Detecting Solidification using Moisture Transport from Saturated Lightweight Aggregate

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Prepared and Presented at the 2009 ACI Spring Convention
San Antonio, Texas, by Ryan Henkensiefken
Introduction

- LWA concrete is used for reduced weight
- Unintentional internal curing
- Typically made with coarse LWA
- Protect more paste with equal volume of fine LWA
Introduction

• Internal curing study at Purdue
  – LWA properties
  – Drying and autogenous shrinkage
  – Restrained and unrestrained shrinkage
  – Plastic shrinkage
  – Sorption/Freeze-Thaw
  – Strength and MOE
  – Full-scale testing

• Use x-ray absorption to help determine protected paste volume

Protected Paste Volume
Objectives

• Use x-ray to track water movement from LWA to paste near the time of set
• Relate water movement to the time of set
• Monitor distance water moves at early age
• Show the importance of protected paste on proportioning
Outline

• Background on Internal Curing
• Background on X-Ray Absorption
• Relate Water Movement to the Time of Set
• How Far the Water Moves at Early Ages
• Shrinkage Measurements
• Why all this is Important
• Conclusions
Background on Internal Curing

- **Chemical Shrinkage**
  - Hydration product volume is smaller than cement and water volume

- **Autogenous Shrinkage**
  - Measured external volume change in sealed conditions

![Diagram showing chemical shrinkage and hydration products]
Background on Internal Curing

Before Set

Chemical Shrinkage

→

Autogenous Shrinkage

After Set

Chemical Shrinkage

> Autogenous Shrinkage

Internal Voids

Vapor-Filled Voids

Autogenous Shrinkage

Autogenous Shrinkage

Internal Voids
Background on Internal Curing

Chemical Shrinkage
Autogenous Shrinkage

Created Void Space = Cause of Shrinkage Cracking

Approximate Time of Set Initial Set

Shrinkage Volume (ml/g Cement)

Age of Specimen (Days)
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Background on X-Ray Absorption

- Observe differences in density
- Lighter is more dense
- As volume of water changes, density changes
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Relate Water Movement to the Time of Set

- LWA prism cast next to cement paste
- Fixed position and macro-water movement
Relate Water Movement to the Time of Set

- Water remains in the pores of LWA until after set

Counts_{@i,LWA} - Counts_{@3.5,LWA}

Counts_{@i,LWA} – Counts_{@3.5,LWA}

X-Ray Measurements

Age of Specimen (h)

Difference in Counts from Initial Counts at 3.5 h

Initial Set

Water is lost from LWA

Void Volume (mL/g cement)

Shrinkage Volume (ml/g cement)
Relate Water Movement to the Time of Set

Water is lost from LWA

Water is lost from LWA

LWA Interface

Water is gained from Paste

Likely Edge
Sample Orientation

- Sample was rotated to correct orientation
- Reduce the size of the ‘interface’
- Reduce Uncertainty
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How Far the Water Moves at Early Ages

- Water is able to move approximately 1.8 mm in first 24-75 hours
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Shrinkage Measurements

Shrinkage Measurements

Typical Response of 3 Samples

Same Volume of Water, More Distribution

LWA-H

LWA-K

Strain (µε)

Age of Specimen (d)

0 2 4 6 8 10

-60 -50 -40 -30 -20 -10 0

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Why is this important

- Water does not move before set
  - Don’t change workability or w/c
- Need paste within close proximity to LWA
  - Want paste within 2 mm of LWA particle
Proper Proportioning

- Select proper grading
- LWA sand is more beneficial than LWA rock
Conclusion

• X-ray absorption can be used to monitor water movement
• Must have proper sample alignment for accurate measurements
• Water does not move before set
• Smaller LWA particles protect more paste
• The distance water can move is important to selecting the proper aggregate grading
Acknowledgements

• This work was supported in part by the Joint Transportation Research Program administered by the Indiana Department of Transportation and Purdue University and the Advanced Center for Cement-Based materials

• John Roberts
  – Northeast Solite Corporation

• Jack Spaulding
  – Hydraulic Press Brick Company
References
