Spring Semester 2008
53:086 Civil Engineering Materials
Department of Civil & Environmental Engineering
The University of Iowa

Assignment #5 **Due: Tuesday 3/04/08**

Problem #1:
The following model is used to predict the degree of hydration of Type I ordinary portland cement. For curing of the paste under "wet" conditions the degree of hydration parameter $m \in [0,1]$ is given as follows:

$$m \le \frac{\left(\frac{M_o^f}{M_o^c}\right)}{\left[\left(1.2\upsilon_g - \upsilon_c\right)/\upsilon_f\right]} \le 1$$

where:
M_o^f is the mass of water in the fresh paste
M_o^c is the mass of cement in the fresh paste
$\upsilon_g = 0.568\,\text{cm}^3 \cdot \text{g}^{-1}$ is the specific volume of the gel product
$\upsilon_c = 0.315\,\text{cm}^3 \cdot \text{g}^{-1}$ is the specific volume of the cement particles
$\upsilon_f = 1.00\text{cm}^3 \cdot \text{g}^{-1}$ is the specific volume of the mix water

Similarly, under sealed curing conditions the degree of hydration parameter m is given as follows:

$$m \le \frac{\left(\frac{M_o^f}{M_o^c}\right)}{\left[\left(1.2\upsilon_g + .0508\upsilon_f - \upsilon_c\right)/\upsilon_f\right]} \le 1$$

Compute and plot volume fractions of unhydrated cement, gel products, and capillary pores in hydrated cement paste (hcp) as a function of water-cement ratio for $w/c = \left(M_o^f / M_o^c\right) \in [0,1]$ under:

a. wet curing conditions; and
b. dry curing conditions.

Plot graphs similar to those of Figures 9.5 a & b in the course notes. Present your spreadsheet results, and the formulas you used in addition to your graphs.

Problem #2: One model for the stiffness of hydrated cement paste is as follows: $E_p = E_g\left(1 - n_c\right)^3$ where E_p is the Young's modulus of the paste; E_g is the Young's modulus of the hcp under the assumption of zero capillary porosity; and n_c is the capillary porosity. For this problem: Assume $E_g = 25\,GPa$. Compute and plot the Young's modulus E_p of the hcp as a function of the w/c ratio. (Assume "wet" curing conditions.)

Problem #3: One of the methods used to predict the stiffness and strength characteristics of portland cement concrete (pcc) as a function of its constituents, their properties, and their volume fractions are the Voigt (iso-strain), Reuss (iso-stress), and mixed Voigt-Reuss (hybrid) models. The objective of this problem is to gain some familiarity with these models and their predictions.

- From your Problem #2 results, select an E_p for the hcp consistent with a w/c ratio of 0.50.
- Assume the aggregate used in the concrete has a Young's modulus E_a of 200 GPa.
- For aggregate volume fractions of 0% through 90% compute and plot the effective Young's modulus of the concrete as predicted by the iso-strain, iso-stress, and hybrid models. To compare the predictions of the different models, plot all of the curves on a single graph. Briefly discuss the main features of the different model predictions.