Advanced Construction Materials

Midterm exam

Name:

Student ID number:

(Total 100 points, 150 minutes)

Problem # 1 (10 pts)

Calculate porosity of cement pastes with W/C ratios of 0.6, 0.5, 0.4, and 0.3. considering below conditions.

$100cm^3$ cement, cement density = 3.14 g/cm^3, degree of hydration = 100%

Problem # 2 (10 pts)

Based on Bogue's approximation, estimate clinker content in cement A.

Bogue's approximation

$\%C_3S = 4.07 \cdot CaO - 7.60 \cdot SiO_2 - 6.72 \cdot Al_2O_3 - 1.43 \cdot Fe_2O_3 - 2.85 \cdot SO_3$

$\%C_2S = 2.87 \cdot SiO_2 - 0.754 \cdot C_3S$

$\%C_3A = 2.65 \cdot Al_2O_3 - 1.69 \cdot Fe_2O_3$

$\%C_4AF = 3.04 \cdot Fe_2O_3$

Oxide composition of cement A from X-ray fluorescence (XRF) method.

SiO_2 = 21.1%

Al_2O_3 = 4.2%

Fe_2O_3 = 4.9%

CaO = 65.0%

SO_3 = 2.0%

Rest = 2.8%

Provide at least two practical problems of this estimation method. Can we solve the problems using X-ray diffraction (XRD) technique? Then explain.

Problem # 3 (20 pts)

An X-ray beam with a wavelength of 0.071 nm is diffracted on an aluminum sample. Aluminum crystal has the FCC structure with a lattice parameter for the conventional simple cubic unit cell of a = 4.05 Å. Find the four smallest diffraction angles (2θ) with corresponding (h,k,l) index.

Problem # 4 (20 pts)

Materials of (A) and (B) consist of identical atom of carbon (C) but they have different crystal system. For the two materials of (A) and (B), calculate material characteristics of:

(1) packing density considering actual radius of atoms

(2) Unit cell weight considering atomic weight

(3) One sample is composed of mixing the two materials. If the ratio of diffraction intensities of (A) and (B) is 6:4, what is the relative weight in the sample?

	(A)	**(B)**
Bravais crystal system	FCC	BCC
Conventional lattice parameter, a	3 Å	3.5 Å
Atomic diameter	1 Å	1 Å
Atomic weight	12 g/mol	12 g/mol

Problem # 5 (20 pts)

Below figure shows thermal gravimetric analysis (TGA) result of ultra-high performance concrete (UHPC) with calcite ($CaCO_3$) substitution. Among total five samples, only LP0 does not contain calcite. Other four samples of LP1, LP2, LP3, and LP4 contain different amounts of calcite. Based on the weight loss plot (top figure) determine the substitution ratio of calcite in each 4 samples.

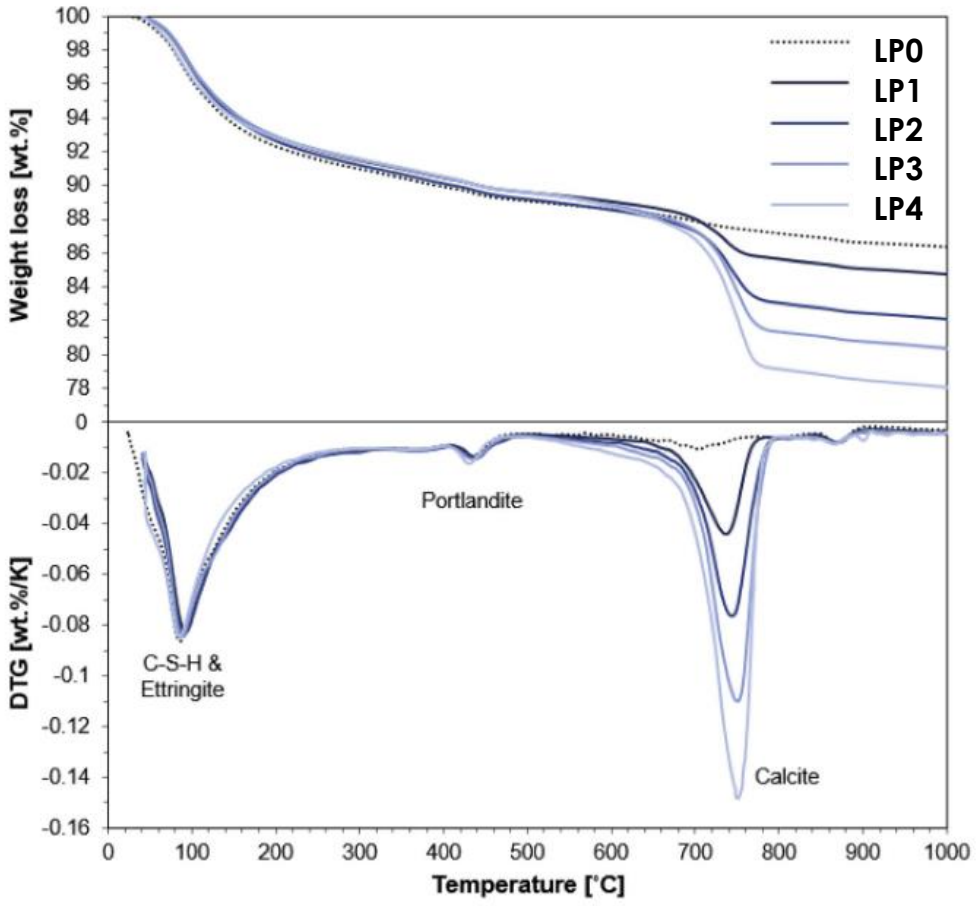
Calcite thermal decomposition: $CaCO_3$ -> CaO + CO_2 at 700-800˚C

Atomic weights of Ca, C, and O are 40, 12, and 16, respectively.

Compare the obtained substitution ratio for all samples after normalization to anhydrous content.

Mass of chemically bound water = 100% - Mass of dry solids

Mass of dry solids = determined as a mass at 600 ˚C



Problem # 6 (20 pts)

Quantitative X-ray diffraction (QXRD) was performed on binary cement consisting of 60% C_3S and 40% C_2S. To consider the amount of amorphous material of C-S-H, internal standard method was adopted by mixing 15wt.% of TiO_2 in total weight of measured sample after removing free water. Thus prepared samples for XRD do not contain free water. They consist of 15wt.% of TiO_2 and 85wt.% of sum of unreacted cement and cement hydrates.

Anticipated chemical reactions from C_3S and C_2S are:

C_3S + water -> C-S-H + CH

C_2S + water -> C-S-H + CH

C-S-H is non-crystalline phase (X-ray non-detectable), CH is $Ca(OH)_2$.

Thermal gravimetric analysis (TGA) was also performed for quantification of chemically bound water (BW). Mass of bound water (BW) was determined by (100%-mass% of solid at 600˚C)

At 28 days of curing age (hydration), the QXRD gives quantitative phase analysis result shown below.

C_3S = 23%, C_2S = 4%, CH = 17%, TiO_2 = 56%, Total sum = 100%

With chemically BW content of 29% at the 28 days, what is the phase quantity normalized to anhydrous content?