CE 60 Final Review

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1 Important equations

- Deriving the level rule is actually helpful to understand where the hell things should go:

  Combining the below equations:

  1. $W_\alpha + W_L = 1$
  2. $W_\alpha C_\alpha + W_L C_L = C_o$ (total carbon)

  yields:

  $W_L = \frac{C_\alpha - C_0}{C_\alpha - C_L}$

- Fineness modulus is the sum of the total percentages retained on each of the specified sieve divided by 100. The specified sieves are 3, 1 1/2, 3/4 and 3/8 in and Nos. 4, 8, 16, 30, 50 and 100

- Compressive strength and porosity:

  S = $S_0 e^{kp}$

  Where S_0 is the strength at zero porosity, p is the porosity and k a constant.

- $\sigma_t = K_r \frac{E}{1+\phi} \alpha$

2 Phase Diagrams

2.1 What do the funny Greek symbols mean in English?

- α = Ferrite
- γ = Austenite **(remember: perlite forms when austenite reaches eutectic point!)**
- Cementite = Fe_3C
- Pearlite = combination of Ferrite (α) and Cementite (Fe_3C)

2.2 Carbon Content

2.2.1 Finding Overall Carbon Content Given Carbon Content of a Phase

Draw tie line at corresponding point given carbon content and solve for x. On the right side of the eutectic point (hypereutectic):

$$\text{Phase amount} = \frac{\text{right tie line - x}}{\text{right tie line intersection - given carbon content for phase amount}} \tag{1}$$

Because, when you multiply both sides by the denominator, the Phase Amount times the (right tie line intersection - given carbon content for phase amount), which is all the carbon in the compound because the entire compound is on that side of the eutectic point, on the left side, is equal to the right side

2.2.2 Finding carbon content given percent of phases

1. Set the left hand of the equation equal to the percentage of the proeutectic portion of the alloy.
2. Determine whether the given phase is going to be to the right or to the left of eutectic point (hypoeutectic or proeutectic).
3. If it's to the left (hypo), the **numerator** of the right-hand side will be (the eutectic point - x). If it's to the right (hyper), it would be (the right-hand boundary - x).
4. The **denominator** of the right-hand side will be (the eutectic point - left boundary) if hypoeutectic or (right boundary - eutectic point) if hypereutectic.

3 Finding Elastic Modulus

3.1 In Steel

1. Find stress:
$$\sigma = \frac{P}{A} \tag{2}$$
2. Find strain:
$$\epsilon = \frac{\Delta L}{L_0} \tag{3}$$
3. $$E = \frac{\sigma}{\epsilon} \tag{4}$$

3.2 In Wood

3.2.1 Given loads and corresponding lengths

1. Find a delta between two loads where the material is still behaving elastically

2. Calculate the stress at that load as usual
3. Calculate the strain at that point by finding the change in length from the last point and dividing by total length **TIMES THE 'MULTIPLYING FACTOR' ON THE EXTENSOMETER!**
4. Calculate E by dividing stress by strain.

3.2.2 Given deflection (Δ)

1. Calculate I using
$$\frac{bh^3}{12} \tag{5}$$
(b and h should be given).
2. Use the equation:
$$\Delta = \frac{PL^3}{48EI} \tag{6}$$
solving for E (all the other variables should be given/you just calculated I)!

4 Gibbs Phase Rule: P + F = C + 2

- P = Number of Phases
- F = Degrees of Freedom (i.e. temperature, pressure)
- C = Number of Components
- 2 = 2 you dumbass

5 Unit Cells

5.1 Calculating Atomic Radius given Lattice Constant

Lattice constant = a, length of the side of 1 square.

- For BCC:
$$\sqrt{3}a = 4r \tag{7}$$
- For FCC:
$$\sqrt{2}a = 4r \tag{8}$$
- For HCP:
$$a = 2r \tag{9}$$

6 I've Got Wood: *A Collection of Facts About Nature's Greatest Gift to Man*

6.1 Saturation

- **Fiber Saturation Point:** moisture at which cell wall of wood is saturated with bound water and no free wter is present. Usually 28 percent. Any more than this and we have **free water**.
- Completely saturated wood would sink!

6.1.1 Strength vs. Saturation

Adding or removing water **above** FSP has almost no effect on strengh or other properties (i.e. strength is constant above FSP), but adding or removing water **below** FSP has a prounounced effect – strength *increases* as moisture *decreases*.

6.1.2 Strength vs. Direction

Strongest in longitudinal, then radial, then tangential. The ratio for these 3 is 20:1.5:1.

6.2 Shrinkage

- Greater in **tangential** direction because all layers want to shrink
- Latewood cells dominate shrinkage since they absorb much more water
- in the tangential direction, shrinkage is greater, there is an unbroken alignment of latewood, which shrinks more easily than earlywood
- Free water content has nothing to do with shrinkage.

6.3 Latewood

- Smaller ring things because it is dryer in the summer so they don't swell up as big

6.4 Annual Growth Ring

- One section of latewood (small rings) plus one section of x (big rings) is one annual growth ring

6.5 Softwood vs. Hardwood

6.5.1 Softwood

- Tree type: conifers

6.5.2 Hardwood

- Tree Type: Broad leaf trees

6.5.3 Things That Can Hurt Wood

- Timber rot is caused by fungi that live parasitically on cellulose because they have no chlorophyll

7 Portland Cement

Portland cement is made up of mostly limestone and clay, which is ground up, mixed, and heated to make clinker. Then, gypsum is added.

7.1 Types

- Type I: *General purpose*
- Type II: Moderate heat of hydration and sulfate resistance (C3A ¡ 8 percent) *general construction, seawater, mass concrete*
- Type III: High early strength (C3A ¡ 15 percent) *Emergency repairs, precast, winter construction*
- Type IV: Low heat (C3S ¡ 35 percent, C3A ¡ 7 percent, C2S ¿ 40 percent)

7.2 Hot In Here: Life in the Kiln

- In the kiln, limestone reacts to form CO2 (along with CaO).
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7.3 Hydration Process for Cement

- The main product of the hydration of Portland cement is CSH, which is made from C3S or C2S and water.
- The miracle of hydration: the Volume of the paste is 2 times the volume of the cement that reacted! Wow! Cool!
- **Degree of Hydration**: percent volume of hydrated cement out of *total* cement

7.3.1 Example Hydration Problem

Compute the maximum amount of cement that will ever hydrate in a 0.25 w/c ratio cement paste! How much paste will we have? How much cement will be left over? Do it now.

1. Assume 100 cm cubed of cement and calculate its mass by multiplying it by its density, 3.14, to get 314 g cement.
2. Calculate the amount of water by multiplying the weight of the cement, 314 g, by the water/cement ratio of 0.25. This yields 78.75 grams of water, and the volume of water will be 78.75 centimeters because of water's cool density of 1g/cm cubed.

3. Since we have 78.75 grams (and therefore 78.75 cubic centimeters) of water and 100 cubic centimeters of cement, all the water will react with the cement, creating a paste with a volume of 2 times 78.75 cm cubed, 157.5 cm cubed.

4. To get the weight of the cement that reacted, we need to calculate the weight of the dry 'leftovers' and subtract it from the total cement weight of 314 grams. Since 78.75 cubic centimeters reacted, we multiply this amount by the cement density of 3.14 to get 247.275 g cement reacted. Subtracting this value from tje total cement weight of 314 grams yields 66.725 grams of dry cement left over.

7.4 Chemical Components and Critical Reactions

7.4.1 Abbreviations

- C = CaO
- S = SiO_2
- A = Al_2O_3
- F = Fe_2O_3
- H = H_2O

7.4.2 Reactions

1. $2C_3S + 6H \rightarrow C_3S2H3$ + 3CH + 120cal/g
2. $2C_2S + 4H \rightarrow C_3S2H3$ + CH + 62cal/g
3. $C_3A + CSH2 \rightarrow$ Ettringite + 300cal/g.

7.4.3 C_3A

- Responsible for rapid stiffening and setting of portland cement
- Creates ettringite when combined with gypsum
- Has a high heat of reaction (high heat output)

8 Thermal Stresses

If thermal stresses are expected, we want a **LOW E**.

$$\Delta T = T_{fresh} + T_{adiabatic} - T_{loss} - T_{Ambient} \tag{10}$$

8.1 How to Control Temperature of Fresh Concrete

Note: this is different than the temperature of the cement before/during reaction (see following subsection). This is the temperature of concrete as it is setting.

- Temperature of water (including ice chips
- Casting at night
- Liquid nitrogen
- Pre-cooling aggregate

8.2 Combatting Adiabatic Temperature Rise

- Lower C_3A (Type II Cement)
- Lower C_3S
- Coarser grain
- Using fly ash
- Type/amount of cement (decrease amount o cement)

8.3 How to control T_{Loss}

- Blocks
- Pipes

9 Strength of Concrete

9.1 Creep

The creep – the tendency of a solid material to deform permanantly under the influence of mechanical stresses – of concrete, which originates from the calcium silicate hydrates (C-S-H) in the hardened Portland cement paste (which is the binder of mineral aggregates), is fundamentally different from the creep of metals and polymers.

In cement paste, calcium ciliate hydrate, or CSH, has water molecules that, when the concrete sustains compressive loads, move off of the CSH, causing it to have a stiffer microstructure. This phenomenon is the mechanism for creep

The **creep coefficient** is a dimensionless measure of the ratio of creep strain to elastic strain.

- Higher E means higher creep
- Higher water cement ratio (more water, less cement) means less creep.
- Larger coarse aggregate means more creep

9.2 (Drying) Shrinkage

CSH, the main product of the hydration of Portland cement, is responsible for drying shrinkage

9.2.1 Things that Can Affect Drying Shrinkage

- A higher percentage of aggregate will decrease drying shrinkage due to the fact that, due to a higher percentage of aggregate, there is a smaller proportion of water to cause the shrinkage.
- Higher E causes less drying shrinkage

10 Durability of Concrete

For durability, **water** plays an important role. It is responsible for both *chemical* and *physical* causes of degredation. Extremely relevant to this is **permeability**: the property that governs the rate of flow of a fluid, in this case water, into a porous solid – our concrete. Below, we will discuss somethings that affect permeability.

10.1 Permeability

Most importantly, larger **aggregate size** leads to a higher coefficient of permeability because microcracks normally present in the interfacial transition zone between aggregate and the cement paste increase the coefficient of permeability, and larger aggregate size leads to a more pronounced interfacial transition zone.

Some other things affecting permeability:

- Water-cement ratio
- Amount of aggregate
- Volume of capillary voids
- Aggregate grading
- Drying shrinkage strains

10.2 Frost Action

Water expands when it freezes. If this occurs in small capillary pores, the ice crystals can damage the cement paste by pushing the capillary walls and by generating hydraulic pressure.

Adding entrained air voids can help. The provision of escape boundaries in the cement paste matrix is determined by the spacing of entrained air and the size of the air bubbles themselves (not necessarily the actual amount). Ensuring escape areas with air entrainment gives the frost a place to go for pressure relief, thus reducing damage due to it having nowhere to go were there not air.

10.2.1 Reminder: How to Measure the Amount of Air in Concrete

To measure the amount of air in fresh concrete, one has to simply **add up the weights of all ingredients in the batch** and calculate how much volume they would take up with their bulk density. After making a trial batch, calculating the expected number of cubic feet per cubic yard (27) and *dividing the actual volume of the materials that were measured when making the batch by this number* and multiplying by 100 will give you the percentage of actual material (water, cement, coarse aggregate, and fine aggregate) in the concrete mix. Subtracting this number from 100 will give you the remainder of what is taking up the volume, which, naturally, is air.

10.3 Burn, Baby, Burn: Fire

When exposed to a fire, the **compressive strength of concrete drops**. This is due largely to *microcracks* that form. However, there are factors that can influence how much compressive strength is lost. *If the concrete is loaded in compression, strength loss can be up to **25 percent higher*** than if the concrete is unloaded. Aggregate type can also influence how much strength is lost.

10.4 ElectroChemical Process of Steel Corrosion in Concrete

Requires both Water and Oxygen. Therefore, steel corrosion depends on relative humidity. However, more humidity doesn't always equal no corrosion. If relative humidity is at 100 percent, that means it is literally submerged in water and therefore has no oxygen present to complete the reaction. The maximum corrosion occurs at around 80-85 percent.

Therefore, reducing the w/c ratio will reduce corrosion. The electrochemical process, however, requires both an anodic and a cathodic process.

10.4.1 Cathodic Process

The cathodic process is when O2 and H2O from the environment combine with electrons from the iron oxide to produce 4 hydroxide ions (OH-). The reaction can be written as follows:

O2 + H2O + 4e- $\rightarrow$ 4OH-

10.4.2 Anodic Process

The anode process occurs when the iron (Fe) oxide sheds two of its electrons (which are then used in the cathodic reaction), becoming Fe++. The reaction can be written as follows:

Fe $\rightarrow$ Fe++ + 2e-

10.5 Alkali Silica Reaction

Leads to cracking and occurs as follows:

1. The high pH in the cement paste promotes the hydrolysis of silica:

   Si-O-Si + H OH $\rightarrow$ Si-OH + Si-OH

2. Si-OH react with the paste to form Si-O-
3. Si-O-, adsorbs Na, K, and Ca to form a gel.

10.6 How to Prevent Against this BooBoo

- Don't use reactive aggregate (especially **opal** – this is very vulnerable to attack)
- Use a cement with a low alkali (¡ 0.6 percent)
- Fly ash contains amorphous silicate and will cause the reaction during setting instead of later on when it will lead to cracking (think LeChatlier)

10.7 Sulfate Attack

11 Things he said might be on final during the semester

1. Why isn't martensite on a phase diagram? Because it's not a stable form, but is instead unstable perlite.
2. What is a simple field test to test tendenecy of a given concrete mix to bleed? Measure how deep the water is relative to the concrete.
3. Bleeding is a water surplus. Segregation is a water deficit.
4. Workability: The effort required to manipulate a concrete mixture with a minimum of segregation
5. For large aggregates, economics is a factor because there is more surface area that we need to cover with cement
6. Casting at a higher temperature and curing at al ower temperature is VERY BAD because the ultimate strength is lower over a long period of time
7. Poisson's ratio is **not** affected by w/c ratio!