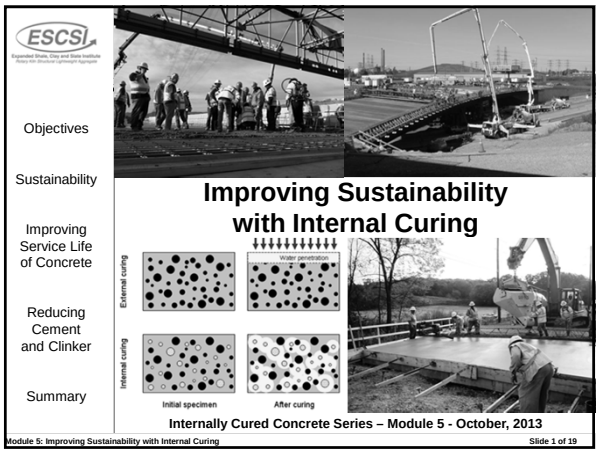
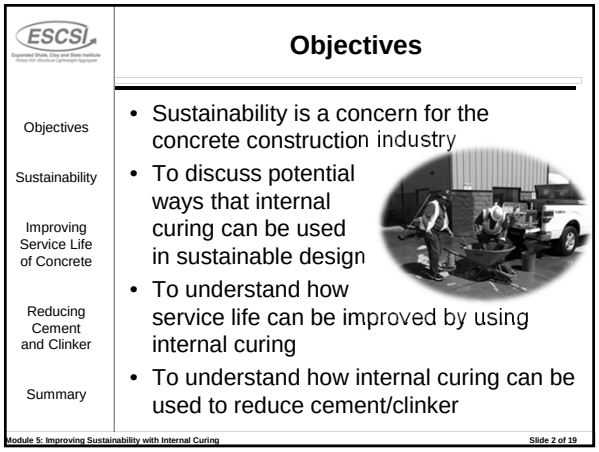
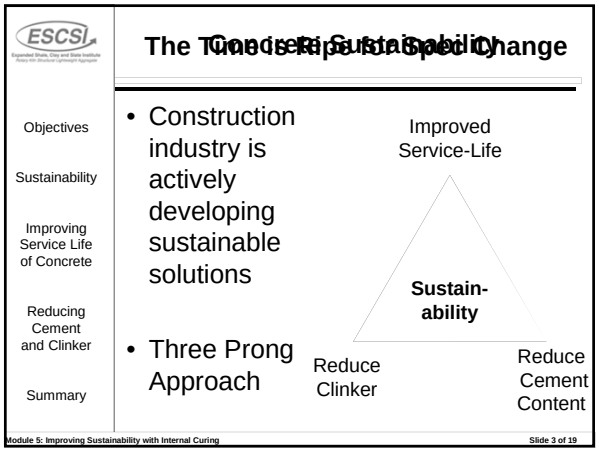

ESCSI
Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary
Improving Sustainability with Internal Curing
Water penetration
External curing
Internal curing
Initial specimen
After curing
Internally Cured Concrete Series – Module 5 - October, 2013
Module 5: Improving Sustainability with Internal Curing
Slide 1 of 19

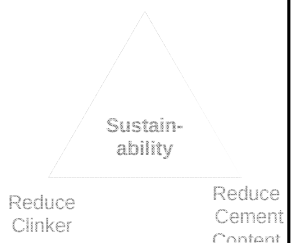

ESCSI
Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary
Objectives
• Sustainability is a concern for the concrete construction industry
• To discuss potential ways that internal curing can be used in sustainable design
• To understand how service life can be improved by using internal curing
• To understand how internal curing can be used to reduce cement/clinker
Module 5: Improving Sustainability with Internal Curing
Slide 2 of 19


ESCSI
Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary
The Three Keys to Sustainability
• Construction industry is actively developing sustainable solutions
• Three Prong Approach
Improved Service-Life
Sustain-ability
Reduce Clinker
Reduce Cement Content
Module 5: Improving Sustainability with Internal Curing
Slide 3 of 19

The Time is Ripe for Concrete Sustainability Change

Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary

- Construction industry is actively developing sustainable solutions
- Three Prong Approach

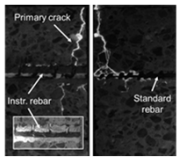


Module 5: Improving Sustainability with Internal Curing Slide 4 of 19

Benefits of Internal Curing

Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary

- Internal curing increases hydration, reduces porosity, reduces interfacial zones
- Internal curing reduces absorption and reduces chloride diffusion
- Internal curing shows similar freeze-thaw resistance
- Internal curing reduces the potential for cracking
  - Cracks accelerate fluid ingress and corrosion of reinforcing steel



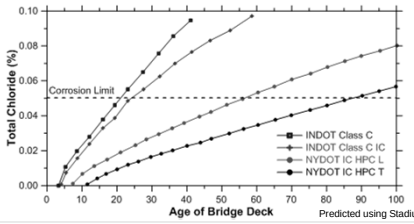
Pease et al. 2008

Module 5: Improving Sustainability with Internal Curing Slide 5 of 19

Service Life Modeling Bridge Decks Conventional vs. High Performance

Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary

- Substantial improvements can occur in service life when HPC mixtures are used
- Model does not account for cracking which shortens life however IC reduces crack risk



Predicted using Stadium

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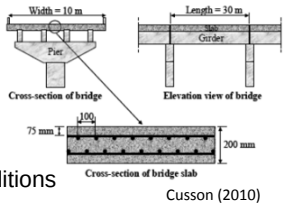
Life Cycle Cost Analysis

Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary

- Cusson et al. 2010 reported results of a case study that compared a convention, high performance and high performance internally cured deck
- 200-mm (8 in) thick bridge deck
- 75 mm (3 in) cover
- Canadian exposure conditions



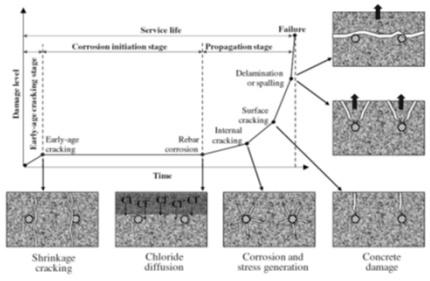
Cusson (2010)

Module 5: Improving Sustainability with Internal Curing Slide 7 of 19

Cusson et al. 2010 Service Life Model

Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary

- Schematic of life cycle model used



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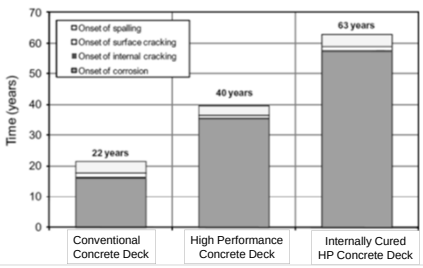
Cusson et al. 2010 Service Life Model

Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary

- Internal curing improved service life
- 38% lower life cycle cost (5 year recovery)

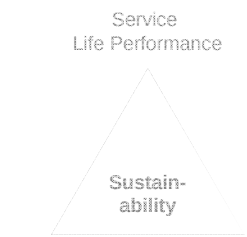


Module 5: Improving Sustainability with Internal Curing Slide 9 of 19

The Time is Ripe for Concrete Sustainability Change

Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary

- Construction industry is actively developing sustainable solutions
- Three Prong Approach



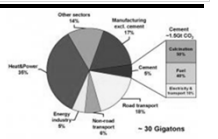
Reduce Clinker **Reduce Cement Content**

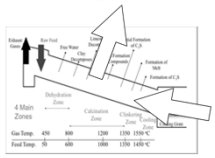
Module 5: Improving Sustainability with Internal Curing Slide 10 of 19

Cement and CO_2 Production

Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary

- Cement accounts for 7-8% of global CO_2 (Mehta 1998)
- Where does CO_2 come from
  - Calcination (50)
    $CaCO_3 \xrightarrow{\text{yields}} CaO + CO_2$
  - Combustion (40)
    $C + O_2 \xrightarrow{\text{yields}} CO_2$
  - Transportation (10)
- Concrete has relatively low carbon emission per unit; however we use a large volume



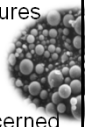


Module 5: Improving Sustainability with Internal Curing Slide 11 of 19

Potential Approach for Sustainability

Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary

- Reduce the cement (clinker) content of concrete used in transportation structures
- Current limits of 20-25% fly ash
- Can higher volumes of ash be used?
  - Contractors and agencies are concerned with slow strength development
  - Other concerns: slow set time, admixture incompatibilities, scaling, freeze-thaw damage, extended times for moist curing

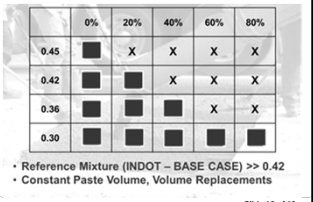


Module 5: Improving Sustainability with Internal Curing Slide 12 of 19

Project Thought Process

Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary

- de la Varga et al. examined potential use of high volume fly ash mixtures (HVFA)
- Typical w/cm 0.42 concrete bridge deck mixture modified using HVFA to obtain similar early age strengths
- Similar paste volume
- Similar workability obtained with chemical admixtures

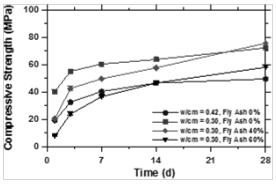


Module 5: Improving Sustainability with Internal Curing Slide 13 of 19

Early Age Compressive Strength

Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary

- As the w/c is reduced and the fly ash volume is increased similar strengths can be obtained at early ages
- Transport properties were also greatly improved
- However, as the w/c is reduced, the autogenous shrinkage and cracking potential can increase

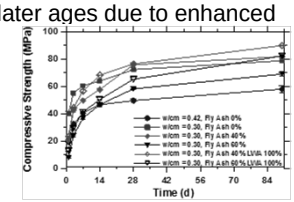


Module 5: Improving Sustainability with Internal Curing Slide 14 of 19

HVFA with Internal Curing

Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary

- Internal curing can improve the strength, especially at later ages due to enhanced hydration
- Internal curing has a residual stress that was much lower than the plain mixture, being similar or less than the 0.42 mixture with benefits of 60% less cement, improved strength, and transport

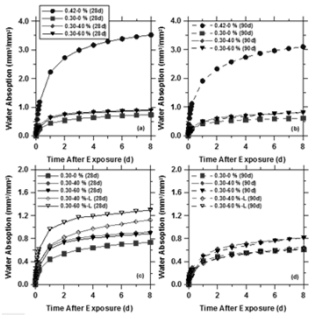


Module 5: Improving Sustainability with Internal Curing Slide 15 of 19

Water Absorption with HVFA

Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary

- Conventional mixture shown in blue
- Replacing 60% of the cement with fly ash and using a lower w/c reduces transport
- Internal curing beneficial



Module 5: Improving Sustainability with Internal Curing Slide 16 of 19

Summary

Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary

- Internal Curing
  - Increases hydration, uses binder efficiently
  - Reduces the potential for cracking
  - Reduces chloride ingress, delays corrosion
- Service life model
  - Showed improved service life
- SCM can be used to reduce clinker per cubic yard of concrete
  - w/c adjusted to counteract slow strength, improving transport and cracking resistance
  - longer moist curing (offset poor curing)

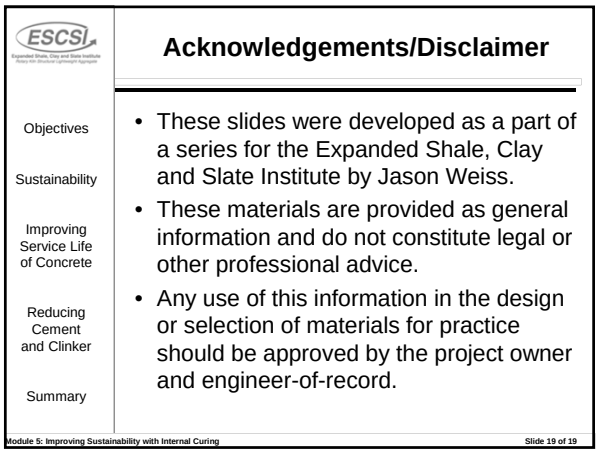
Module 5: Improving Sustainability with Internal Curing Slide 17 of 19

More Information

Objectives
Concrete Problems
Defining Internal Curing
Science of Internal Curing
Internal Curing Applications

- 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.
- Pease, B.J., Geiker, M. R., Stang, H. R, and Weiss, W. J., (2006) "Cracking Behavior of Reinforced Concrete Beams Under Service Loads," Advances in Concrete through Science and Engineering, RILEM Quebec abstract p. 281 (electronic proceedings pp. 11)
- Bentz, D. P. and Weiss, W. J., (2010) "Internal Curing: A State of the Art Review", NISTIR 7765 http://ciks.cbt.nist.gov/~bentz/NISTIR7765.pdf
- D Cusson, Z Lounis, L Daigle (2010) Benefits of internal curing on service life and life-cycle cost of high-performance concrete bridge decks – A case study Cement and Concrete Composites 32: 339-350.
- De La Varga, I, Bentz, D. P., and Weiss, W. J., (2012) "Application of Internal Curing to Mixtures Containing High Volumes of Fly Ash," Cement and Concrete Composites, Vol. 34/9, p. 1001-1008
- 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
- http://www.escsi.org/ContentPage.aspx?id=205&ekmensel=1b7c39fc_61_74_205_1

Module 5: Improving Sustainability with Internal Curing Slide 18 of 19


ESCSI
Acknowledgements/Disclaimer
Objectives
Sustainability
Improving Service Life of Concrete
Reducing Cement and Clinker
Summary
• These slides were developed as a part of a series for the Expanded Shale, Clay and Slate Institute by Jason Weiss.
• These materials are provided as general information and do not constitute legal or other professional advice.
• Any use of this information in the design or selection of materials for practice should be approved by the project owner and engineer-of-record.
Module 5: Improving Sustainability with Internal Curing
Slide 19 of 19