



American Concrete Institute®
Advancing concrete knowledge


Design of Sustainable Concrete Bridges

ACI Fall 2010 Convention
October 24 - 28, Pittsburgh, PA

ACI WEB SESSIONS

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 40). 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.

ACI WEB SESSIONS

ACI Web Sessions

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.

Please adjust your audio to an appropriate level at this time.




ACI WEB SESSIONS

ACI Web Sessions

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.




ACI WEB SESSIONS


ACI Online CEU Program

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.



Visit www.concrete.org/education/edu_online_CEU.htm for more information.




ACI WEB SESSIONS

ACI Conventions

ACI conventions provide a forum for networking, learning the latest in concrete technology and practices, renewing old friendships, and making new ones. At each of ACI's two annual conventions, technical and educational committees meet to develop the standards, reports, and other documents necessary to keep abreast of the ever-changing world of concrete technology.

With over 1,300 delegates attending each convention, there is ample opportunity to meet and talk individually with some of the most prominent persons in the field of concrete technology. For more information about ACI conventions, visit www.aciconvention.org.




ACI WEB SESSIONS

ACI Web Sessions

This ACI Web Session includes two speakers presenting at the ACI fall convention held in Pittsburgh, PA, October 24 – 28, 2010.

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

Please enjoy the presentations.



ACI WEB SESSIONS




American Concrete Institute®
Advancing concrete knowledge



Design of Sustainable Concrete Bridges

ACI Fall 2010 Convention
October 24 - 28, Pittsburgh, PA

ACI WEB SESSIONS



John Roberts, an ACI member and Chairman of Northeast Solite Corp. He is a member of ACI Committees 224, Cracking; 308, Curing Concrete; 325, Concrete Pavements; and 362, Parking Structures.

ACI WEB SESSIONS

Sustainable Concrete Bridges Using New Structural Design Concepts with High Performance Concrete (HPC) Internal Curing (IC) and High Volume Supplementary Cementitious Materials (HVSCM)



Bruce W Jones Northeast Solite Corporation
Nur Yazdani, Ph.D., P.E. University of Texas at Arlington
John W. Roberts, P.E. Northeast Solite Corporation

ACI Fall Convention
October 24, 2010
Pittsburgh, PA

ACI WEB SESSIONS

Sustainable Concrete Bridges Should Have:

- Lifecycle of 100 to 150 Years
- Because they have minimum of shrinkage and cracking
- Low Permeability
- Low Long Term Carbonation
- Good wearing Surface
- Dimensional Stability

ACI WEB SESSIONS

For Sustainable Structural Design

- Predictable modulus of elasticity
- High compressive and flexural strengths
- Controlled trouble free mixing placing, finishing and curing
- Surface free of cracks and deterioration

ACI WEB SESSIONS

To Achieve Optimum Concrete Characteristics

- Low water/cement ratio
- Reduce drying shrinkage
 - Cracking
 - Permeability
- Increase flexure strength
 - Compression strength in < 3d
 - in > 90d
- Use High Performance Concrete, Internal Curing and High Volume SCM

ACI WEB SESSIONS

Mechanism of Internal Curing

- Incorporation of a water curing agent into its concrete mixture for the purpose of promotion of hydration to minimize shrinkage and cracking.
- Improve permeability, strength, durability, expense, interfacial transition zone warping.
- The accepted agent for Internal Curing is preconditioned, saturated surface dry, absorbent lightweight aggregate sand (LWAS)
- Water absorbed in tiny pores and capillaries (reservoirs) provides High Internal Relative Humidity

ACI WEB SESSIONS

FORMULA for Quantity of LWAS to Substitute for Normal Weight Sand

$$M_{LWA} = \frac{C_f \times CS \times \alpha_{max}}{S \times \Phi_{LWA}}$$

M_{LWA} = mass of dry fine LWA (kg/m³)
 C_f = cement content (kg/m³)
 CS = chemical shrinkage of cement (g of water/g of cement)
 α_{max} = maximum expected degree of cement hydration
 S = degree of saturation of aggregate (0 to 1)
 Φ_{LWA} = absorption of LWAS (kg water/kg dry LWA)

For actual mix design test for a 3 point curve to decide an amount of LWAS to substitute for some of the natural sand

ACI WEB SESSIONS

MIXTURE PROPORTIONING WITH INTERNAL CURING

Starting with the cement content in the graph on the upper right, find the chemical shrinkage of the mixture (a good default value is 0.07). Proceed to the value on the y-axis and starting with this same value in the graph on the upper left, find the line for the mixture's w/c ratio. (Note that there is a single (thick) line for all w/c ratios greater than or equal to 0.36 as for these w/c ratio values, it is assumed that complete hydration of the cement powder can be achieved.) Proceed to the value on the x-axis and starting with this same value in the graph on the lower left, find the line for the absorption (dry mass of aggregate basis) of the lightweight aggregate. Finally, proceed to the value on the y-axis to obtain the recommended level of lightweight aggregate (dry mass basis) to be added to the concrete mixture. This replacement should then be conducted on a volumetric basis, replacing an equal volume of normal weight aggregates with pre-wetted (SSD) lightweight aggregates.

ACI WEB SESSIONS

Figure 1 Three-dimensional color-coded image of original x-ray microtomography data set subtracted. From that obtained after 1d of hydration for a high performance mortar with internal curing [11]. Aqua volumes indicate regions where the LWAS particles have lost water (to the surrounding hydrating cement paste). 3-D volume is 4.6 mm x 4.6 mm x 4.7 mm (0.181 in x 0.181 in x 0.185 in).

Figure 2 Two-dimensional image (4.6 mm x 4.6 mm or 0.181 in x 0.181 in) of a portion of the original mortar microstructure with the locations of the evacuated water (in aqua) superimposed [11].

ACI WEB SESSIONS

CURING

External Curing
Sprinkling, Wet Burlap, Ponding, Fogging

Curing 20mm Penetration

Internal Curing
Saturated Lightweight Aggregate Sand

Full Slab Curing with LWAS

ACI WEB SESSIONS

Freedom from Corrosion

- 1) Impermeable to the passage of corrosion agents
- 2) Protection from Carbonation
- 3) Eliminates the possibility of shrinkage and cracking

Internal Curing can provide assistance to all three

Curing, internal — supplying water throughout a freshly placed cementitious mixture using reservoirs, via pre-wetted lightweight aggregates, that readily release water as needed for hydration or to replace moisture lost through evaporation or self-desiccation.

ACI WEB SESSIONS

**Unblemished Reinforcing Steel after 45 years
Boulevard Bridge, Richmond, VA**

ACI WEB SESSIONS

Diminish or Eliminate Carbon Footprint

<ul style="list-style-type: none"> • Use less carbon energy in manufacturing and installation • Use less energy for maintenance and operation • Increases the lifecycle for an extended period 	<p>Diminish</p> <p>Diminish</p> <p>Eliminate</p>
---	---

ACI WEB SESSIONS

ACI WEB SESSIONS

Cracking and Shrinkage

Causes: Shrinkage (drying, plastic, chemical, and autogenous)

Solution: To minimize Drying Shrinkage use HPC

But: Autogenous shrinkage increases

Solution: Use Internal Curing pre-conditional SSD absorbent lightweight aggregate sand (LWAS)

ACI WEB SESSIONS

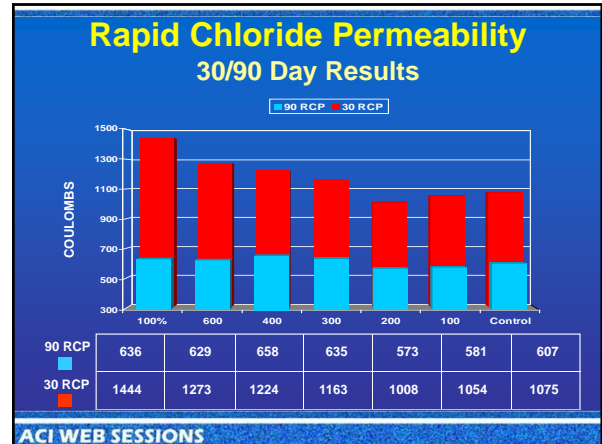
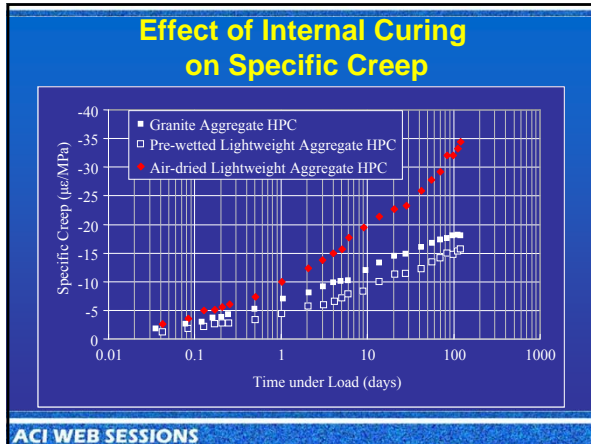
Mortar Strength Provides Resistance to Cracking

Cracking Tendencies

Stress > Strength – Cracking Occurs

Stress < Strength – No Cracking

ACI WEB SESSIONS



Economical Sustainability is Achieved
by Mechanical properties That Are:

- Proven
- Reproducible
- Reliable

Internal Curing Can Provide

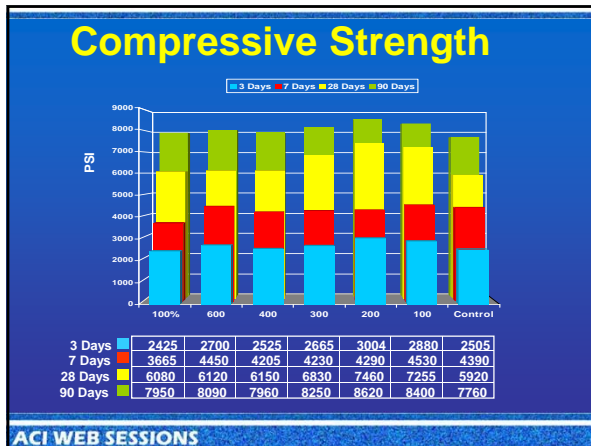
- Greater Uniformity
- Greater Strength
- Greater Predictability

ACI WEB SESSIONS

IMPROVE THE MORTAR STRENGTH
by

- LWAS Being Stronger than Standard as Measured by ASTM C109/C 109M
- Improve the Early Age (<3d) Strength by SSD LWAS Desorbing Immediately
- Improve the Later Age (>90d) Strength by Higher Internal Relative Humidity
- Improve the Reliability by Using LWAS that Meets ASTM C33 as well as ASTM C330

ACI WEB SESSIONS



IMPROVE THE MORTAR STRENGTH

by
LWAS Being Stronger than Standard
as Measured by ASTM C109/C 109M

Improve the Early Age (<3d) Strength by
SSD LWAS Desorbing Immediately

Improve the Later Age (>90d) Strength by
Higher Internal Relative Humidity

Improve the Reliability by
Using LWAS that Meets
ASTM C33 as well as ASTM C330

ACI WEB SESSIONS

Normal Weight Concrete Without Moist Curing

Even with High w/c but Without Internal Curing Is Adversely Affected

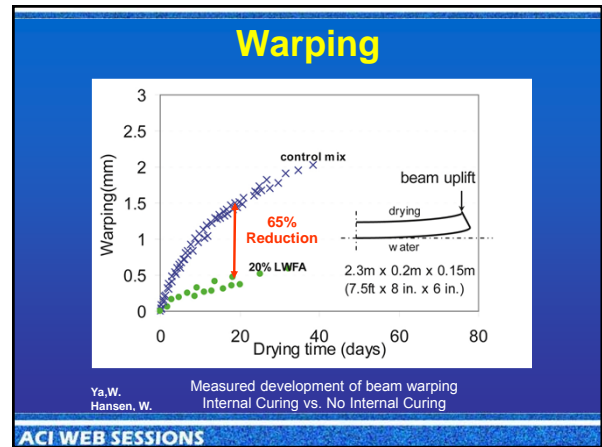
Reduction in Hydration ↓ 15%

Compressive Strength ↓ 20%

Permeability ↓ 27%

Mauricio Lopez

ACI WEB SESSIONS



Applications

Structural Flatwork Precast

Prestressed Walls Columns

Repair and Maintenance

Where the Objective is Sustainability
and Longer Life-Cycles

ACI WEB SESSIONS

Applications Needing:

Rapid Chloride Permeability
28 Day Results

CURING

Compressive Strength

Mortar Strength Provides
Resistance to Cracking

Concrete with Internal Curing

Warping

Concrete

Road Construction

ACI WEB SESSIONS

Conclusions

The optimum water-cement ratio can now be ascertained to attain Sustainability and Longer Life-Cycle

Through Using
HPC, IC, and HVSCM

Because of
Past research of the materials, methods, and practices which can improve sustainability. Global warming, which has made the public aware of the causes, which include carbon burning, ACI's decision to make Sustainability a priority. An earlier decision of ACI to develop requirements for HPC
The development by ASCE, ACEC, and APWA of a Sustainable Infrastructure Rating System (SIPRS)
The formation by PCA, NRMCA and the Massachusetts Institute of Technology of the MIT Hub
The research of the internal curing of concrete, the replacement of cement with supplementary cementitious materials, and the reduction of drying shrinkage by using HPC.

ACI WEB SESSIONS

Conclusions

The Future for Sustainability is NOW

Design engineers can consider using 90 days as the measure for compressive strength instead of 28

The amount of concrete might be reduced by 5 %.

The amount of cement might be reduced by 50 %.

The carbon footprint might be reduced by 55 %.

The life cycle of concrete might be extended to 100 to 150 years.


ACI WEB SESSIONS

Recommendations

Now that we know that the water-cement ratio of 0.38 will improve all the characteristics of concrete, we do not know the optimum for each application, for each project, for each climate, for each normal weight coarse and fine aggregate, for each cement and cementitious material, and each location. We do know the improvements that 0.38 will provide and that construction users, architects, engineers, design builders, contractors, and furnishers of ready-mixed concrete can save money and provide sustainability by using it.

The optimum for each project will be achieved through using the known, and modifying it in order to achieve the optimum.

ACI WEB SESSIONS



Larry Rowland, Larry Rowland is a gifted educator with more than 25 years of experience in the material supply and construction industries. He oversees Lehigh's educational outreach programs that provide professional development units for American Institute of Architects members and US Green Building Council (USGBC), green building professionals. Larry is an industry leader on the topic of sustainability and architectural concrete. Larry has been a USGBC, LEED Accredited Professional since 2004. He is a former Director of the Delaware Valley Green Building Council, his region's chapter of the USGBC, and served as Chair of the DVGBC's Lehigh Valley Branch. Larry has presented at multiple National Conventions of the American Institute of Architects and the American Concrete Institute and frequently trains architects, engineers, contractors, product manufacturers and students about concrete best practices and the topic of sustainability.

ACI WEB SESSIONS

Reflective Concrete for Safe, Sustainable Bridges


Design of Sustainable Concrete Bridges
Pittsburgh, PA
October 24, 2010

ACI WEB SESSIONS

Sustainability

Sustainability – What is it?

- The Triple Bottom Line
 - People
 - Planet
 - Profit

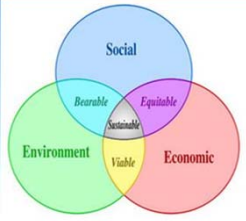


ACI WEB SESSIONS

Sustainability

Sustainability – What is it?

- The Triple Bottom Line
 - Social
 - Environmental
 - Economic



... Sustainability is in the Overlap

ACI WEB SESSIONS

Reflective Concrete for Safe, Sustainable Bridges

Reflective (White) Concrete Barriers:

- Satisfy the Triple Bottom Line by Meeting Needs
 - Social / Reflective Concrete is More Visible and Safer
 - Environmental / Durable, Resource and Energy Efficient
 - Economic / Low Maintenance, with Safety Savings

ACI WEB SESSIONS

Social Responsibility

Meeting The Needs Of Our Communities

- Mon/Fayette Expressway & Southern Beltway
 - Creates ~ 100 Miles of Limited-access Highways
 - West And South of Pittsburgh
 - Serving Allegheny, Washington and Fayette Counties

ACI WEB SESSIONS

Social Responsibility

Meeting the Needs of Our Communities



Mon/Fayette Expressway & Southern Beltway

ACI WEB SESSIONS

Social Responsibility

PA Turnpike Commission

Mission:

To operate and manage a safe, reliable, cost-effective and valued Toll Road System

ACI WEB SESSIONS

Social Responsibility

PA Turnpike Commission

Vision:

A safe, non-stop, free-flowing Toll Road System offering reliable and enjoyable travel and services that is considered by customers to be a premiere transportation value

ACI WEB SESSIONS

Social Responsibility

PA Turnpike Commission

Key Terms


- Safe
- Reliable
- Value
- Toll Road System

ACI WEB SESSIONS

Social Responsibility

PA Turnpike Commission

Safety is Priority #1



ACI WEB SESSIONS

Social Responsibility

Highway Safety for Drivers and Workers

- 90% of a driver’s reaction depends on vision
- Non-daylight crashes 69% more deadly
- “Driving in the dark is one of the most hazardous situations drivers face ...especially on roads with no street lighting.”

ACI WEB SESSIONS

Social Responsibility

Reflectivity = Safety



ACI WEB SESSIONS

Social Responsibility

Reflectivity = Safety

- Our Population is Aging
 - Mature drivers are over-represented in crashes
 - You need 10x more light at age 60 vs. 19-years old
 - Americans age 65-plus will reach 70.3 million by 2030

ACI WEB SESSIONS

Social Responsibility



Visibility is Critical 24 Hours a Day

ACI WEB SESSIONS

Social Responsibility

Iowa DOT Reflectance Data	1997	2001	2001
Mix & Surface Condition	Dry	Dry	Wet
White Cement & Natural Sand	75.1	75.1	49.8
White Cement & Mfgd Sand	77.5	77.5	56.4
Gray Cement w/35% Slag & Mfgd Sand	61.5	59.1	43.6
White Cement w/35% Slag & Mfgd Sand	76.0	75.9	50.7
Gray Cement & Mfgd Sand	49.4	45.1	18.6

ACI WEB SESSIONS

Social Responsibility

Gray Cement, Regular Sand	White Cement, White Sand	Gray Cement, Slag & Regular Sand	White Cement, Regular Sand	Gray Cement, Natural Pozzolan & Regular Sand
---------------------------	--------------------------	----------------------------------	----------------------------	--

ACI WEB SESSIONS

Social Responsibility To Employees

Goal: Enhanced Highway Worker Safety

ACI WEB SESSIONS

Social Responsibility To Employees

Work Zone Traffic Control

Reflective White Precast Barriers Help Channel Traffic Safely Through Dangerous Construction/Work Zones

ACI WEB SESSIONS

Social Responsibility

Reflective Concrete Barriers Connect People to Their...

- Community
- Family
- Employment
- Education
- Social Services

ACI WEB SESSIONS

Environmental Responsibility

ACI WEB SESSIONS

Environmental Responsibility

Reflective Concrete Resource Efficiency:

- Concrete Structures Over Their Lifecycle Make Efficient Use of:
 - Energy
 - Water
 - Land and Other Resources

ACI WEB SESSIONS

Environmental Responsibility

Energy Efficiency:

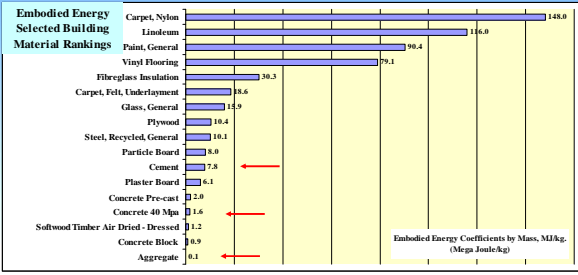
- Reflective concrete requires less energy for lighting



ACI WEB SESSIONS

Environmental Responsibility

Low Embodied Energy:




ACI WEB SESSIONS

Environmental Responsibility

Compare CO₂ Impact of Concrete Barrier vs. Driving

- Typical Car, 12,500 miles / Yr @ 25 mpg, 500 gal = 9,700# CO₂ / yr
 - EPA Emission Factor / gal of gas = 19.4# CO₂
- Bridge Parapet, 625' x 4.3 cflf, or 100 cy @ 750# / yd = 75,000# CO₂
 - Barrier Service Life 30+ Years
- Barrier's Impact is ~ 2,500# CO₂ / yr
- Average car is ~ 9,700# CO₂ / yr




ACI WEB SESSIONS

Environmental Responsibility

Compare CO₂ Impact of Concrete Barrier vs. Driving

- Typical Car, 12,500 miles / Yr @ 25 mpg, 500 gal = 9,700# CO₂ / yr
 - EPA Emission Factor / gal of gas = 19.4# CO₂
- Bridge Parapet, 625' x 4.3 cflf, or 100 cy @ 750# / yd = 75,000# CO₂
 - Barrier Service Life 50 - 60 Years
- Barrier's Impact is ~ 1,500# CO₂ / yr
- Average car is ~ 9,700# CO₂ / yr



ACI WEB SESSIONS

Environmental Responsibility

Resource Efficiency:

- The Reflective Concrete is the Finish
 - No Painting Needed
- Regional Materials





ACI WEB SESSIONS

Environmental Responsibility

Durability:

- Reflective Concrete with White Cement For a Lasting Finish

ACI WEB SESSIONS

Economic Responsibility

Durability = Less Maintenance \$\$

Less Maintenance = Less Costs




ACI WEB SESSIONS

Economic Responsibility

Maintenance & Repair Cost

- Reflective Concrete – Practically Nil
- Repair, Metal Beam Guard Rail \$50/Meter
- Repair, Cable Barrier \$200 - \$550/Impact
- Initial Cost Painting Concrete Railing is \$0.75 - \$1.00 / sf

ACI WEB SESSIONS

Economic Responsibility

Removal/Repaint Concrete Costs \$3 - \$5 / SF

... Federal Highway Administration Information

- Report on Texas DOT's Cost Control Task Force Recommendation for Structures
 - Reduce Painting of Concrete
- Task Force Example Project - Hartman Bridge

ACI WEB SESSIONS

Economic Responsibility

The Cost of Safety

- Injury Crashes are Expensive*
 - \$36,000 For a Moderate Injury
 - \$180,000 For a Severe Injury
 - \$2,600,000 For a Fatality

* FHWA Comprehensive Accident Cost Figures

ACI WEB SESSIONS

Construction Applications

The Mix


- Standard Structural Concrete Mixes
 - Use White Cement Instead of Gray
 - White Fine & Coarse Aggregate
 - GGBFS And Metakaolin - Good SCM Matches

ACI WEB SESSIONS

Construction Applications

Construction/Application

- Standard Forms & Equipment
 - Use Non-staining Form Release / Cures
 - Trial Batches a Must
 - Admixture Compatibility
 - Reflectivity Results



ACI WEB SESSIONS

Reflective Concrete for Safe, Sustainable Bridges

Meeting the Triple Bottom Line

- Making Economic, Social and Environmental Sense
 - Superior Safety
 - Durable / Low Maintenance
 - Long Lasting
 - Beautiful

ACI WEB SESSIONS

Reflective Concrete for Safe, Sustainable Bridges




Thank You

ACI WEB SESSIONS


Click on the image below to go to the web page.



Seminar Schedule




Bookstore




ACI Web Sessions




WAMPA Bay 2011
FLORIDA UNIVERSITY CENTER



Online CEU Program



ACI eLearning



Concrete Knowledge Center

ACI WEB SESSIONS