

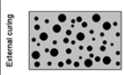
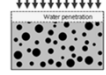
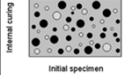
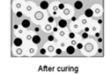

 <p>Objectives</p> <p>Concrete Problems</p> <p>Defining Internal Curing</p> <p>Science of Internal Curing</p> <p>Internal Curing Applications</p>	 
	<h3>Improving the Performance of Concrete with Internal Curing</h3>
	 
	 
	
<p>Internally Cured Concrete Series – Module 1 - October, 2013</p> <p>Module 1: Improving the Performance of Concrete with Internal Curing <span style="float: right;">Slide 1 of 17</span></p>	

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 <p>Objectives</p> <p>Concrete Problems</p> <p>Defining Internal Curing</p> <p>Science of Internal Curing</p> <p>Internal Curing Applications</p>	<h3>Objectives</h3> <ul style="list-style-type: none"> <li>• Understand difference between external and internal curing</li> <li>• Understand why the use of internal curing is needed today</li> <li>• Understand the science of internal curing</li> <li>• Understand which properties of concrete can be improved with internal curing</li> <li>• Examine recent steps the industry is taking to implement internal curing</li> </ul>
	
<p>Module 1: Improving the Performance of Concrete with Internal Curing <span style="float: right;">Slide 2 of 17</span></p>	

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 <p>Objectives</p> <p>Concrete Problems</p> <p>Defining Internal Curing</p> <p>Science of Internal Curing</p> <p>Internal Curing Applications</p>	<h3>Concrete Problems</h3> <ul style="list-style-type: none"> <li>• American's spend 4.2 billion hours a year stuck in traffic</li> <li>• Bridges (&gt;25%) are structurally deficient or functionally obsolete</li> <li>• Highways (&gt;33%) are in poor or mediocre condition</li> <li>• Cracked and spalling concrete</li> <li>• Corroding steel reinforcement</li> </ul>
	
<p>Module 1: Improving the Performance of Concrete with Internal Curing <span style="float: right;">Slide 3 of 17</span></p>	

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 <h2 style="text-align: center;">Curing</h2>	
<p>Objectives</p> <p>Concrete Problems</p> <p>Defining Internal Curing</p> <p>Science of Internal Curing</p> <p>Internal Curing Applications</p>	<ul style="list-style-type: none"> <li>• When concrete is placed it is sensitive and can be easily damaged if not treated properly</li> <li>• We want to maintain appropriate temperature and moisture during the first few weeks</li> <li>• Proper curing enables concrete to hydrate (chemically react) developing potential strength and durability</li> <li>• Proper curing reduce stress and cracking potential due to drying or temperature changes</li> <li>• Important but frequently overlooked step</li> </ul>  <p style="font-size: small; text-align: right;">Photo C. DiBella</p>
<p>Module 1: Improving the Performance of Concrete with Internal Curing <span style="float: right;">Slide 4 of 17</span></p>	

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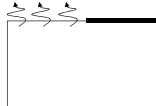
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 <h2 style="text-align: center;">External Curing</h2>	
<p>Objectives</p> <p>Concrete Problems</p> <p>Defining Internal Curing</p> <p>Science of Internal Curing</p> <p>Internal Curing Applications</p>	<ul style="list-style-type: none"> <li>• Conventional curing works by treating the 'outside' of concrete after placement             <ul style="list-style-type: none"> <li>– Placing water (water curing) on the concrete surface</li> <li>– Placing a curing compound that helps to reduce water loss to evaporation</li> </ul> </li> </ul>  
<p>Module 1: Improving the Performance of Concrete with Internal Curing <span style="float: right;">Slide 5 of 17</span></p>	

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 <h2 style="text-align: center;">Challenges with External Curing</h2>	
<p>Objectives</p> <p>Concrete Problems</p> <p>Defining Internal Curing</p> <p>Science of Internal Curing</p> <p>Internal Curing Applications</p>	<ul style="list-style-type: none"> <li>• External curing has worked for centuries, why is something different needed now?</li> <li>• In an effort to make concrete less permeable (i.e., HPC) we use more low w/c systems with supplementary cement</li> <li>• While reduced porosity is good for durability, it can limit water movement limiting the effectiveness of water curing</li> <li>• Supplementary cementitious materials requires longer curing times (slower reactions) and have more chemical shrinkage with hydration</li> </ul>
<p>Module 1: Improving the Performance of Concrete with Internal Curing <span style="float: right;">Slide 6 of 17</span></p>	

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## Internal Curing

Objectives

Concrete Problems

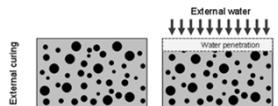
Defining Internal Curing

Science of Internal Curing

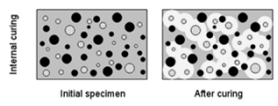
Internal Curing Applications

- Internal curing - process by which the hydration of cement occurs when internal reservoirs provide additional water that is not part of the mixing water
- Allows curing to be well distributed
- Allows curing as needed

External curing



Internal curing



Initial specimen      After curing

● Normal aggregate    ○ Water filled inclusion    ○ Cured zone

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## How Does Internal Curing Work?

Objectives

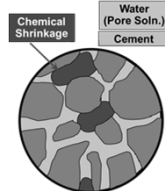
Concrete Problems

Defining Internal Curing

Science of Internal Curing

Internal Curing Applications

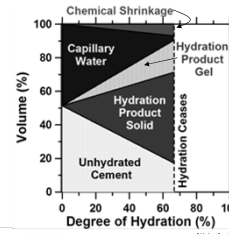
- Water can be lost due to drying
- Water can be consumed by hydration resulting in self desiccation



Chemical Shrinkage

Water (Pore Soln.) Cement

Measured by Absorption of External Water



Volume (%)

Degree of Hydration (%)

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## How Does Internal Curing Work?

Objectives


Concrete Problems

Defining Internal Curing

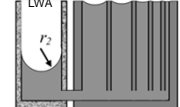
Science of Internal Curing

Internal Curing Applications

- Porous lightweight aggregate is 'prewetted' before mixing
- Water moves from the 'pores' in LWA to the paste on demand as needed
- This movement is due to fact that smaller pores want to remain 'water filled'



Conventional Concrete



Conceptual Model of Pores In Concrete

LWA

Internally Cured Concrete

Module 1: Improving the Performance of Concrete with Internal Curing Slide 9 of 17

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 <h2 style="text-align: center;">Internal Curing Applications</h2>	
<p>Objectives</p> <p>Concrete Problems</p> <p>Defining Internal Curing</p> <p>Science of Internal Curing</p> <p>Internal Curing Applications</p>	<ul style="list-style-type: none"> <li>• NYDOT using internal curing in bridge decks (map showing bridges as of 2012)</li> <li>• General experience is positive</li> <li>• Reduced cracking with no problems to contractor or supplier</li> </ul> <div style="display: flex; justify-content: space-around;">   </div> <p style="text-align: right; font-size: small;">Streeter et al. 2012</p>
<p>Module 1: Improving the Performance of Concrete with Internal Curing <span style="float: right;">Slide 10 of 17</span></p>	

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 <h2 style="text-align: center;">Internal Curing Applications</h2>	
<p>Objectives</p> <p>Concrete Problems</p> <p>Defining Internal Curing</p> <p>Science of Internal Curing</p> <p>Internal Curing Applications</p>	<ul style="list-style-type: none"> <li>• Building large slabs is complex</li> <li>• Denver Water 10-Million Gallon Lone Tree Tank No. 2</li> <li>• Negligible differences in placing &amp; finishing</li> <li>• Opinion – less cracking and maintenance</li> </ul> <div style="display: flex; justify-content: space-around;">   </div> <p style="text-align: right; font-size: x-small;">Bates et al. 2012</p>
<p>Module 1: Improving the Performance of Concrete with Internal Curing <span style="float: right;">Slide 11 of 17</span></p>	

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 <h2 style="text-align: center;">Internal Curing Applications</h2>	
<p>Objectives</p> <p>Concrete Problems</p> <p>Defining Internal Curing</p> <p>Science of Internal Curing</p> <p>Internal Curing Applications</p>	<ul style="list-style-type: none"> <li>• RR intermodal facility <span style="float: right; font-size: x-small;">Friggle et al. 2008</span> <ul style="list-style-type: none"> <li>– 250,000 yd<sup>3</sup> of low slump IC material</li> </ul> </li> <li>• CRC Paving for TxDOT           <ul style="list-style-type: none"> <li>– 6 months 1 crack, 5.5 years minor drying or plastic shrinkage cracking</li> </ul> </li> </ul> <div style="display: flex; justify-content: space-around;">   </div> <p style="text-align: right; font-size: x-small;">06/21/2010</p>
<p>Module 1: Improving the Performance of Concrete with Internal Curing <span style="float: right;">Slide 12 of 17</span></p>	

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 <h2 style="text-align: center;">Internal Curing Applications</h2>	
<p>Objectives</p> <p>Concrete Problems</p> <p>Defining Internal Curing</p> <p>Science of Internal Curing</p> <p>Internal Curing Applications</p>	<ul style="list-style-type: none"> <li>• Two bridge decks were cast in 2010 at the same time in Monroe Co (Bloomington) IN</li> <li>• Internally cured bridge: similar workability, higher strength, lower transport and no cracking (3 cracks in the plain bridge)</li> <li>• Additional bridges being constructed</li> </ul> <div style="display: flex; justify-content: space-around;">   </div> <p style="font-size: small; text-align: right;">Photo Credit: D.Bella</p>
<p>Module 1: Improving the Performance of Concrete with Internal Curing <span style="float: right;">Slide 13 of 17</span></p>	

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 <h2 style="text-align: center;">Summary</h2>	
<p>Objectives</p> <p>Concrete Problems</p> <p>Defining Internal Curing</p> <p>Science of Internal Curing</p> <p>Internal Curing Applications</p>	<ul style="list-style-type: none"> <li>• US infrastructure is aging &amp; deteriorating: IC offers one approach to extend the service life of concrete</li> <li>• LWA can be used as a reservoir to 'hide water' throughout the cross section that can be used during hydration</li> <li>• Internal curing can reduce shrinkage and shrinkage induced cracking</li> <li>• Internal curing is being implemented, with examples shown, in practice and showing great potential</li> </ul>
<p>Module 1: Improving the Performance of Concrete with Internal Curing <span style="float: right;">Slide 14 of 17</span></p>	

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 <h2 style="text-align: center;">Upcoming Modules</h2>	
<p>Objectives</p> <p>Concrete Problems</p> <p>Defining Internal Curing</p> <p>Science of Internal Curing</p> <p>Internal Curing Applications</p>	<ul style="list-style-type: none"> <li>• Internal curing increases hydration 'getting more' from cementitious materials</li> <li>• Modules on how to proportion internally cured concrete</li> <li>• Internal curing reduces shrinkage and the potential for shrinkage cracking</li> <li>• Internal curing reduces fluid transport (absorption/diffusion) reducing corrosion</li> <li>• Internally cured concrete can be used to increase the sustainability of concrete</li> </ul>
<p>Module 1: Improving the Performance of Concrete with Internal Curing <span style="float: right;">Slide 15 of 17</span></p>	

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 <h2 style="text-align: center;">More Information</h2>	
<p>Objectives</p> <p>Concrete Problems</p> <p>Defining Internal Curing</p> <p>Science of Internal Curing</p> <p>Internal Curing Applications</p>	<ul style="list-style-type: none"> <li>• Internal Curing of Concrete, RILEM Report 41, Eds. K. Kovler and O.M. Jensen, RILEM Publications S.A.R.L., 2007.</li> <li>• Internal Curing of High Performance Concretes - Laboratory and Field Experiences, ACI SP-256, Eds. D. Bentz and B. Mohr, American Concrete Institute, CD-RoM, 2008.</li> <li>• Radlinska, A., Rajabipour, F., Bucher, B., Henkensiefken, R., Sant, G., and Weiss, W. J., (2008), "Shrinkage Mitigation Strategies in Cementitious Systems: a Closer Look at Sealed and Unsealed Behavior," Transportation Research Record, Volume 2070, pp. 59-67</li> <li>• Friggle, T., and Reeves, D., Internal Curing of Concrete Paving Laboratory and Field Experiences, ACI SP-256, Eds. D. Bentz and B. Mohr, American Concrete Institute, 71-80, CD-Rom, 2008.</li> <li>• Bentz, D. P. and Weiss, W. J., (2010) "Internal Curing: A State of the Art Review", NISTIR 7765 <a href="http://ciks.cbt.nist.gov/~bentz/NISTIR7765.pdf">http://ciks.cbt.nist.gov/~bentz/NISTIR7765.pdf</a></li> <li>• The Economics, Performance, and Sustainability of Internally Cured Concrete, ACI SP-290, Eds. A.K. Schlinder, J.G. Grygar, and W.J. Weiss, American Concrete Institute, CD-RoM, 2012 (papers by Bastes, Streeter, DiBella)</li> <li>• <a href="http://www.escsi.org/ContentPage.aspx?id=205&amp;ekmensel=1b7c39fc_61_74_205_1">http://www.escsi.org/ContentPage.aspx?id=205&amp;ekmensel=1b7c39fc_61_74_205_1</a></li> </ul>
<p style="font-size: small;">Module 1: Improving the Performance of Concrete with Internal Curing <span style="float: right;">Slide 16 of 17</span></p>	

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 <h2 style="text-align: center;">Acknowledgements/Disclaimer</h2>	
<p>Objectives</p> <p>Concrete Problems</p> <p>Defining Internal Curing</p> <p>Science of Internal Curing</p> <p>Role of LWA in Internal Curing</p>	<ul style="list-style-type: none"> <li>• These slides were developed as part of a series for the Expanded Shale, Clay and Slate Institute by Jason Weiss.</li> <li>• These materials are provided as general information and do not constitute legal or other professional advice.</li> <li>• Any use of this information in the design or selection of materials for practice should be approved by the owner and project engineer-of-record.</li> </ul>
<p style="font-size: small;">Module 1: Improving the Performance of Concrete with Internal Curing <span style="float: right;">Slide 17 of 17</span></p>	

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