[redacted]

UNIVERSITY OF CALIFORNIA
CE 60
Fall 2010
Professor: C.P. Ostertag

Question 1	13	/ 14
Question 2	17	/ 17
Question 3	18	/ 19
Total	48	**/ 50**

Great

CE 60/E 47 PROPERTIES OF CIVIL ENGINEERING MATERIALS

SECOND MIDTERM EXAMINATION
Nov. 9, 2010

Question 1: general questions on concrete [13 /14]

a) This questions deals with the soundness of an aggregate. Which of the three aggregates are "sound", hence resist frost action: i) basalt, ii) sandstone, iii) limestone? Please discuss in regards to **both** pore structure and strength.

i. basalt is sound as it has very high strength and low pore structure as an igneous rock, it is a great aggregate

ii. sandstone is less sound than basalt but still able to be used it does not have many pores and has less strength

✓

iii. limestone is not sound compared to the previous two, as a sedimentary rock, there are lots of pores and its strength is not relatively high. we can crush it if we need to use it in cold temperatures

b) The clinker grains contain different compositions which chemically react when water is added to the mix.

$C_3S \rightarrow 3CH$
$C_2S \rightarrow CH$
$C_3A \rightarrow$ Ettringite no CH

i) Which composition of the clinker grain produces less CH when it reacts with water?
C_3A, C_2S technically ✓ C_3A does not produce CH use less C_3S use silica to make $CH \rightarrow CSH$

ii) Which one leads to the highest heat evolution when it reacts with water? C_3A 300 cal/g

iii) Concrete needs to be placed on I- 80 in the Sierra's in the winter (i.e. at low temperature).

−1

Which type of cement would you chose? air entrained type 2 cement

How does the clinker composition differ in the type of cement you chose above from type I cement?

mainly less C_3S !

need to use cement type that increases heat evolution

Type 2 cement has less C_3A than type 1 cement. C_3A has a high heat evolution and so using type 2 cement will lower the overall heat evolution. This is important because when cement cools down, there is thermal shrinkage, creating tensile stresses which weaken the concrete.

air entrainment will reduce hydraulic pressure

c) Which of the raw materials listed are necessary for the production of Portland cement?
[✓ Fe_2O_3], [✓ Al_2O_3], SiC, Si_3N_4, [✓ SiO_2], [✓ $CaCO_3$]; please circle the correct ones.

C_3S C_2S C_3A C_4AF

d) Why is gypsum added to the clinker grains in the process of making Portland cement?

✓

Gypsum slows the hydration of C_3A. If it was not added, the cement would be unuseable as it would set too quickly

C_3A + gypsum + 26H → Ettringite

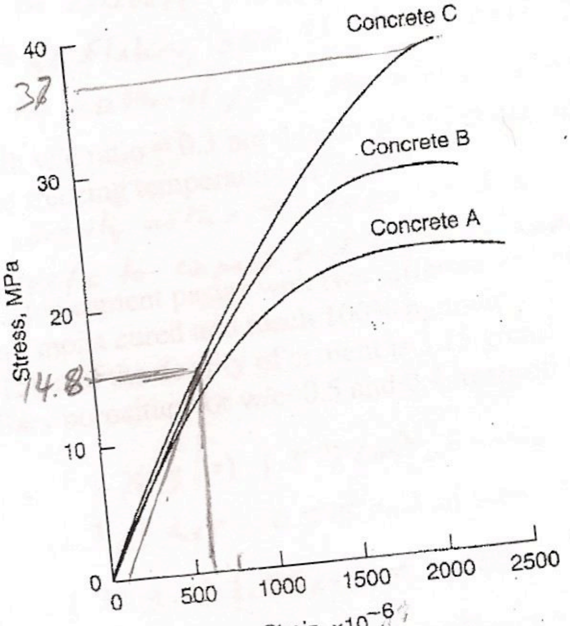
e) The workability of concrete is too low and hence can not be placed between reinforcing bars. How can the workability of the concrete mix be increased?

by adding water and cement with the w/c ratio proportions ✓

f) List at least two factors (besides capillary porosity and high w/c ratio) that influence the strength of concrete.

the strength of the coarse aggregate, the temperature of the mixing/curing, the thickness of the member, the loading conditions ← speed of loading
size of member
height/diameter ratio.

g) Determine the E-modulus of the Concrete C shown in the graph below.



Could use tangent, secant, dynam
met

40% of f'c overall

.4 × 37 = 14.8

chord method 50×10^{-6} microstrain /

$\frac{\sigma}{\varepsilon} = E$ $\frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1}$ $\frac{14.8 - 0 \text{ Mpa}}{(600 - 50)10^{-6}_{\text{strain}}} =$ $\boxed{\begin{matrix} E \\ 26909 \text{ MPa} \end{matrix}}$

$\varepsilon_2 \cong 600 \times 10^{-6}$

Question 2: questions on durability [17 /17] good!

a) You need to perform a forensic analysis on a bridge pier that exhibits sulfate attack. The contractor claims that he followed the necessary concrete mix requirements to prevent sulfate attack for concretes that will be exposed to very high amounts of sulfate ions in the water.

i) List three precautions that are necessary to prevent sulfate attack in concrete exposed to very high amount of sulfate ions.

type 5 cement should be used, $w/c \leq 0.45$ so that there is low porosity, admixtures can be added as well, pozzolans, sound aggregates

ii) How could you proof in court that the contractor did not follow these requirements which would have lead to a sulfate resistant concrete?

You could look at the concrete to see if there is any cracking, spalling, D cracks, Pieces of concrete will be flaking off if the sulfate has been attacked, we can check porosity of the material, check aggregates in concrete, check for ettringite formation

b) Why does a concrete with w/c ratio = 0.3 not exhibit any frost damage at temperatures close to the freezing temperature of water?

there would be 0 porosity with a w/c ratio of 0.3 meaning that no free water is in the concrete to expand and cause damage

c) We are comparing hydrated cement pastes with two different w/c ratios: w/c=0.5 and w/c=0.4. Both pastes are moist cured and reach 100% hydration. The amount of cement to be used is 315g and the density of cement is 3.15 g/cm^3.

i) Calculate the capillary porosities for w/c=0.5 and 0.4, respectively at 100% hydration.

$w/c = 0.5$ $w = 0.5(3.15) = 1.575\,g \Rightarrow 1.575\,cm^3$ of water $3.15\,g \Rightarrow 1\,cm^3$ of cement

at 100% hydration $2\,cm^3$ of hcp $0.575\,cm^3$ of water left $\frac{0.575}{2.575} = .2233$ $\boxed{22\%\ \text{porosity}}$

$w/c = 0.4$ $w = 0.4(3.15) = 1.26\,g \Rightarrow 1.26\,cm^3$ of water $3.15\,g \Rightarrow 1\,cm^3$ of cement

at 100% hydration $2\,cm^3$ of hcp $0.26\,cm^3$ of water left $\frac{0.26}{2.26} = .115$ $\boxed{11.5\%\ \text{porosity}}$

ii) Will the hydrated cement paste with the w/c ratio = 0.5 have the **same/higher/lower** permeability compared to the one with the w/c ratio = 0.4? Please explain briefly.

0.5 w/c ratio will have similar permeability to w/c ratio of 0.4. 30% porosity is the place where permeability changes are low as lower than this number means isolated pores as compared to inter connected pores. technically lower but very very close

d) i) Which concrete will be more fire resistant, the concrete [✓ with w/c =0.5] or the one with w/c ratio = 0.4? Please circle and explain briefly.

The w/c ratio of 0.5 will be more fire resistant as there is more water in the concrete. This is important as during a fire, the water must evaporate before the concrete's temperature itself rises. with more water, the concrete will resist the rise in temperature longer

ii) Which concrete will be more frost resistant, the concrete with w/c=0.5 or the one with w/c ratio = [✓ 0.4]? Please circle and explain briefly.

The 0.4 w/c will be more frost resistant as there will be less overall porosity in the concrete. There will be less capillary pores, which hold free water that will expand in low temperatures.

Question 3: ACI mix design [18/19] good!

The following data are given:
Specified 28 days compressive strength: 6000 psi
Required slump: for mass construction

	CEMENT	FINE AGGREG.	COARSE AGGREG.
Specific Gravity	3.14	2.7	2.6
Fineness Modulus		2.5	
Dry Rodded Unit Weight, (pcf)			103
Aggregate Size			0.5"
Moisture Deviation from SSD		-2%	+0.7%

a) Determine the ACI mix proportions based on SSD conditions for a concrete used in a mild climate. Show your computations on the back page and give your answers below in lb/yd^3 ↑ no need for air entrainment

lb/yd^3:
Cement: 817
Water: 335 ✓
CA: 1613
FA: 1153

b) Determine the trial mix proportions based on the deviation from the SSD conditions.

Trial mix proportions

lb/yd^3:
Cement: 817 — 817 → 817 lb/yd^3
Water: 347 ✓ — 335 −11 +23 → 347 lb/yd^3
CA: 1624 — 1613 × 0.007 = 11 lb/yd^3 → 1624 lb/yd^3
FA: 1130 ✓ — 1153 x −0.02 = 23 lb/yd^3 → 1130 lb/yd^3

c) Assume concrete with the **same compressive strength** and same aggregate characteristics as in (a) need to be designed and placed in an area where freezing will occur. Circle the appropriate ACI mix proportions listed below that will change due to the new mix design.

[✓ i) Cement]
−1 [✓ ii) Water]
iii) CA
[✓ iv) FA]

different w/c | air entrained! |

water changes which changes cement which changes FA ↖ affects volume

CA does not change as fineness modulus of FA and size of CA does not change ✓

→ H_2O → f(size of CA) which does not change!

iii) The contractor asks you to design a more economical, hence less expensive mix as the mix in (a) but it needs to exhibit the **same compressive strength** but not the same aggregate characteristics as in (a). What do you need to change in order to make the concrete mix more economical? Will your change affect the amount of (please circle):

[✓ i) Cement]
[✓ ii) Water]
[✓ iii) CA]
[✓ iv) FA] ✓

→ but f'c ↑ !! −1

Having larger coarge aggregate and finer fine aggregate will allow for less cement and water in the w/c ratio proportions ✓
More coarse aggregate will be used as it can fill a larger space. The fine aggregate will change as well due to the change in proportions

less w/c in ratio proportions
more aggregates

---

non air entrained
1-2" slump for mass concrete
1/2" max coarge aggregate size

335 lb water/yd³

0.41 w/c ratio

$\frac{335}{0.41} = 817 \text{ lb of cement}/\text{yd}^3$

w 335
c 817
CA 1613

vol of dry coarse = 0.58

$0.58 \times \frac{27 \text{ ft}^3}{\text{yd}^3} \times 103 \frac{\text{lb}}{\text{ft}^3} = 1612.98 \frac{\text{lb}}{\text{yd}^3} \text{ CA}$

$V_w = \frac{335 \text{ lb}}{62.4 \frac{\text{lb}}{\text{ft}^3}} = 5.37 \frac{\text{ft}^3}{\text{yd}^3}$

$V_c = \frac{817 \text{ lb}}{3.14 (62.4 \text{ lb}/\text{ft}^3)} = 4.17 \frac{\text{ft}^3}{\text{yd}^3}$

$V_{CA} = \frac{1613 \text{ lb}}{2.6 (62.4 \text{ lb}/\text{ft}^3)} = 9.94 \frac{\text{ft}^3}{\text{yd}^3}$

$V_{Air} = 0.025 \times \frac{27 \text{ ft}^3}{\text{yd}^3} = 0.675 \frac{\text{ft}^3}{\text{yd}^3}$

$V_{FA} = 6.845$

$W = Vp = 6.845 (2.7)(62.4) = 1153 \text{ lb}/\text{yd}^3$

$V_{TOT} = \underbrace{V_w + V_c + V_{CA} + V_{air}} + V_{FA}$

$V_{FA} = V_{TOT} - \Sigma V = 27 - 5.37 - 4.17 - 9.94 - 0.675 = 6.845 \text{ ft}^3/\text{yd}^3$

TABLE 9-1 - ACI RECOMMENDED SLUMPS FOR VARIOUS TYPES OF CONSTRUCTION

Types of Construction	Slump, in.	
	Maximum*	Minimum
Reinforced foundation walls and footings	3	1
Plain footings, caissons, and substructure walls	3	1
Beams and reinforced walls	4	1
Building columns	4	1
Pavements and slabs	3	1
Mass concrete	2	1

* May be increased 1-in. for methods of consolidation other than vibration.

TABLE 9-2 APPROXIMATE MIXING WATER AND AIR CONTENT REQUIREMENTS FOR DIFFERENT SLUMPS AND MAXIMUM SIZES OF AGGREGATES*

Slump, in.	Water, lb./cu. yd. of concrete for indicated maximum sizes of aggregate						
	3/8"	1/2"	3/4"	1"	1½"	2"+	3"+
	Non-air-entrained concrete						
1 to 2	350	335	315	300	275	260	240
3 to 4	385	365	340	325	300	285	265
6 to 7	410	385	360	340	315	300	285
Air (Vol.%)	3	2.5	2	1.5	1	0.5	0.3
	Air-entrained concrete						
1 to 2	305	295	280	270	250	240	225
3 to 4	340	325	305	295	275	265	250
6 to 7	365	345	325	310	290	280	270
Air (Vol.%)	8	7	6	5	4.5	4	3.5

* These quantities of mixing water are for use in computing cement factors for trial batches. They are maxima for reasonably well-shaped angular coarse aggregates graded within limits of accepted specifications.

+The slump values for concrete containing aggregate larger than 1½" are based on slump tests made after removal of particles >1½" by wet-screening.

TABLE 9-3 RELATIONSHIP BETWEEN WATER/CEMENT RATIO AND COMPRESSIVE STRENGTH OF CONCRETE

Compressive strength at 28 days, psi	Water/cement ratio, by weight	
	Non-air-entrained concrete	Air-entrained concrete
6000	0.41	---
5000	0.48	0.40
4000	0.57	0.48
3000	0.68	0.59
2000	0.82	0.74

TABLE 9-5 VOLUME OF COARSE AGGREGATE PER UNIT OF VOLUME OF CONCRETE

Maximum size of aggregate (in.)	Vol. dry-rodded coarse aggregate per unit vol. concrete for different fineness moduli of sand.			
	2.40	2.60	2.80	3.00
3/8	0.50	0.48	0.46	0.44
1/2	0.59	0.57	0.55	0.53
3/4	0.66	0.64	0.62	0.60
1	0.71	0.69	0.67	0.65
1-1/2	0.75	0.73	0.71	0.69
2	0.78	0.76	0.74	0.72
3	0.82	0.80	0.78	0.76
6	0.87	0.85	0.83	0.81