53:086 Civil Engineering Materials

Dept. of Civil & Environmental Engineering

The University of Iowa

Midterm Exam #1

Spring Semester 2007 Instructor: C.C. Swan

Questions 1-4 are multiple-choice.

1. On the relation between the melting temperature of a material and its **theoretical** ultimate strength:
    a. The two tend to be completely unrelated;
    b. Generally, the higher the melting temperature, the lower the strength;
    c. Generally, the higher the melting temperature, the higher the strength;
    d. Such a relation between melting temperature and strength exists only for covalently bonded compounds.

2. On the relationship between a material's actual strength and its theoretical strength:
    a. Theoretical strength is higher and is based on the primary bonds between atoms in the material, whereas actual strength is lower and is based on weaker secondary bonds;
    b. Theoretical strength is lower and is based on the primary bonds between atoms in the material, whereas actual strength is higher and is based on weaker secondary bonds;
    c. Defects in material structure tend to weaken materials, making their actual strength lower than their theoretical strength;
    d. Defects in material structure tend to strengthen materials, making the actual strengths larger than theoretical strengths.

3. The most common defects in metals that affect strength are:
    a. impurities;
    b. dislocations;
    c. interstitial alloying;
    d. substitutional alloying.

4. 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.

For questions 5-15 provide the range of the material property values for the following (where units are used, provide values in both English and metric units):

5. Young's modulus of structural steels
6. Yield strength of structural steels
7. Ultimate strength of structural steels
8. Specific gravity of structural steels
9. Young's modulus of structural aluminum
10. Yield strengths for structural aluminum
11. Ultimate strengths for structural aluminum
12. Specific gravity for structural aluminum
13. Young's modulus for fully cured normal weight/strength portland cement concrete
14. Unconfined compressive strength for fully cured normal weight/strength portland cement concrete
15. Mass density or unit weight for normal weight portland cement concrete

Some short answer questions:

16. Name the four common chemical compounds that make up ordinary portland cement and give their representation in cement chemistry shorthand notation.
17. In general terms, how is the composition and fineness of Type I ordinary portland cement changed to achieve a high early strength (Type III) portland cement?
18. 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.

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

19. Briefly state the effects of quenching a metal on:
    a. grain size
    b. ultimate strength
    c. ductility

20. Briefly state the effect of carbon content on:
    a. ultimate strength of steel
    b. ductility of steel

Questions 21-32 are true/false.

21. 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).
22. Pure aluminum is generally much stronger but less corrosion resistant than the most of the common aluminum alloys.
23. A large fineness modulus for concrete aggregate generally indicates a very fine aggregate.
24. The cement hydration reaction is endothermic, taking in heat from the environment.
25. Type IV ordinary portland cement is a low-heat cement achieved by using less C_3S and more C_2S.
26. 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.
27. In normal strength pcc, one expects the strength of the aggregate particles to be greater than that of the hcp.
28. 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 *pfa* as it can result in very low-slump concrete.
29. 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.
30. The cement replacement material *pfa* tends to lead to high early strength although somewhat lower mature strength of pcc.
31. Cement replacement materials can lead to hydrated cement paste having lower permeability and higher durability.
32. Aggregates with low absorption capacities may have problems with degradation under freeze-thaw action.

Finally, a few problems to solve:

33. Calculate the composition of a 0.35% 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 mass content.

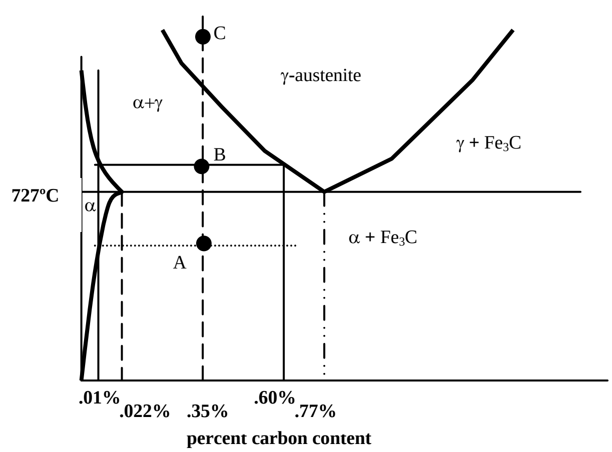

Figure 1. Portion of the iron-carbon phase diagram. (Not drawn to scale)

34. A mixture of fresh portland cement paste has a water to cement ratio of 0.6. 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.

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

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

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