Concrete:
Mixing and Testing

Objectives

- Learn the ASTM Standard for hand mixing
- Understanding the time dependency of concrete properties
- Learn how to conduct the mechanical and durability testing
- Learn the effects of fly ash
- Effects of w/c on workability, electrical measurements, and strength
- Learn the principles of isothermal calorimeter testing
- Learn an application of Power's Gel Space Ratio Theory

Outline

- Mixtures
- Sample Preparation
- Mixing & Placement
- Conditioning
- Hardened Testing Procedures
- Calorimetry Testing
- Powers Model
- Report

Mixtures

w/c=0.36

w/c=0.36, 40 % Fly Ash

We will distribute the data for these mixtures

w/c = 0.3

w/c=0.3 w/o WRA

w/c=0.36

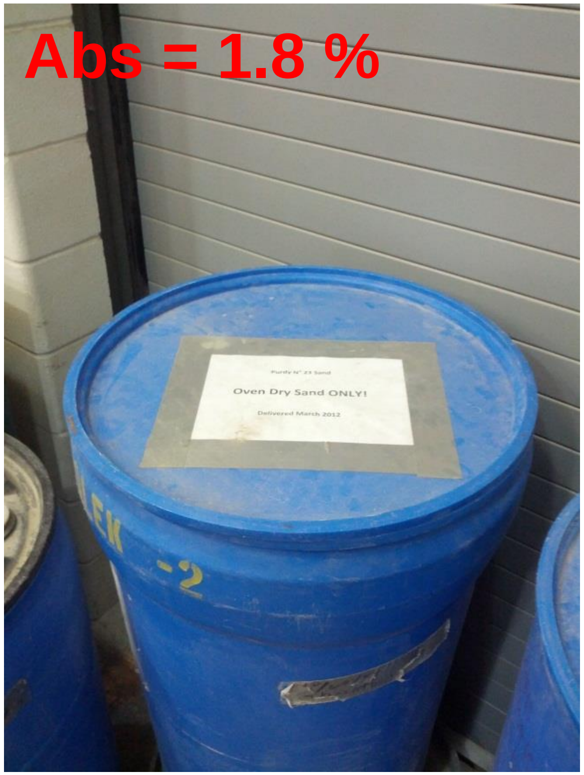
w/c=0.42

w/c=0.6

You will make these mixtures in the lab

Mixtures are 30% fine aggregate, 30% coarse aggregate by volume
There will be a water reducing admixture as well

Materials



We will use oven dry aggregate and increase the mix water to correct for absorption

Sample Preparation

Prepare a label with your lab section and mixture number

Mixing Procedure

1. Assemble Mixing Equipment

We will be utilizing the hand-mixing procedure described in ASTM C192

Mixing Procedure

2. Measure materials with the mixture design your group is given in class.

3. Mix cement and fine aggregate

We will be utilizing the hand-mixing procedure described in ASTM C192

Mixing Procedure

4. Mix in the coarse aggregate

5. Slowly mix in the water and chemical admixtures

We will be utilizing the hand-mixing procedure described in ASTM C192

Placing Procedure

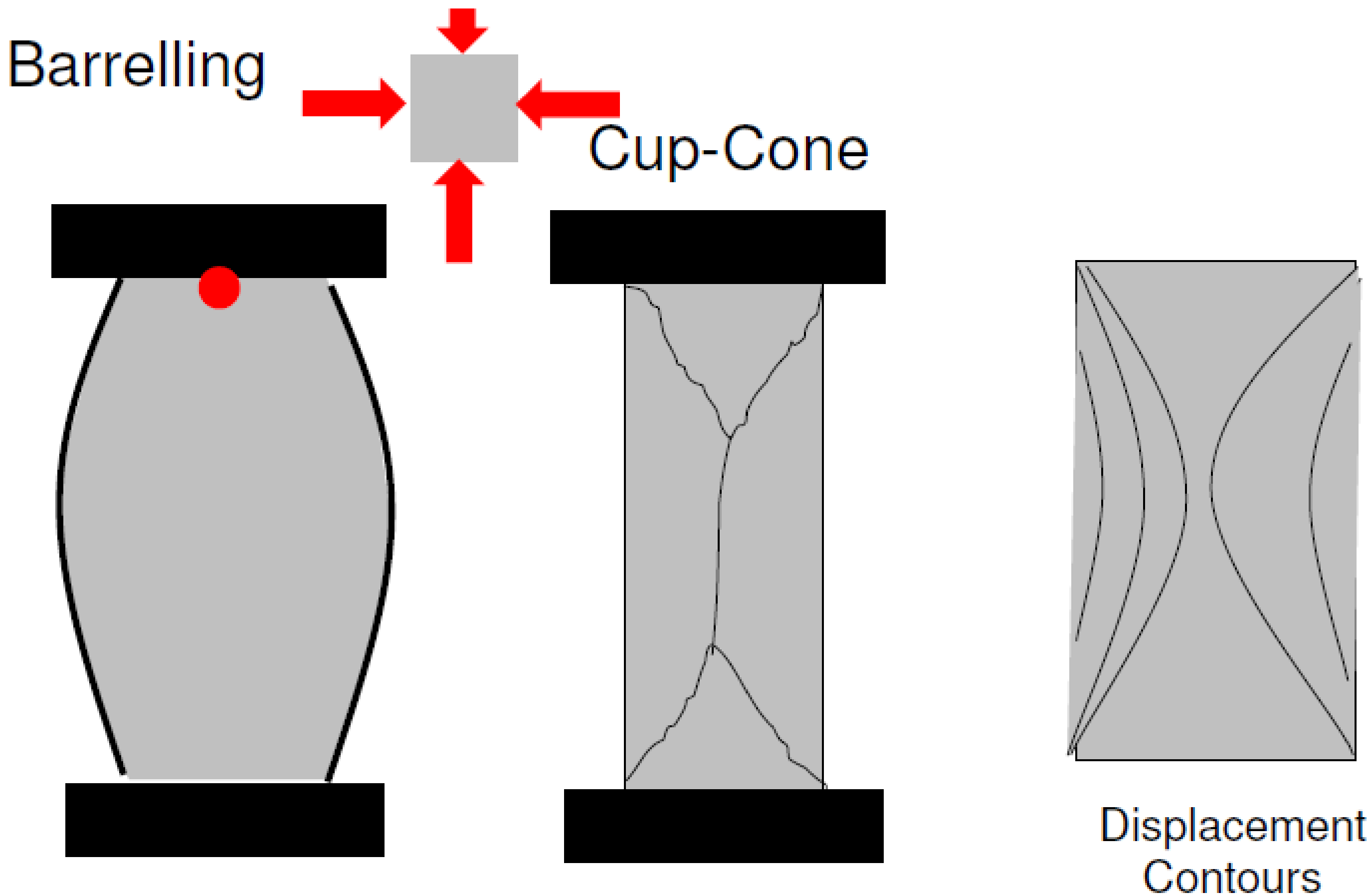
- Fill your 3x6 cylinders in 3 equal layers, rod each 25 times

- Each group should make

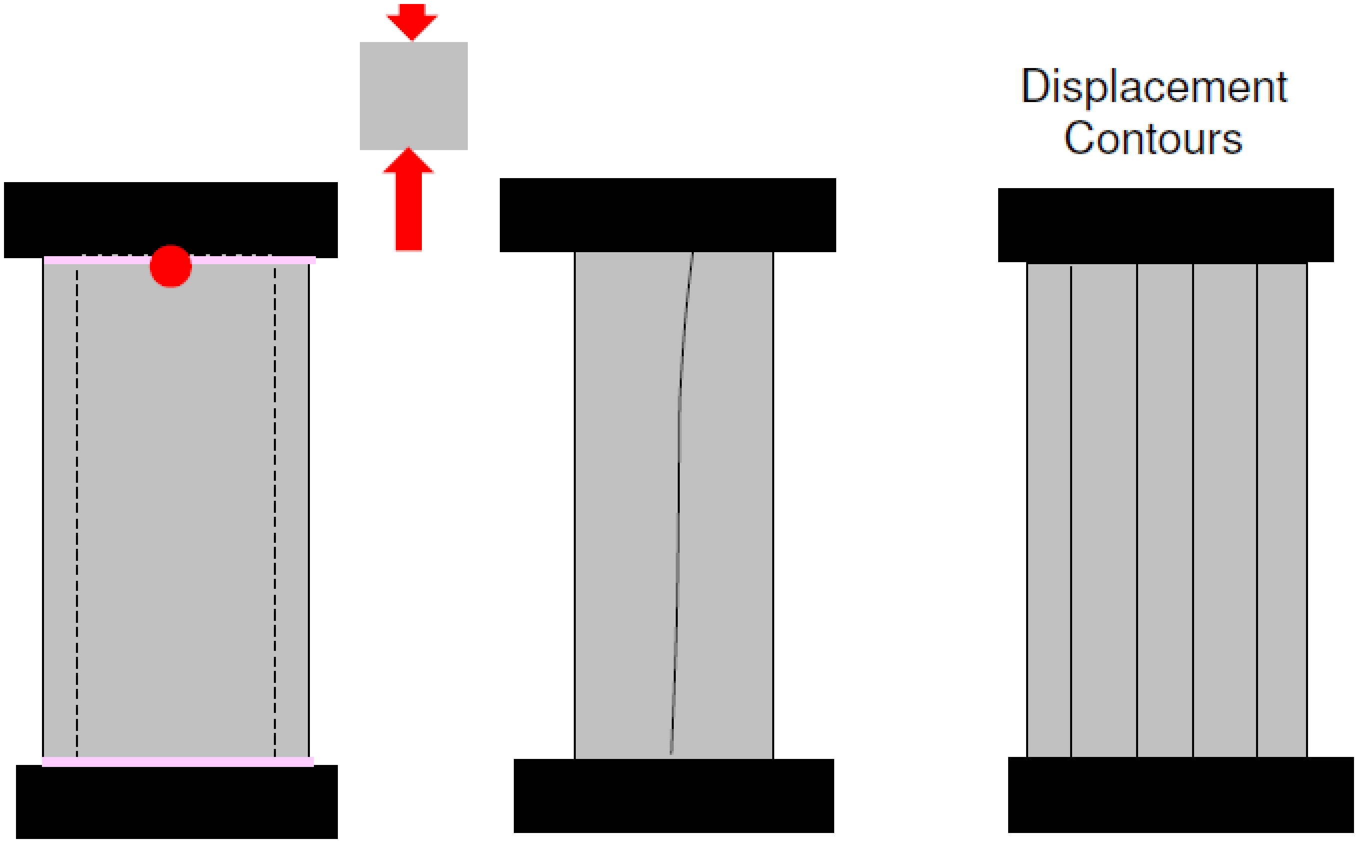
  3— 3x6s

- Clean and dispose of excess materials

Compression Testing w/ Friction



Compression Testing w/o Friction



We will use neoprene caps smooth the ends and ensure uniform stress

Compression Testing

Forney 700 kip compression machine in Pankow Laboratory

$$\boxed{f'_c = \frac{\mathbf{P}}{\mathbf{A}}}$$

A is cross-sectional area

We are using a 3” diameter cylinder

Electrical Resistivity Testing

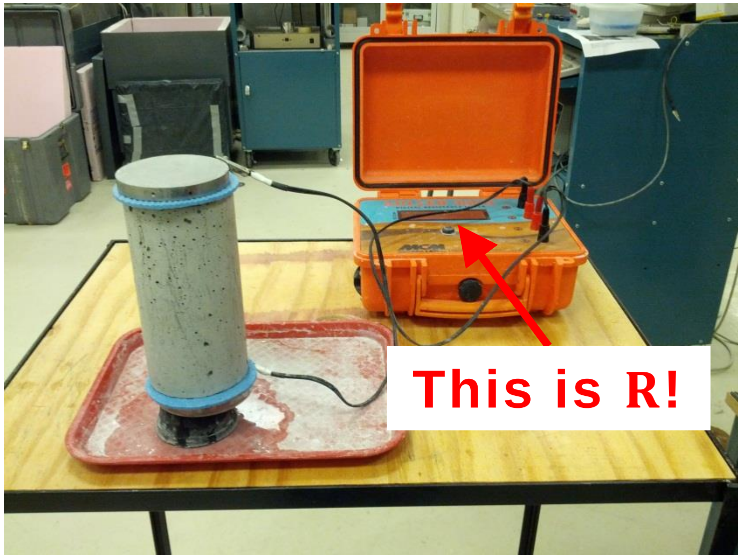
An upcoming and popular rapid test to give an indication of durability

$$\boxed{\rho = \mathbf{R}\mathbf{k}}$$

Electrical Resistivity

Resistance (measured in lab)

Geometry Factor (A/L)



Electrical Resistivity

Resistivity is a measure of electrical resistance independent of geometry, units of ohm-m ($\Omega \cdot \mathrm{m}$)

Concrete is a porous composite

- Solid Phase (reactancts, products, and aggregates)

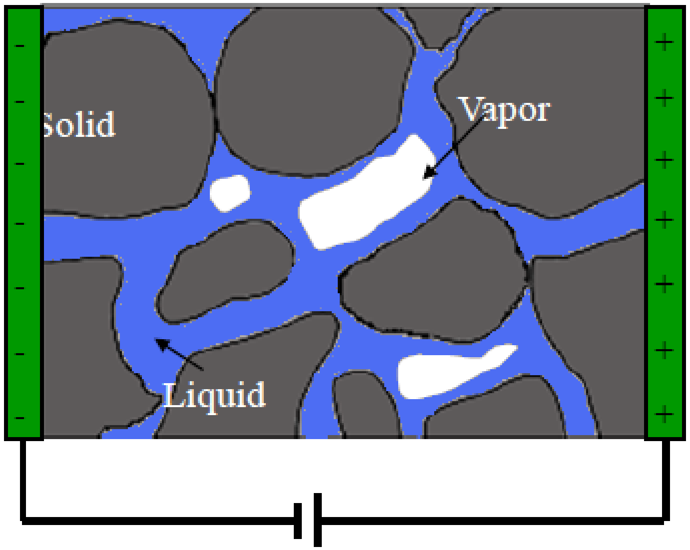
  $\rho_{solids} \approx 10^9\ \Omega \cdot \mathrm{m}$

- Vapor Phase

  $\rho_{vapor} \approx 10^{15}\ \Omega \cdot \mathrm{m}$

- Liquid Phase (pore solution)

  $\rho_{liquid} < 1\ \Omega \cdot \mathrm{m}$

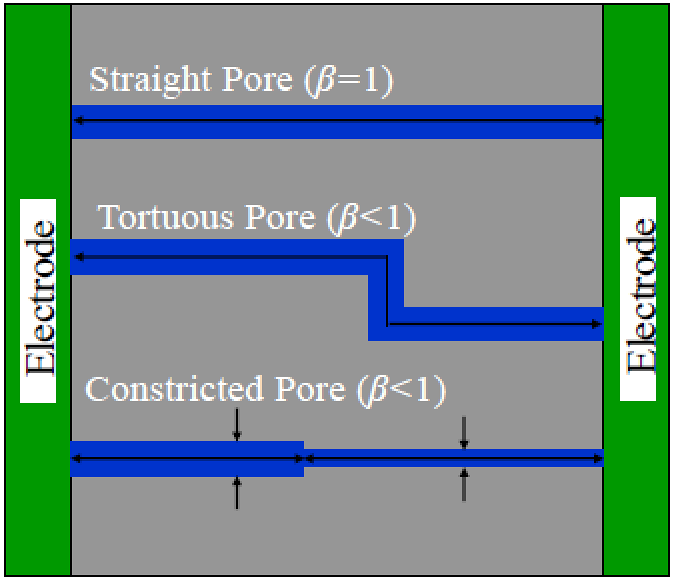


Electricity is conducted primarily through the liquid

Weiss ('05), Rajabipour ('06)

Electrical Resistivity

$$\rho = \rho_0 \frac{1}{\phi\beta} = \rho_o \mathrm{F}$$



Weiss ('05), Rajabipour ('06)

ρ_{bulk}: resistivity (easily measured)

ρ_0: pore solution (model/experimental data)

ϕ: liquid volume fraction
β: connectivity(related to pore distribution)
F: Formation Factor

These parameters can be used to quantify the durability of a mixture

These tests are highly dependent on moisture content and temperature!

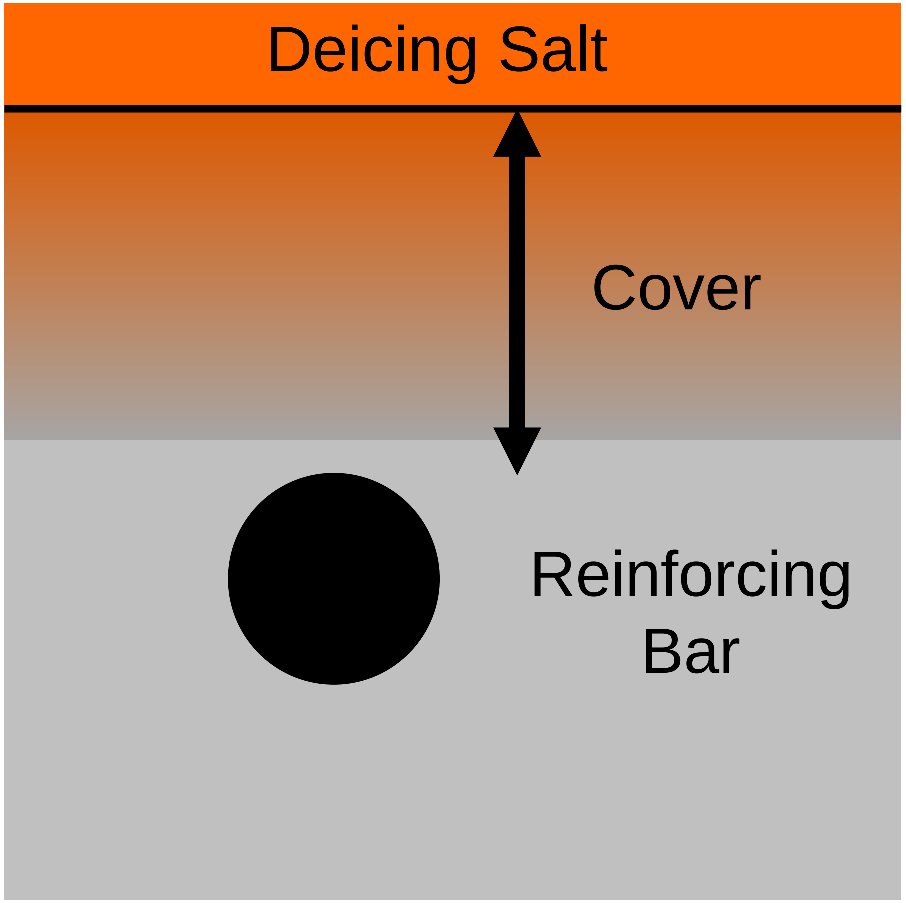
Formation Factor

Deicing salts -> pavements and bridge decks

Salt (Cl-) and steel = corrosion

We need to know how the Cl- moves through the concrete

Main parameter is the "Diffusion Coefficient" which describes the speed



<u>Nernst-Einstein</u>

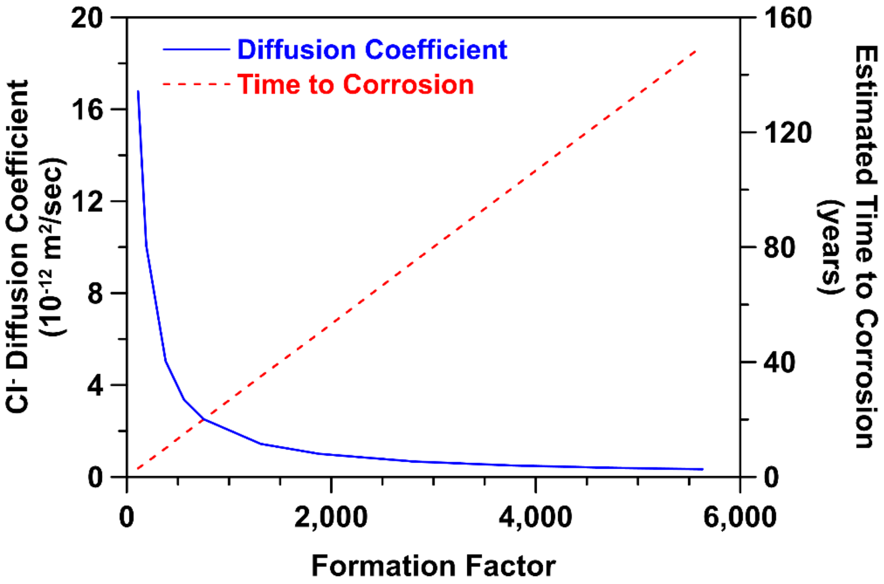
$$\mathrm{D} = \frac{1}{F} \cdot constant$$

Formation Factor

The diffusion coefficient can be used to estimate the time to reach a critical concentration level $C_{x,t}$:

$$\frac{C_{x,t} - C_o}{C_s - C_o} = 1 - \mathrm{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

(with a few assumptions that you will discuss later in the semester)



Steel depassivation and corrosion can begin when this reaches a critical level

Cement hydration

Calcium Silicates

$$2C_3S + 6H \rightarrow C_3S_2H_3 + 3CH$$

$$2C_2S + 4H \rightarrow C_3S_2H_3 + CH$$

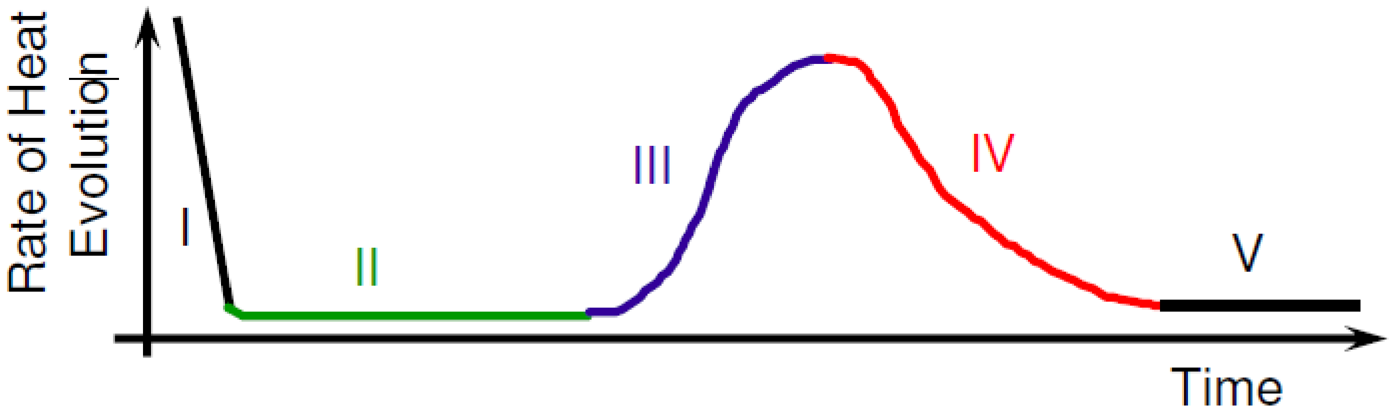
Tricalcium Aluminates

$$C_3A + 3C\overline{S}H_2 + 26H \rightarrow C_6A\overline{S}_3H_{32}$$

CE530 slides

Cement hydration is an exothermic reaction.

Five stages in cement hydration by heat



Stage I	Rapid Heat Evolution		(<15 mins)
Stage II	Dormant Period	Important for transportation	(2-4 hrs)
Stage III	Accelerating Stage	Begins with initial set	(4-8 hrs)
Stage IV	Deceleration Stage	No longer workable	(12-24 hrs)
Stage V	Steady State		

CE 530 slides

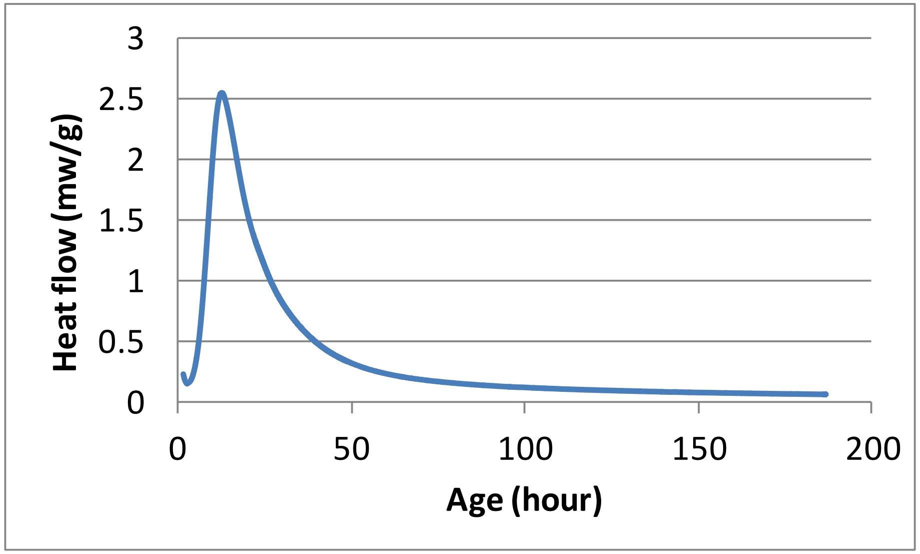
Isothermal calorimetry

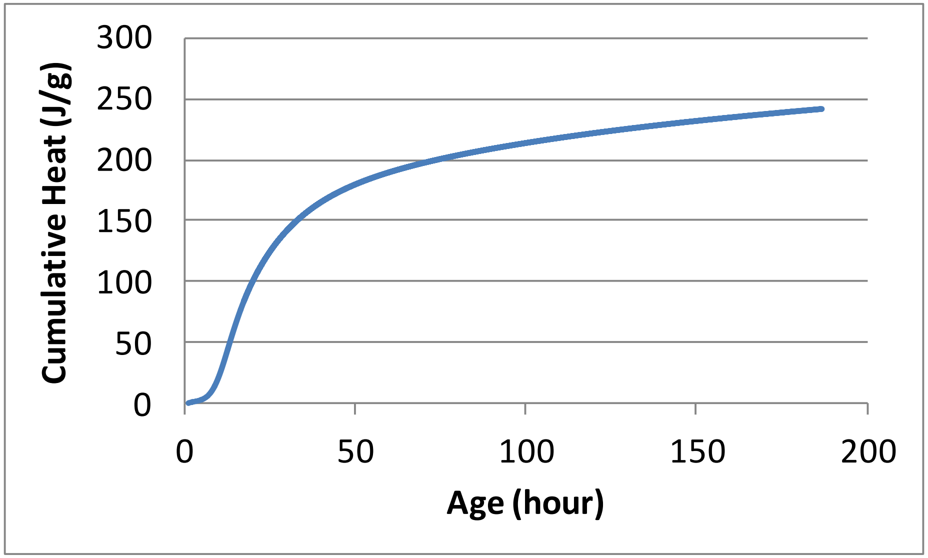
- A good method for the study of cement hydration process.
- Relevant standards include ASTM C186 and ASTM C1702
- Widely used for studying the reaction kinetics of pure cement pastes as well as the temperature dependence of the reaction.
- Degree of hydration can be determined by calorimetry.
- Q(max) is determined from the chemical composition of the materials

$$\mathrm{DOH(calo)} = \frac{\mathrm{Q(t)}}{\mathrm{Q(max)}}$$

For the raw materials in this lab:
Q(max) cement: 512 J/g cement

Heat flow and cumulative heat

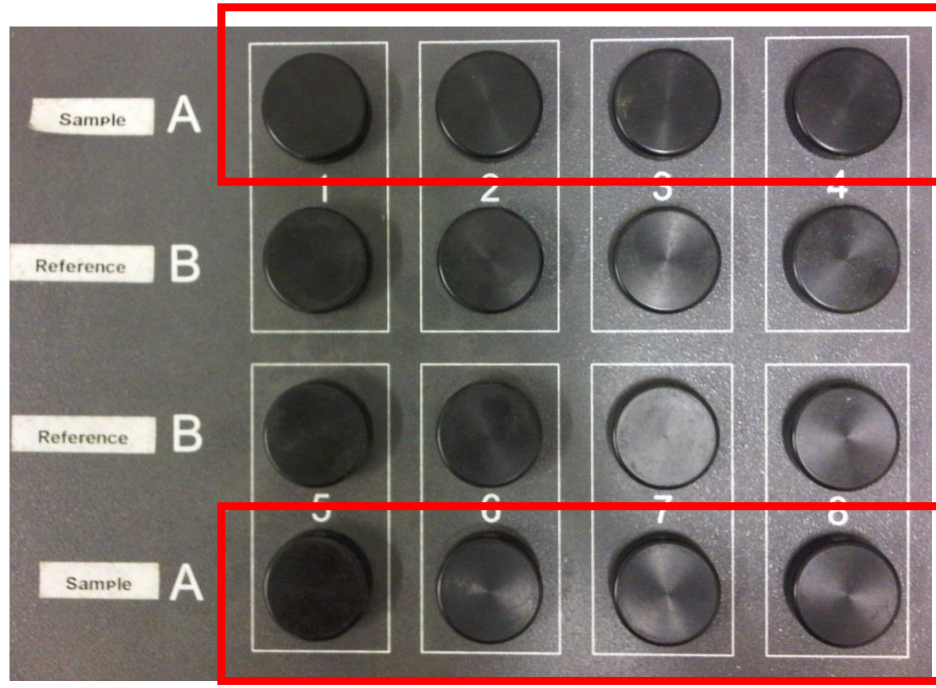




In general one test generates two plots: heat flow and cumulative heat.
They are intrinsically the same data. Cumulative heat is an integral of heat flow on time.

TAM air

8 samples in total



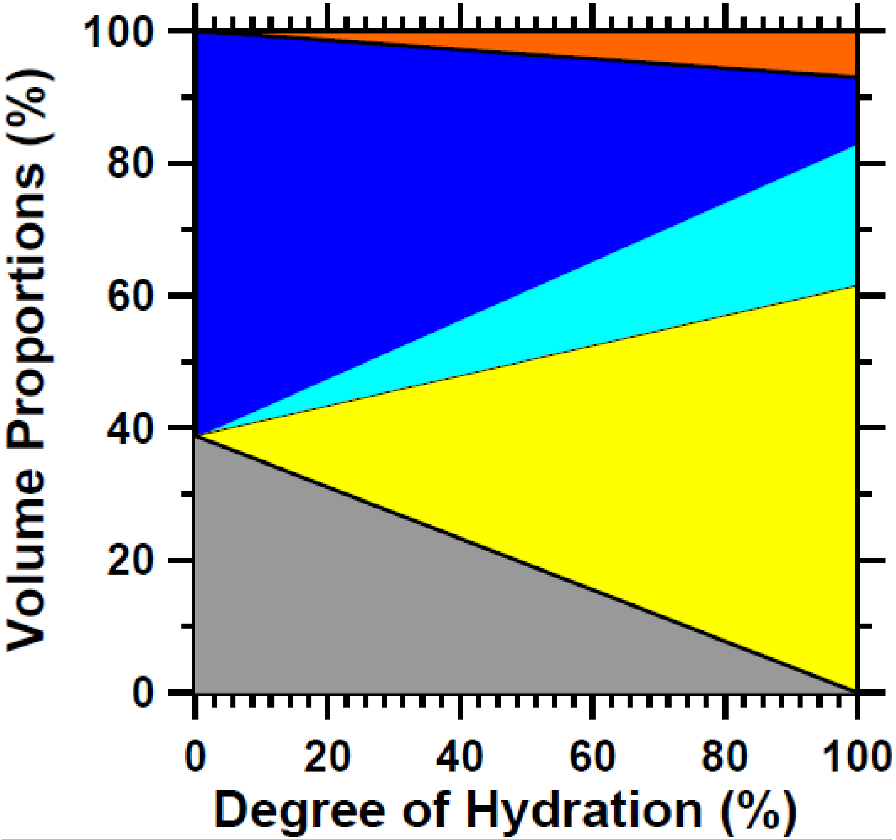
Ampoules

Powers Model

A simple yet effective model that can be used to describe the microstructure of hydrating cement

Inputs

- water-cement ratio (w/c)
- degree of hydration (α)



This is an example for a w/c=0.5

Powers Model - Calculations

You can program the equations or use spreadsheet on website

For the Maximum DOH in N6 Use Solver set N10 to 0 by changing N6

w/c	0.36	~											
density of water	1000	kg/m3											
density of cement	3150	kg/m3											
Initial Porosity (p)	0.53	--											
Calculations													
Degree of Hydration (0 to1)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1		0.87
Volume of Chemical Shrinkage	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.07	0.08	0.09		0.08
Volume of Gel Water	0.00	0.03	0.06	0.08	0.11	0.14	0.17	0.20	0.22	0.25	0.28		0.25
Volume of Hydrated Solid (Gel Solid)	0.00	0.07	0.14	0.21	0.28	0.35	0.42	0.49	0.56	0.63	0.70		0.61
Volume of Capillary Water	0.53	0.47	0.41	0.35	0.29	0.23	0.17	0.10	0.04	-0.02	-0.08		0.00
Volume of Cement	0.47	0.42	0.37	0.33	0.28	0.23	0.19	0.14	0.09	0.05	0.00		0.06
Total Volume	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00

Report

- Three weeks of lab work will be in this report
- Worth twice as much as previous write-ups
- Sections
  - Executive Summary (15 %)
  - Introduction and Background (10 %)
  - Materials and Methods (10 %)
  - Results and Discussion (50 %)
  - Summary and Conclusions (15 %)

Report

Introduction and Background

- Brief description of the **main concepts** being investigated
- Present appropriate equations and/or figures
- Use sources such as books, lecture notes, etc and cite them!

Remember, It Is About Concept And Theory,
NOT Lab Procedure Or Results!

Report

Materials and Methods

- What materials did we use? Be specific
- Describe the following procedures in your own words:
  - Mixing
  - Strength Testing
  - Electrical Testing
  - Isothermal Calorimetry

Report

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Report

Results and Discussion

Strength

- f_c' vs age for the plain and fly ash concrete
- f_c' vs w/c for the class mixtures

Resistivity

- ρ vs age for the plain and fly ash concrete
- ρ vs w/c for the class mixtures

Comment on trends and observations

Check units, captions, and legends

Hint: This section is the most important part of a lab report

Report

Results and Discussion

Isothermal Calorimetry

- Heat flow vs age
  - Identify the regions discuss in class
- Cumulative heat vs age
- Degree of hydration vs Age

You will be given data for three mixtures of differing *w/c*

Comment on trends and observations

Check units, captions, and legends

Hint: This section is the most important part of a lab report

Report

Results and Discussion

Powers' Model

– Prepare a figure of capillary porosity vs DOH for the 3 mixtures analyzed for calorimetry

Qualitative Comparison of the workability of the different mixtures

Comment on trends and observations

Check units, captions, and legends

Hint: This section is the most important part of a lab report

Report

Summary and Conclusions

- Summarize the experiments
- Mention the **Main Conclusions**
- Clear and Concise

There will be a rubric posted

Lab Schedule

3/5	Mixing in Lab
3/12	Analyzing Data
3/19	Spring Break
3/26	Hardened Testing
	Lab Reports Due by 4/2/15