



**American Concrete Institute®**  
*Advancing concrete knowledge*


**Technical Session in Honor of  
 Tony Fiorato, Part 1(B)**

ACI Spring 2010 Xtreme Concrete Convention  
 March 21 - 25, Chicago, IL

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**ACI Web Sessions**

The audio for this web session will begin momentarily and will play in its entirety along with the slides.

However, if you wish to skip to the next speaker, use the scroll bar at left to locate the speaker's first slide (indicated by the  icon in the bottom right corner of slides 9 and 65). Click on the thumbnail for the slide to begin the audio for that portion of the presentation.

**Note:** If the slides begin to lag behind the audio, back up one slide to re-sync.

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ACI is bringing you this Web Session in keeping with its motto of "Advancing Concrete Knowledge." The ideas expressed, however, are those of the speakers and do not necessarily reflect the views of ACI or its committees.

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ACI Web Sessions are recorded at ACI Conventions and other concrete industry events. At regular intervals, a new set of presentations can be viewed on ACI's website free of charge.

After one week, the presentations will be temporarily archived on the ACI website or made part of ACI's Online CEU Program, depending on their content.

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ACI offers an easy-to-use Online CEU Program for anyone who needs to earn Continuing Education credits.

Once registered, you can download and study reference material. After passing a 10-question exam on the material, you will receive a certificate of completion that you can present to local licensing agencies.

Topics recently added to the program:

- RAP Bulletin 10: Leveling and Reprofileing of Vertical and Overhead Surfaces
- RAP Bulletin 11: Slabjacking
- RILEM Report on Self-Compacting Concrete (Parts 1 and 2)



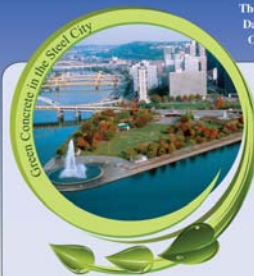
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ACI Fall 2010 Convention

**Pittsburgh**

The Westin Convention Center Hotel & David L. Lawrence Convention Center  
 October 24-28, 2010 • Pittsburgh, PA



ACI Conventions are dedicated to improving the design, construction, maintenance, and repair of concrete structures by offering 30+ committee meetings, 30+ technical and educational sessions, a number of networking events, and the opportunity to visit with exhibitors.

To coincide with the growing focus on "green" building practices, ACI has tailored numerous aspects of this fall's convention to place emphasis on sustainability. Learn about the methods for reducing environmental impact and increasing the efficiency of concrete during committee meetings, sessions, and other events at the ACI Fall 2010 Convention. For more information and to register, visit [www.aciconvention.org](http://www.aciconvention.org)


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## ACI Web Sessions

This ACI Web Session includes 2 speakers presenting at the ACI Xtreme Concrete convention held in Chicago, IL, March 21<sup>st</sup> through 25<sup>th</sup>, 2010.

Additional presentations will be made available in future ACI Web Sessions.

Please enjoy the presentations.



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## Technical Session in Honor of Tony Fiorato, Part 1(A)


ACI Spring 2010 Xtreme Concrete Convention  
March 21 - 25, Chicago, IL



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ACI Fellow **Ronald Burg** is the incoming Executive Vice President of ACI. Prior to joining ACI, he was Vice President at CTLGroup in Skokie, IL. He is an expert in research and development of concrete materials technology and has managed multi-disciplinary research and consulting projects. He has also served as an expert witness on cases concerning concrete performance, fire resistance of industrial and commercial buildings, and construction material failures. Mr. Burg received a B.S. in Civil Engineering from Iowa State University, and is a registered professional engineer in several states. He received the Frank G. Erskine Award “Outstanding Contribution to the Use of Lightweight Aggregate” from the Expanded Shale, Clay and Slate Institute, and the Leonard C. Wason Award for Materials Research “Compressive Testing of HSC: Lateral Technology,” from ACI.




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## Technical Session in Honor of Tony Fiorato

### Evaluation of Pre-test Moisture Conditioning of Concrete Cores on Measured Compressive Strength


ACI – Convention  
March, 2010  
Ronald Burg, P.E.  
CTLGroup



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## Program Objective


Evaluate the effect of pre-test core conditioning on the measured compressive strength of concrete cores in light of test standards and code requirements.



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## Program Features

- ↪ Joint PCA/NRMCA effort
- ↪ PCA Funding, - \$70,000
- ↪ NRMCA – In kind labor support
- ↪ Outside funding
  - CRC - \$20,000
  - Coring industry - \$5,000



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## Some Factors Affecting Core Strengths...

- ↪ Core size
- ↪ Location of core
- ↪ Direction of coring
- ↪ Length/Diameter ratio
- ↪ End preparation
- ↪ Embedded steel
- ↪ *Moisture conditioning*



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## Core Conditioning Standards



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## Test “Standards”

- ↪ ASTM C 42
- ↪ ACI 318
- ↪ ACI 301



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## ASTM C 42-94

- ↪ Section 6.3 – Soak cores in lime saturated water for at least 40 hr immediately prior to test and keep wet until test
- ↪ Section 6.3.1 – Specifying authority can direct other conditioning: ACI 301 chapter 17, ACI 318 chapter 5



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## Core Conditioning (ACI 318-99)

- ↪ If structure dry in service, air dry cores at between 60 and 80°F and < 60% RH for 7 days and test dry.
- ↪ If structure more than “superficially” wet in service, immerse cores in water for at least 40 hr and test wet.



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## Core Conditioning (ASTM C42-99)

### 7.3 Moisture Conditioning

“Test specimens shall be tested in a moisture condition representative of the in-place concrete or as directed by the specifying authority.”

7.3.1 If the concrete service condition is dry, the cores can be tested in either an “as received condition” or in a “dry condition.”

7.3.4 See ACI 318, Chapter 5


7.4 Cap in accordance with ASTM C 617.



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### “As-Received Condition” (ASTM C42-99)


- ↪ After drilling, transport cores to the testing laboratory within 24 hr.
- ↪ Dry the cores for 12 to 24 hr. in air between 60 and 80°F and < 50% RH
- ↪ Cap or grind the cores and test within 48 hr of receipt



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### “Dry Condition” (ASTM C42-99)


- ↪ Air dry at between 60 and 80°F and < 60% RH
- ↪ Dry for seven days



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### Core Conditioning (ACI 318-05)


5.6.5.3 — Cores shall be prepared for transport and storage by wiping drilling water from their surfaces and placing the cores in watertight bags or containers immediately after drilling. Cores shall be tested no earlier than 48 hours and not later than 7 days after coring unless approved by the registered design professional.



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### Core Conditioning (ACI 318-08)


5.6.5.3 — Cores shall be obtained, moisture conditioned by storage in watertight bags or containers, transported to the laboratory, and tested in accordance with ASTM C42. Cores shall be tested no earlier than 48 hours and not later than 7 days after coring unless approved by the licensed design professional. The specifier of tests referenced in ASTM C42 shall be the licensed design professional.



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### Core Conditioning ASTM C 42-04


7.3 *Moisture Conditioning*—Test cores after moisture conditioning as specified in this test method or as directed by the specifier of the tests. The moisture conditioning procedures specified in this test method are intended to preserve the moisture of the drilled core and to provide a reproducible moisture condition that minimizes the effects of moisture gradients introduced by wetting during drilling and specimen preparation.



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### Core Conditioning ASTM C 42-04

7.3.1 After cores have been drilled, wipe off surface drill water and allow remaining surface moisture to evaporate. When surfaces appear dry, but not later than 1 h after drilling, place cores in separate plastic bags or nonabsorbent containers and seal to prevent moisture loss. Maintain cores at ambient temperature, and protect cores from exposure to direct sunlight. Transport the cores to the testing laboratory as soon as possible. Keep cores in the sealed plastic bags or nonabsorbent containers at all times except during end preparation and for a maximum time of 2 h to permit capping before testing.




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### Core Conditioning ASTM C 42-04

7.3.3 Allow the cores to remain in the sealed plastic bags or nonabsorbent containers for at least 5 days after last being wetted and before testing, unless stipulated otherwise by the specifier of tests.


NOTE 5—The waiting period of at least 5 days is intended to reduce moisture gradients introduced when the core is drilled or wetted during sawing or grinding.



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### Core Conditioning ASTM C 42-04


7.3.4 When direction is given to test cores in a moisture condition other than achieved by conditioning according to 7.3.1, 7.3.2, and 7.3.3, report the alternative procedure.



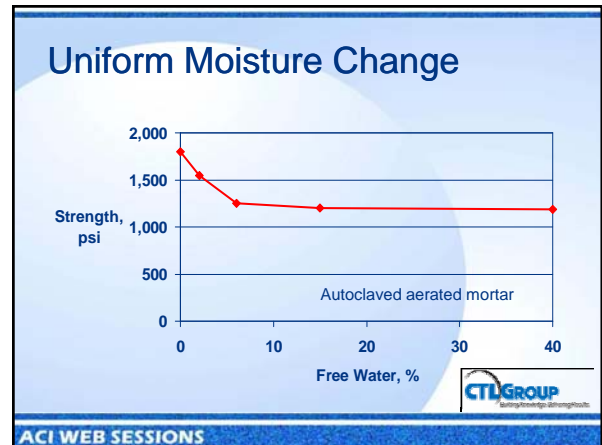
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### Effects of Conditioning

- Changes internal moisture content
- Changes internal moisture distribution




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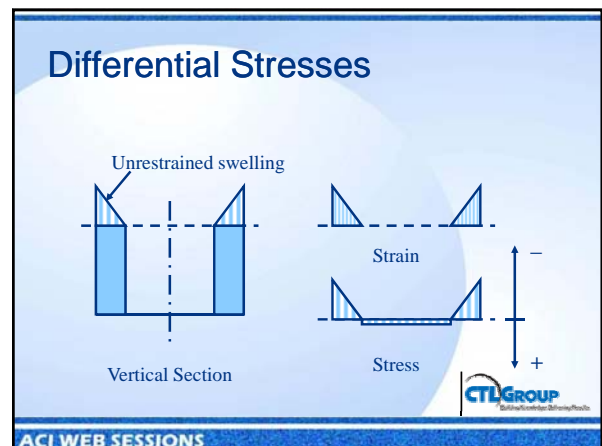
### Nonuniform Moisture Changes

Moisture Profile

28 days  
90 days  
4 years



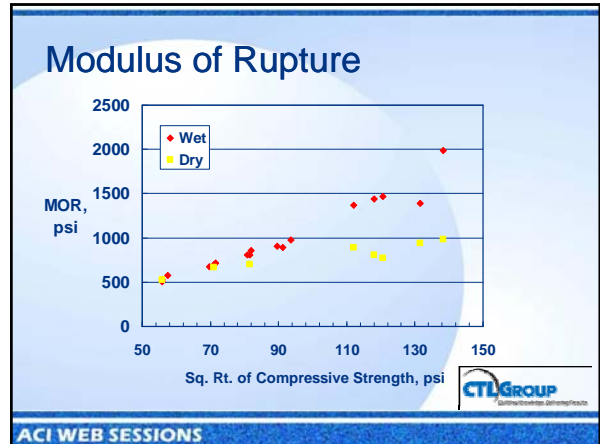
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## Flexural Strength



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## Test Program Details...

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## Phase I

- One concrete strength
  - Design strength - 4000 psi
- Cores taken from wall elements at 27 days
- Comparisons to moist-cured control cylinders
- Comparisons to companion cylinders "conditioned" same as cores

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## Variables

- Conditioning methods
  - Sealed in plastic bags after extraction
  - Air-dried at 73 F and 50% RH
  - Soaked
- Duration of conditioning
  - 1 to 56 days after coring

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## Phase II

- Two concretes to evaluate strength development and permeability effects
  - 4,000 psi portland cement mixture
  - 10,000 psi high-strength mixture
- Test age after coring (moisture equilibrium)
  - 8 hr to 180 days

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### Concrete Properties

Mix 1 - 4000 psi Design Strength (C+FA)

- Cement 390 pcy
- Fly ash 150 pcy
- w/cm = 0.47
- Slump = 7 in.
- Air content = 6.2%
- Unit wt. = 138.8 pcf
- Control cylinders (moist cured 28 days)
  - 4800 psi (4x8 in.)

(Contributed by Prairie Materials)



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### Concrete Properties

Mix 2 - 4000 psi Design Strength

- Cement 564 pcy
- w/c = 0.51
- Slump = 7 in.
- Air content = 1.2%
- Unit wt. = 147.3 pcf
- Control cylinders (moist cured 28 days)
  - 7090 psi (4x8 in.)

(Contributed by Prairie Materials)



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### Concrete Properties

Mix 3 - 10,000 psi Design Strength

- Cement 821 pcy
- Fly ash 150 pcy
- w/cm = 0.29
- Slump = 8 in.
- Air content = 0.9%
- Unit wt. = 150.3 pcf
- Control cylinders (moist cured 28 days)
  - 12,120 psi (4x8 in.)

(Contributed by Prairie Materials)



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### Casting Setup



4 ft. x 8 ft. x 8-in. wall elements



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### Wall Fabrication



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### Concrete for Cylinders



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### Casting Cylinders



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### Finishing and Curing Cylinders



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### Wall Conditioning



- Stripped forms at 7 days
- Stored at 73° F and 50% RH until cored at 27 days



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### Wall Coring



Cores taken in central 2x6 ft. section of each wall



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### Wall Coring



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### Wall Coring



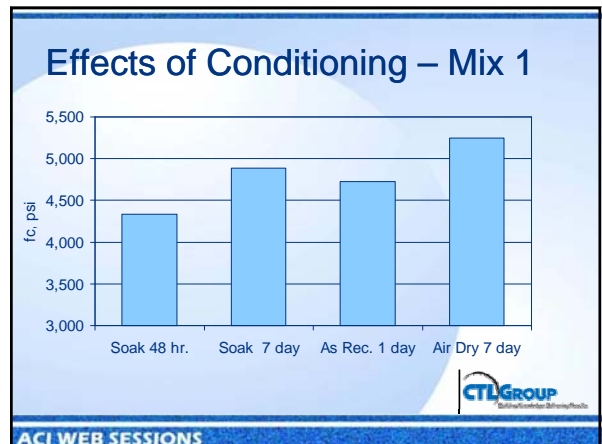
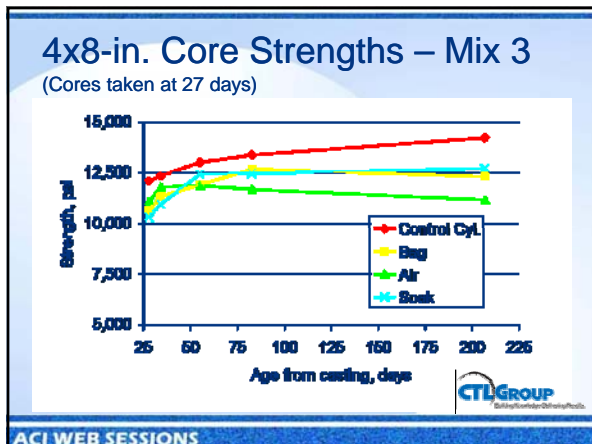
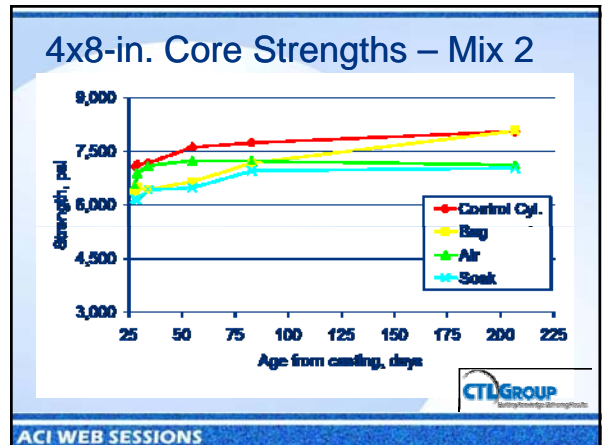
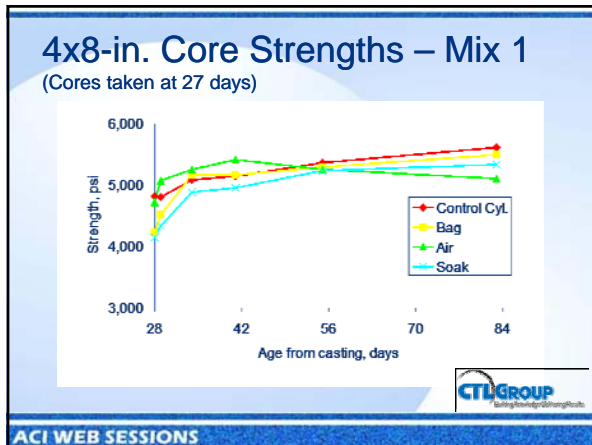
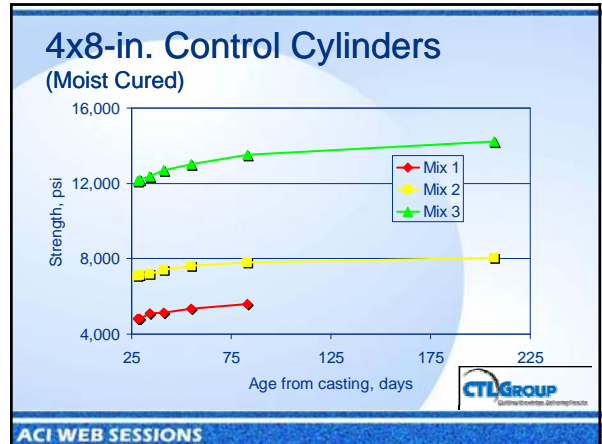
4-in. dia. cores



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## Test Results...

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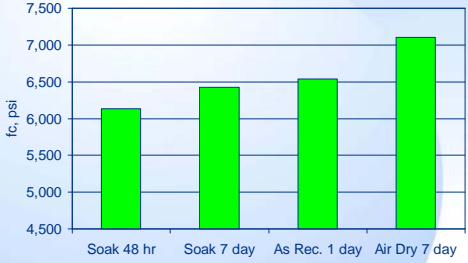
### Strength Change 1 to 7 Days (Mix 1 – 28 to 34 Days After Casting)

Condition	psi	%
Soaked Cores	745	18
Air Dry Cores	525	11
Bagged Cores	945	22
Control Cyl. (Moist Cure)	275	6




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### Effects of Conditioning – Mix 2




Condition	fc, psi
Soak 48 hr	~6,100
Soak 7 day	~6,400
As Rec. 1 day	~6,500
Air Dry 7 day	~7,100



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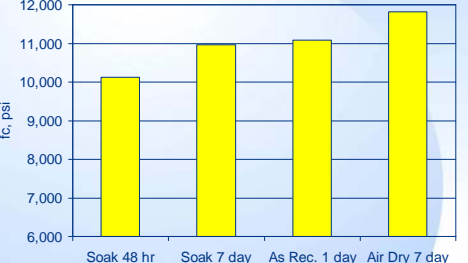
### Strength Change 1 to 7 Days (Mix 2 – 28 to 34 Days After Casting)

Condition	psi	%
Soaked Cores	260	4
Air Dry Cores	570	9
Bagged Cores	86	1
Control Cyl. (Moist Cure)	95	1




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### Effects of Conditioning – Mix 3




Condition	fc, psi
Soak 48 hr	~10,100
Soak 7 day	~11,000
As Rec. 1 day	~11,100
Air Dry 7 day	~11,800



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### Strength Change 1 to 7 Days (Mix 3 – 28 to 34 Days After Casting)


Condition	psi	%
Soaked Cores	1165	12
Air Dry Cores	725	7
Bagged Cores	700	7
Control Cyl. (Moist Cure)	560	5



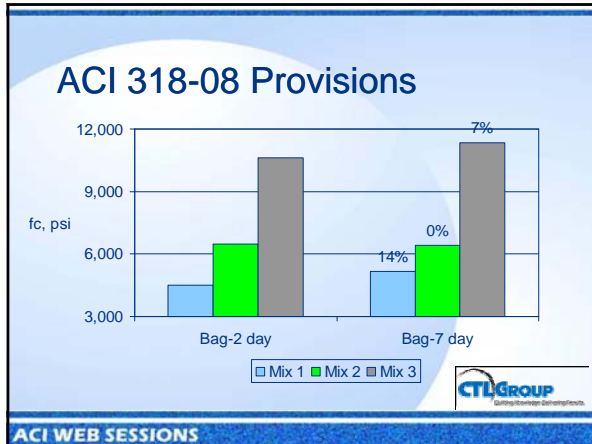
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### Core Conditioning (ACI 318-08)

**5.6.5.3** — Cores shall be obtained, moisture conditioned by storage in watertight bags or containers, transported to the laboratory, and tested in accordance with ASTM C42. Cores shall be tested no earlier than 48 hours and not later than 7 days after coring unless approved by the licensed design professional. The specifier of tests referenced in ASTM C42 shall be the licensed design professional.



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### Implications of Test Results

- Moisture conditioning has major impact on apparent compressive strength.
- Duration of conditioning is critical, especially first seven days.
- Core conditioning method should be agreed to prior to testing

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### In Summary

- Test plan should be established and agreed to by interested parties before coring.
  - Purpose of tests
  - Size and location of cores
  - Conditioning environment and duration
  - Basis for evaluation of results
- Testing vs. interpretation
- The "right" answer


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**Peter Taylor** is the Associate Director of the National Center for Concrete Pavement Technology at Iowa State University. He is a graduate of University of Cape Town in South Africa and has spent several years working in southern Africa. Mr. Taylor is a licensed Professional Engineer in Illinois and a member of ASTM Committee C9 and TRB Committees AFN30 and AFN40.

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### Effect of Cement Properties on Concrete Performance




Dr. Peter Taylor P.E. (IL)  
CP Tech Center  
Iowa State University

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### Can we predict concrete properties from cement characteristics?

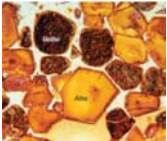

- Nope



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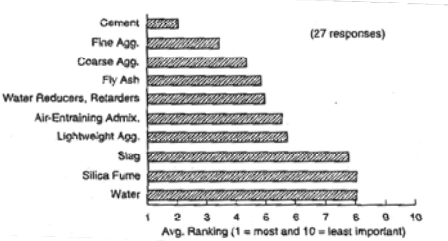
### Performance affected by:

- Cement chemistry and fineness
- Interactions of compounds
- Mixture proportions
- Workmanship
- Environment
- Color of observer's shirt

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### Is variability important?




(27 responses)

Avg. Ranking (1 = most and 10 = least important)

Most Important Least Important

ASTM STP 169 D




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### Cement Composition

- Variability

Type	C <sub>3</sub> S	C <sub>2</sub> S	C <sub>3</sub> A	Na <sub>2</sub> O <sub>e</sub>	SO <sub>3</sub>	Fine-ness
I	42-67	9-30	6-14	0.1-1.3	2.3-4.4	310-497
III	42-65	9-28	1-14	0.1-1.2	2.6-4.3	319-672
V	42-64	13-46	1-5	0.1-1.0	1.9-3.1	287-681

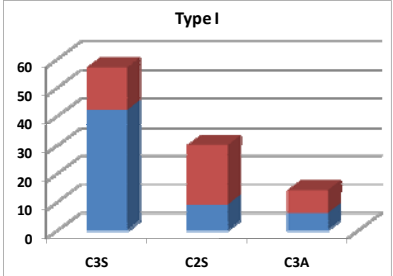
1998 data



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### Cement Composition

- Variability



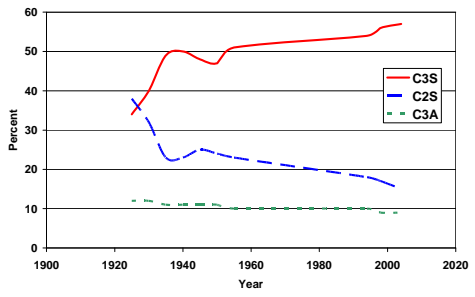
Type I

1998 data



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### Chemical Composition



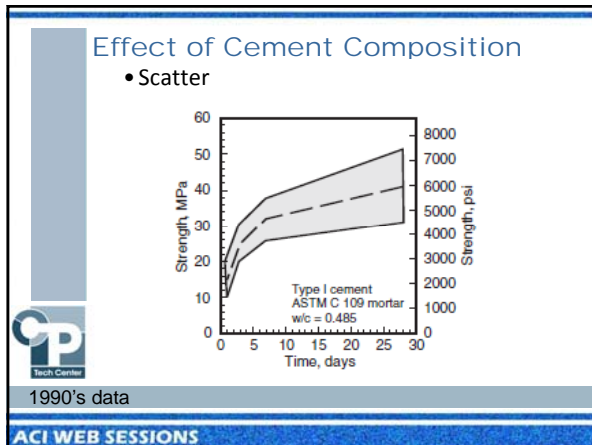
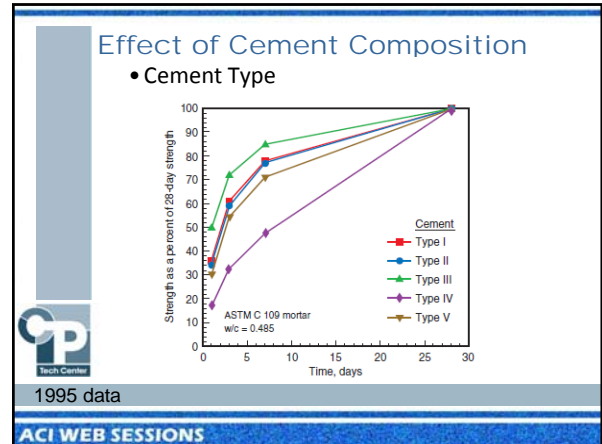
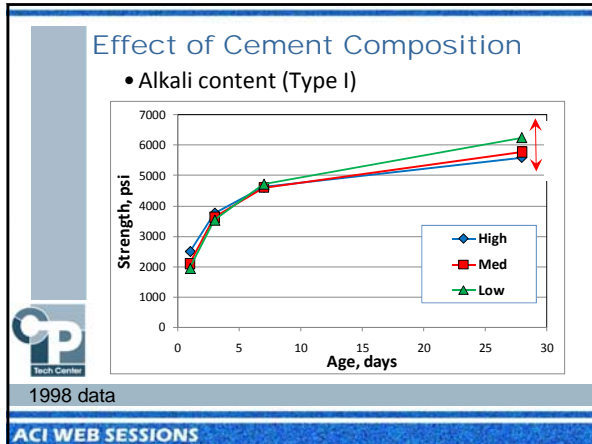
Percent

Year

— C<sub>3</sub>S  
— C<sub>2</sub>S  
— C<sub>3</sub>A



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### All things being equal...

- But they are not
  - The system is inter-related
  - Sulfates and alkalis move together
  - Fineness and gypsum are controlled together
- We can discuss trends

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### What Properties?

- Water requirement
- Setting
- Heat of hydration
- Strength development
- "Durability"

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### Workability



- Increases with
  - Decreasing  $C_3A$
  - Decreasing alkali
  - Decreasing fineness
- Paste content
- Aggregate gradation
- SCM type and dose
- Admixtures

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### Setting Time

- Increases with
  - Decreasing  $C_3S$
  - Decreasing  $C_3A$
  - Changing alkali
  - Decreasing fineness

w/cm  
SCM type and dose  
Admixtures






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### Early strength

- Increases with
  - Increasing  $C_3S$
  - Increasing  $C_3A$
  - Increasing alkali
  - Increasing fineness

w/cm  
SCM type and dose  
Admixtures






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### Potential Durability

- ASR – decrease alkalis
- Sulfate attack – decrease  $C_3A$
- Chlorides/corrosion – increase  $C_3A$
- Cold weather – increasing alkali increases air entrainment



w/cm  
SCM type and dose  
Admixtures

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### So what?

- Can't predict mixture performance solely on cement chemistry
- Do choose cements based on needs
- Don't switch products in mid-flight






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### The Challenge

- How does the user know that the latest load of cement is
  - OK
  - The same as the last

Now

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