curing
   - (b) In cold weather
   - (c) In hot weather
   - (d) To keep concrete workable for longer time
   - (e) None of the above

7. Which of the following does affect concrete workability?

(a) Amount of mixing water
(b) Aggregate-mix proportion
(c) Aggregate shape
(d) Loss of water through evaporation
(e) All of the above

8. Which clinker compound is reduced to produce sulphate-resistant Portland cement?

(a) C3S
(b) C2S
(c) C3A
(d) None of the above

9. The change in volume of concrete due to sustained load over a long period of time is due to:

(a) Plastic shrinkage
(b) Drying shrinkage
(c) Creep
(d) All of the above

10. The compressive strength of concrete:

(a) Increases with increasing w/c
(b) Is independent of w/c
(c) Increases with increasing age
(d) Decreases with increasing age

11. Shrinkage in concrete refers to:

(a) Change in deformation due to sustained load
(b) Loss of strength
(c) Change in deformation due to moisture loss
(d) All of the above