University of California
Department of Civil and Environmental Engineering
Structural Engineering, Mechanics and Materials
Spring Semester, 2017

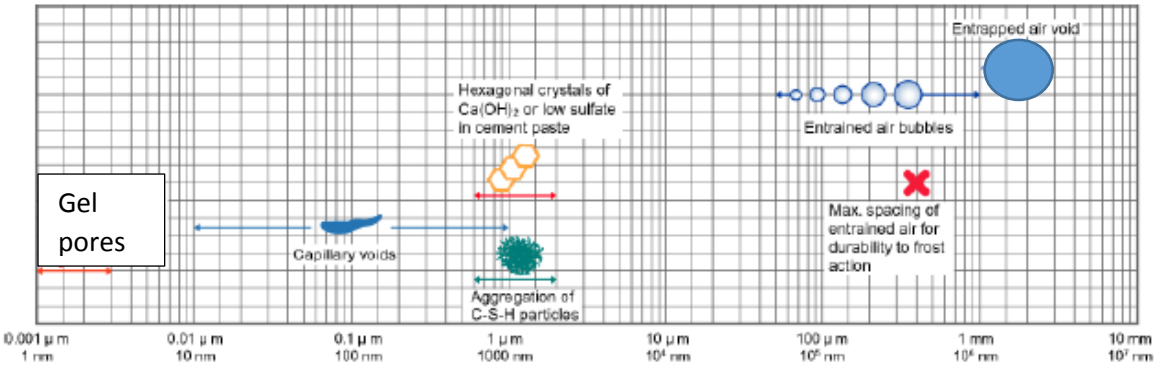
Name: _____

MS Comprehensive Examination
Materials

Question #1: [75%]
This question deals with Concrete and has two parts.

Part I: The hydrated cement paste (hcp) contains various types and sizes of voids/pores at multiple scales as indicated in the figure below.

a) Which type of void has the strongest influence on the compressive strength of the hydrated cement paste?
b) How can that type of void you mentioned above be completely removed from the hcp? (Please show your calculation; density of water: $1 g/cm^3$ and density of cement: $3.14 g/cm^3$)
c) Why do some hydrated cement pastes contain entrained air voids? What are their functions?
d) What is the reason for entrapped air voids in hcp?
e) Do the entrapped air voids enhance the permeability of the hcp? Please provide a brief explanation.
f) Are capillary voids responsible for shrinkage and creep of the hcp?
g) Assume all these pores contain water. Will the water freeze at 0°C in all these pores? Please provide a brief explanation.



Part II:

a) For an electro-chemical reaction such as corrosion to take place we need an electrolyte, an anode and a cathode. Does the concrete pore solution act as an electrolyte? Yes/No. Please circle and provide an explanation.
b) There are two types of cathodic reactions that can take place at the rebar embedded in concrete: Which one is more detrimental and why.
c) The brittleness of concrete is characterized by the characteristic length l_{ch}: $l_{ch}=EG_f/f_t^2$
   i) Why does Concrete with a large maximum coarse aggregate size have a larger characteristic length compared to concrete with a small maximum coarse aggregate size?
   ii) If you want a high strength concrete to have the same characteristic length as a normal strength concrete, what needs to be done?
d) High performance fiber reinforced concrete (HPFRC) composites exhibit strain hardening behavior in pure tension. What causes the strain hardening behavior in these composites?
e) Please plot the stress strain curve of a conventional FRC and a HPFRC in the same stress strain diagram.

Question 2: [25%]

This question deals with Steel

a) Please schematically draw the microstructures of the three construction steels (A36, A572 and A514).

b) Which of these three construction steels has the highest yield strength and what mechanism is responsible for this high yield strength?

c) Plot the stress strain curves of these three construction steels in the same stress strain diagram.

d) Steel is known for its strain hardening behavior. What mechanism is responsible for the strain hardening behavior in steel?

e) Give two examples on how the yield strength of steel can be increased.

f) The ultimate strength in steel is associated with the onset of neck formation. Is there a type of high performance steel that delays the onset of necking to higher strain levels? If yes, what is the name of that high performance steel and how was it designed.

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Question 1: (70%)

I) Normal Strength Concrete (NSC) versus High Strength Concrete (HSC)

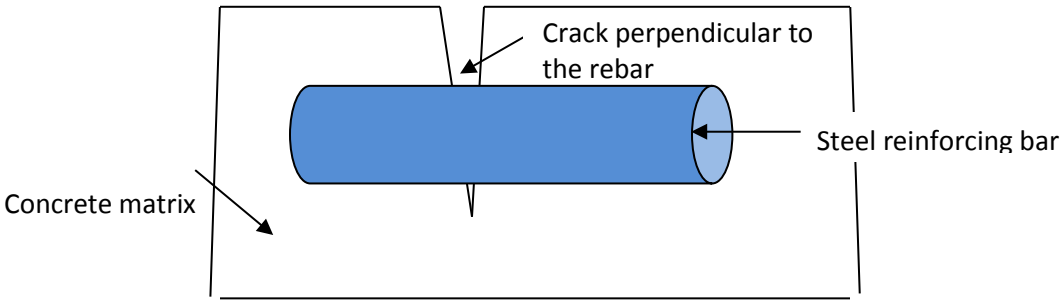
a) What causes the formation of a porous region (i.e. transition zone) between the coarse aggregates and the cement paste in NSC?
b) This transition zone is either absent or considerably reduced in HSC; please explain why.
c) HSC and NSC specimens are being tested in tension.
   i) Draw the stress strain curve of both specimens in the same diagram.
   ii) Explain the reason for their differences in the ascending and descending portion of the stress strain curve.

II) Corrosion

These questions deal with the corrosion of steel reinforcements embedded in concrete.

a) Why does a passive film protect the steel from corrosion?
b) What causes the destruction of the passive film in concrete at high ph (i.e. ph>12)?
c) Corrosion is an electro-chemical process.
   i) Will corrosion be enhanced in a wet or in a dry concrete? Please explain.
   ii) Assume the cathodic reaction consumes less electrons (i.e. cathodic reaction based on water decomposition instead of hydroxyl formation). Will this slow down the corrosion rate? **Yes/No**? (Circle)

d) A cracked specimen shown below is exposed to a moist environment. Indicate in the schematic the location of the cathode and the location of the anode.



e) Why are longitudinal cracks (cracks parallel to rebars) more detrimental compared to crack formations perpendicular to rebars?

Question 2: (30%)

a) Let's compare two types of common construction steels: A36 (yield strength: 36 ksi) and A514 (yield strength: 100ksi).
   i. Do they exhibit the same/different microstructures? Please provide some information on their microstructures.
   ii. What strengthening mechanisms are responsible for the increase in yield strength in A 514 from 36 ksi to 100 ksi?
   iii. Does the increase in yield strength modify the toughness of the steel?
   iv. How do dislocations interfere with the A514 microstructure?

b) Both A514 and the Maraging steel exhibit the same strengthening mechanisms but the Maraging steel is far more ductile even though it contains martensite. Please explain.