53:086 Civil Engineering Materials
Dept. of Civil & Environmental Engineering
The University of Iowa
Midterm Exam #1

Spring Semester 2008 Instructor: C.C. Swan

PART A: METALS (34 points)

1. What is metallic bonding and how does it explain that metals are generally good conductors of heat and electricity?

2. Please address the following:
   a. Sketch the unit cell of a face-centered-cubic (FCC) lattice.
   b. How many complete atoms are in the unit cell?
   c. If in a given FCC metal each atom has an average mass of $4.479*10^{-26}$ kg and an average radius of $1.43*10^{-10}$m what would be its expected mass density in kg/m^3?

3.
   a. What are grain boundaries in metals and how are they formed?
   b. How can a metal with very small grains be achieved?
   c. How would the strength and ductility of a fine-grained metal differ from that of a coarse-grained metal?

4.
   a. Why is carbon such an integral part of making steel?
   b. All other things being equal, how would the properties of high-carbon steel differ from those of a mild steel?

5. Calculate the composition of a 0.45% carbon steel alloy in terms of α-ferrite, γ-austenite, and Fe_3C cementite at states A, B, and C shown in Figure 1. Note that cementite has a 6.7% carbon content by mass.

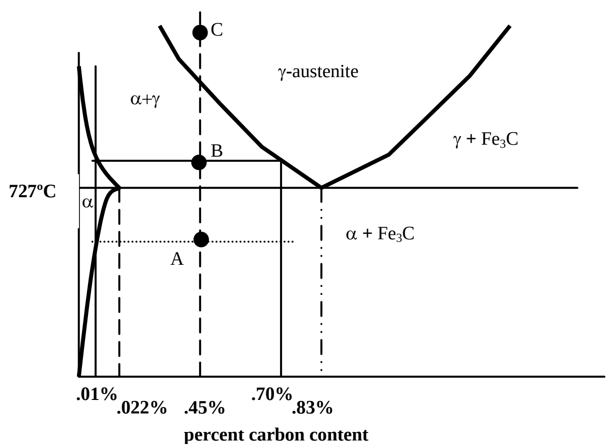

Figure 1. Portion of the iron-carbon phase diagram. (Not drawn to scale)

6. Choose the option below that best describes zinc-galvanized steel:
   a. A thin, uniform layer of zinc coating on steel, achieved by application of vaporized zinc at ambient temperatures.
   b. A hard, multi-layered zinc-iron alloy coating achieved by dipping steel parts into molten zinc.
   c. A thin, uniform layer of zinc on steel achieved through electro-deposition.
   d. A zinc-iron alloy with uniform composition throughout a structural part.

The following two questions are true/false.

7. When welding high-strength metals achieved via heat treatments or work hardening, there can be significant reduction of strength in the heat-affected zone (HAZ).
8. Pure aluminum is generally much stronger but less corrosion resistant than the most of the common aluminum alloys.
9. If iron and nickel were both placed together in an electrolyte, the nickel would be expected to corrode thus providing sacrificial protection to the iron.

PART B: PORTLAND CEMENT CONCRETE (35 points)

10. Name the four common chemical compounds that make up ordinary portland cement and give their representation in cement chemistry shorthand notation.
11. Which type of ordinary portland cement (no pozzolans) is best at resisting severe sulfate attack and what is unique about its composition?
12. The Griffith micro-crack model suggests that the stress level required to make a void or crack of diameter 2a propagate in a linear elastic medium is given by the formula below. Can this formula explain why the strength of hcp decreases with increasing w/c ratio? If yes, briefly explain how.

$$\sigma_{fract} = \sqrt{\frac{4EG_c}{\pi a}}$$

13. A mixture of fresh portland cement paste has a water to cement ratio of 0.35. In a volume of 1cm^3 of paste:
    a. compute the mass of cement and the mass of water.
    b. This fresh paste then cures under wet conditions. Calculate the volume composition of the hcp in terms of: (1) unhydrated cement; (2) gel products; and (3) capillary voids or pores.
    c. Calculate the volume composition of the same hcp under sealed curing.

$$m \le \frac{\frac{M_0^f}{M_0^c} * \upsilon_f}{\left(1.2\upsilon_g - \upsilon_c\right)} = m_{max} \le 1 \text{ : wet curing}$$

$$m \le \frac{\frac{M_0^f}{M_0^c} * \upsilon_f}{1.282\upsilon_g - \upsilon_c} = m_{max} \le 1 \text{ : sealed curing}$$

Phase	Mass density (g/cm^3)	Specific volume (cm^3/g)
Mix water	ρ_f=1.00	υ_f=1.00
Cement particles	ρ_c=3.17	υ_c=.315
Gel products	ρ_g=1.76	υ_g=.568

14. In portland cement concrete mix design, what are moisture corrections, and why are they important?
15. A cured portland cement concrete (pcc) has an aggregate volume fraction of 80% and an hcp volume fraction of 20% (this contains some gel and capillary pores). If the Young's modulus of the aggregate is 100 GPa, and that of the hcp is 10 GPa, estimate the effective Young's modulus of the pcc using:
    a. The Voigt (iso-strain) rule of mixtures; and
    b. The Reuss (iso-stress) rule of mixtures.
    c. Which of these two estimates seems more realistic?

The following questions are true/false. Enter either T or F in your test booklet. If you find the question ambiguously worded, you may expand on your answer.

16. The cement hydration reaction is endothermic, taking in heat from the environment.
17. Type IV ordinary portland cement is a low-heat cement achieved by using less C_3S and more C_2S.
18. It is generally best to use high early strength portland cement in large concrete pours so that the forms can be removed as soon as possible.
19. In normal strength pcc, one expects the strength of the aggregate particles to be greater than that of the hcp.

20. Three common cement replacement materials are: (1) pulverized fly ash [pfa] ; (2) ground granulated blast-furnace slag [ggbs]; and (3) condensed silica fume [csf]. Of these three, care must be used with *csf* as it can result in very low-slump concrete.
21. About 5 percent gypsum (chalk) is typically added to ordinary portland cement to give it a whiter appearance that is sometimes desirable for architectural applications.
22. The cement replacement material *pfa* tends to lead to high early strength although somewhat lower mature strength of pcc.
23. Cement replacement materials can lead to hydrated cement paste having lower permeability and higher durability.
24. Water reducers are admixtures that allow concrete mixes to use less mix water to achieve a desired level of slump or workability.
25. A large fineness modulus for concrete aggregate generally indicates a very fine aggregate.
26. One property of portland cement concrete that generally leads to good durability characteristics is high permeability.

MATERIAL PROPERTIES (30 points)

For questions 27-37 provide the <u>range</u> of the material property values for the following (where units are used, provide values in both English and metric units):

27. Young's modulus of structural steels
28. Yield strength of structural steels
29. Ultimate strength of structural steels
30. Specific gravity of structural steels
31. Young's modulus of structural aluminum
32. Yield strengths for structural aluminum
33. Ultimate strengths for structural aluminum
34. Specific gravity for structural aluminum
35. Young's modulus for fully cured normal weight/strength portland cement concrete
36. Unconfined compressive strength for fully cured normal weight/strength portland cement concrete
37. Mass density or unit weight for normal weight portland cement concrete.

Table 6.1. Standard Electrode Potentials of Different Elements

Metal	Reaction	Electrode Potential (V)
Li	$Li \leftrightarrow Li^{+}+e^{-}$	-2.96
K	$K \leftrightarrow K^{+}+e^{-}$	-2.92
Na	$Na \leftrightarrow Na^{+}+e^{-}$	-2.71
Mg	$Mg \leftrightarrow Mg^{++}+2e^{-}$	-2.40
Al	$Al \leftrightarrow Al^{+++}+3e^{-}$	-1.70
Zn	$Zn \leftrightarrow Zn^{++}+2e^{-}$	-0.76
Cr	$Cr \leftrightarrow Cr^{3+}+3e^{-}$	-0.74
Fe	$Fe \leftrightarrow Fe^{++}+2e^{-}$	-0.44
Cd	$Cd \leftrightarrow Cd^{++}+2e^{-}$	-0.40
Ni	$Ni \leftrightarrow Ni^{++}+2e^{-}$	-0.22
Sn	$Sn \leftrightarrow Sn^{++}+2e^{-}$	-0.13
Pb	$Pb \leftrightarrow Pb^{++}+2e^{-}$	-0.12
H_2		0.00
Cu	$Cu \leftrightarrow Cu^{++}+2e^{-}$	+0.34
Ag	$Ag \leftrightarrow Ag^{+}+e^{-}$	+0.80
Hg	$Hg \leftrightarrow Hg^{++}+2e^{-}$	+0.86
Cl	$2Cl^{-} \leftrightarrow Cl_2+2e^{-}$	+1.36
Au	$Au \leftrightarrow Au^{+}+e^{-}$	+1.50

More likely to corrode ↕ Less likely to corrode