Ultrasonic Monitoring of Concrete Structures Affected by Alkali-Silica Reaction (ASR)

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Online Monitoring System for Concrete Structures Affected by Alkali-Silica Reaction (ASR)

Sponsor: Department of Energy NEUP 16-10214

Program: RC-5 (PD: Bruce Hallbert)

Research Team

The University of Nebraska Lincoln (lead)
The University of South Carolina
The University of Alabama
Georgia Institute of Technology
Idaho National Laboratory

Project objective

❖ Shor term objective

Develop a dual-mode online SHM system that integrates active and passive sensor networks with advanced signal processing algorithms to monitor ASR induced degradation in reinforced concrete structures.

❖ Long term goal

Provide support to a probabilistic SHM framework under development at INL, and support long-term operational and maintenance decision making

Alkali-Silica Reaction (ASR)

- ASR is a chemical reaction between Alkaline in cement and silica in aggregate of concrete.
- The expansive reaction product will cause microcrack in concrete.
- ASR is a slow process. It may take many years to show cracks.
- ASR was found in Seabrook NPP in 2010

ASR microcrack

ASR in Bridge Pier

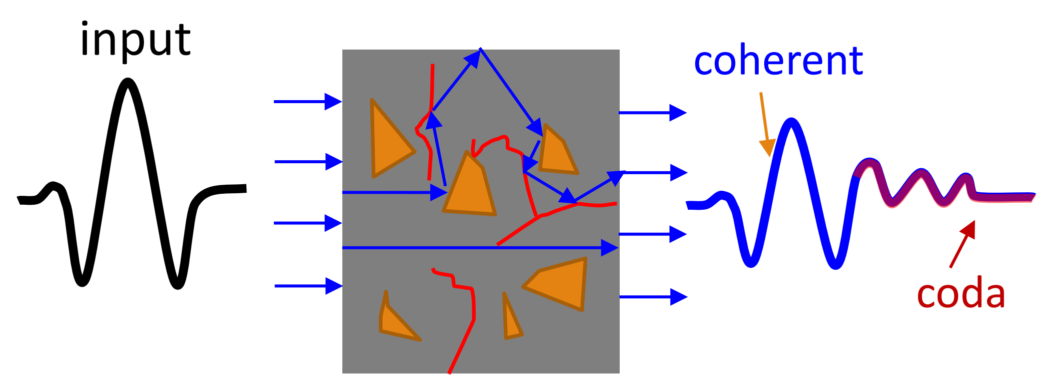
ASR in Seabrook NPP

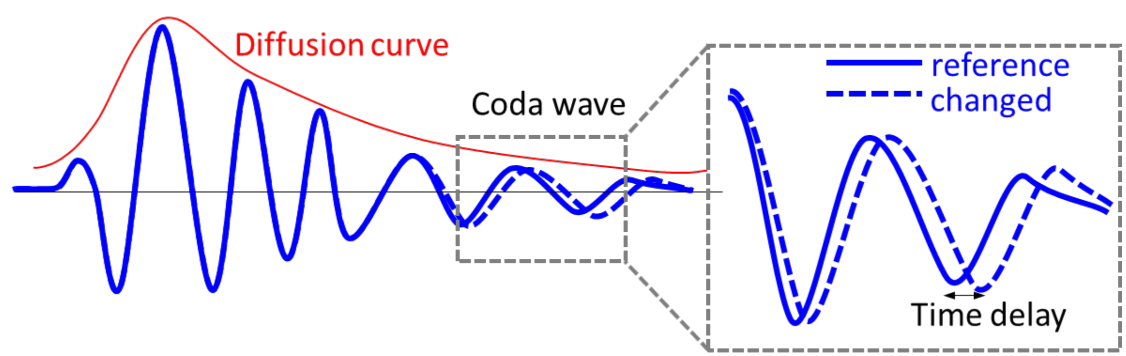
ASR Evaluation

- Problems
  - How to detect initiation of ASR cracking?
  - How to evaluate the progression of ASR damage?
- Proposed Solutions
  - Active sensing using diffuse ultrasonic wave (U Nebraska)
  - Passive sensing using acoustic emission (S Carolina)
- Other Tasks
  - Specimen fabrication and material research (U Alabama)
  - Signal processing and prognosis modeling (Gatech and INL)
  - Validation on large scale specimens

Diffuse Ultrasonic Waves

- Waves scattered by aggregates and microcracks
- Coda wave interferometry (CWI)
  - Measure relative wave velocity change
  - Need a reference signal





Research Tasks at UNL

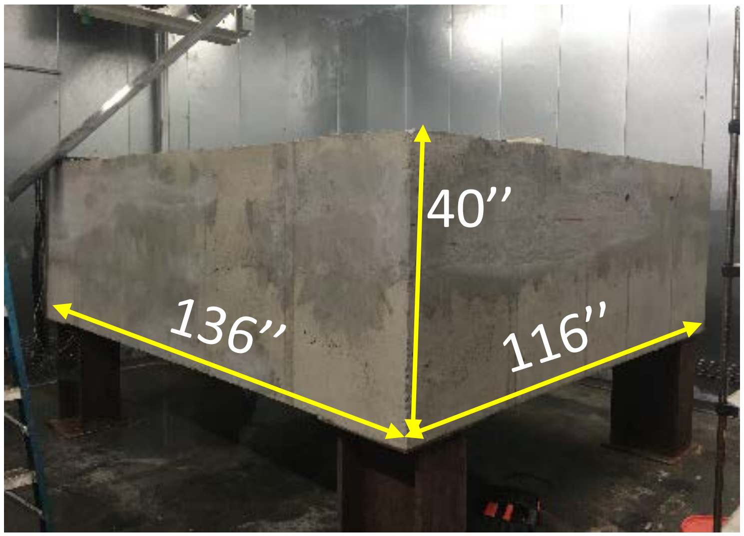
- Experimental program
  - Monitoring large scale ASR concrete specimens using diffuse ultrasonic waves – system was installed in April 2017
  - Monitoring of small scale ASR specimens – will start soon
  - CWI analysis on small specimens with mechanical cracks
- Numerical study
  - Modeling of concrete with randomly distributed aggregates and microcracks

Three Large Scale Concrete Specimens

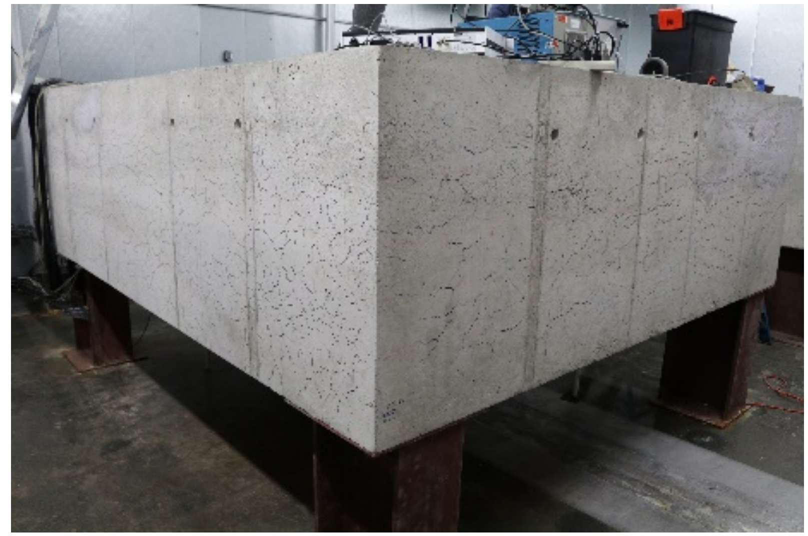
- ORNL and University of Tennessee built three large concrete specimens to study stress effect on ASR
  - Dimension: 3.5 x 3 x 1 m, cast in August 2016
  - Control specimen
  - Unconfined ASR specimen
  - Confined ASR specimen
- NDE researchers are invited to test on the specimens
  - Evaluate the effectiveness and reliability of NDE techniques
  - Monitor the ASR progression

Three Large Scale Concrete Specimens –

Control specimen



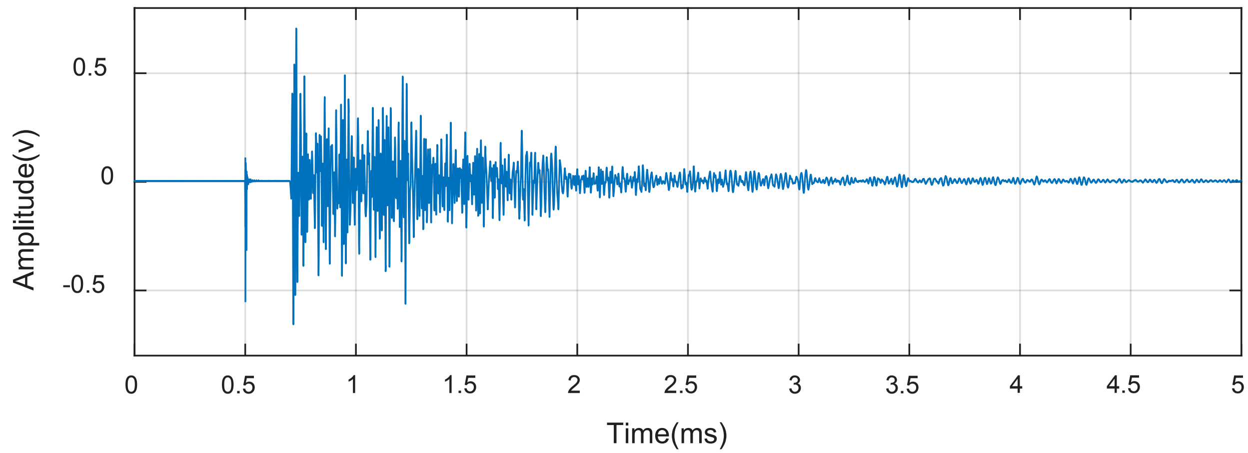
Unconfined ASR specimen

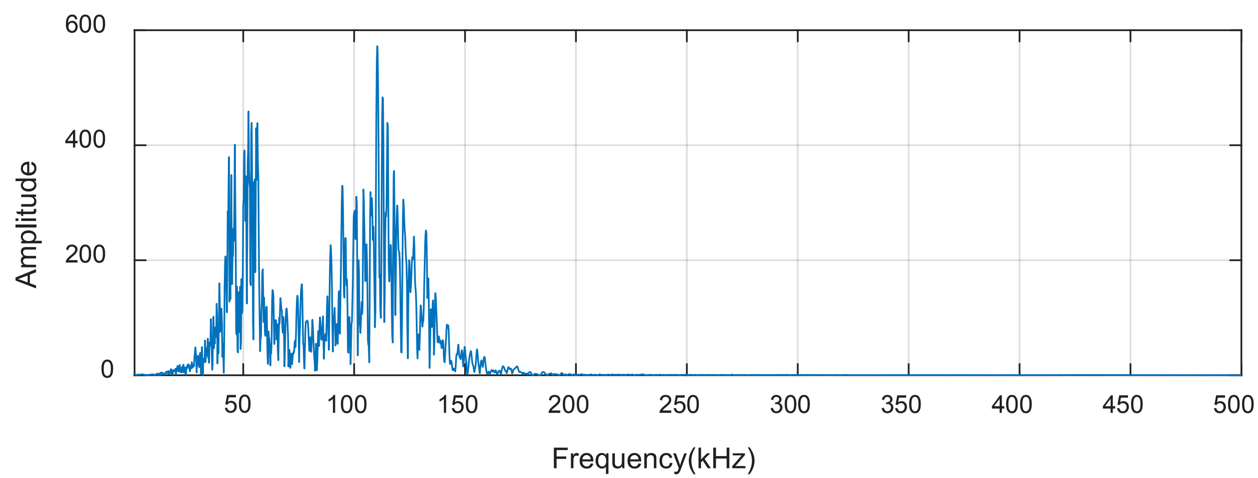


Confined ASR specimen

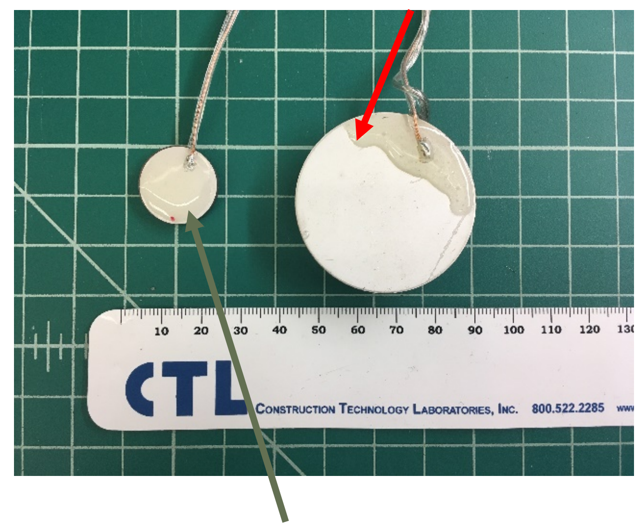
Extensive cracks observed at sensor installation (April 2017).

Sensor selection



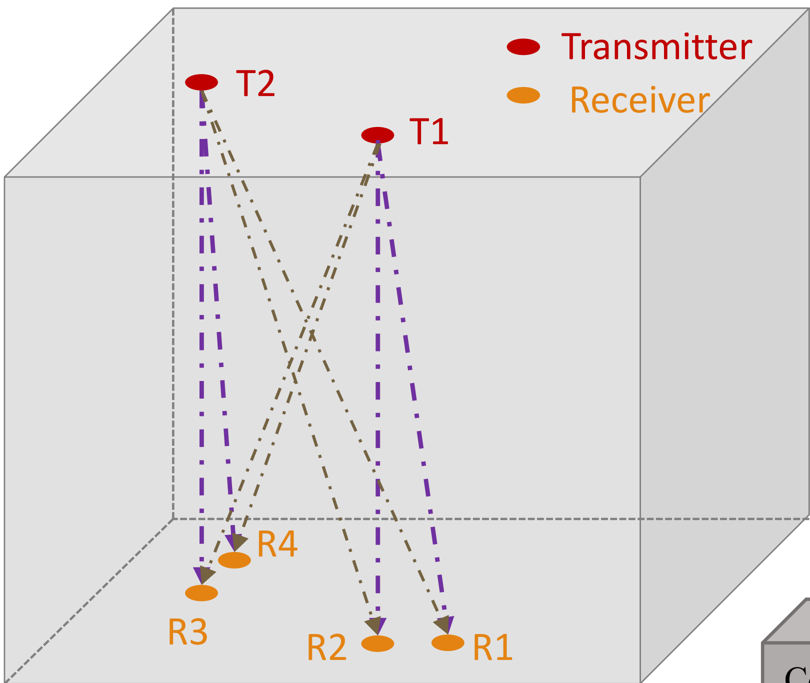


Transmitter
(45mm)



Receiver

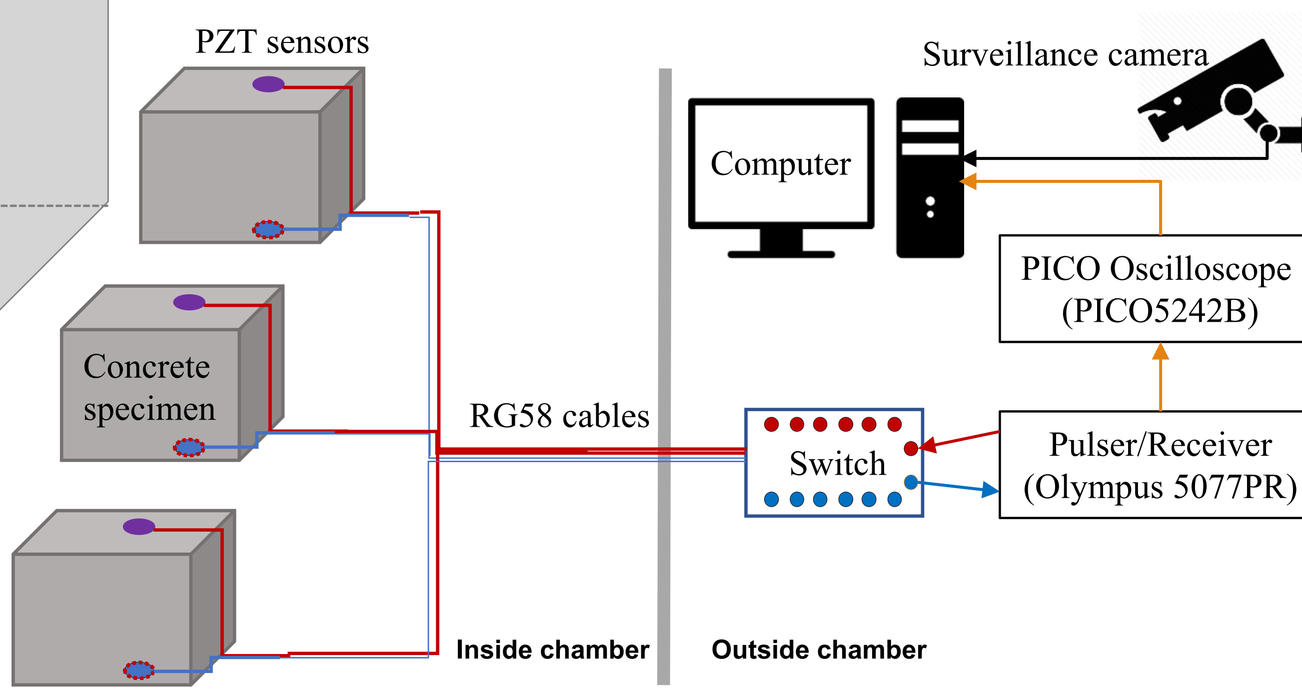
Experimental setup



SENSOR ARRANGEMENTS

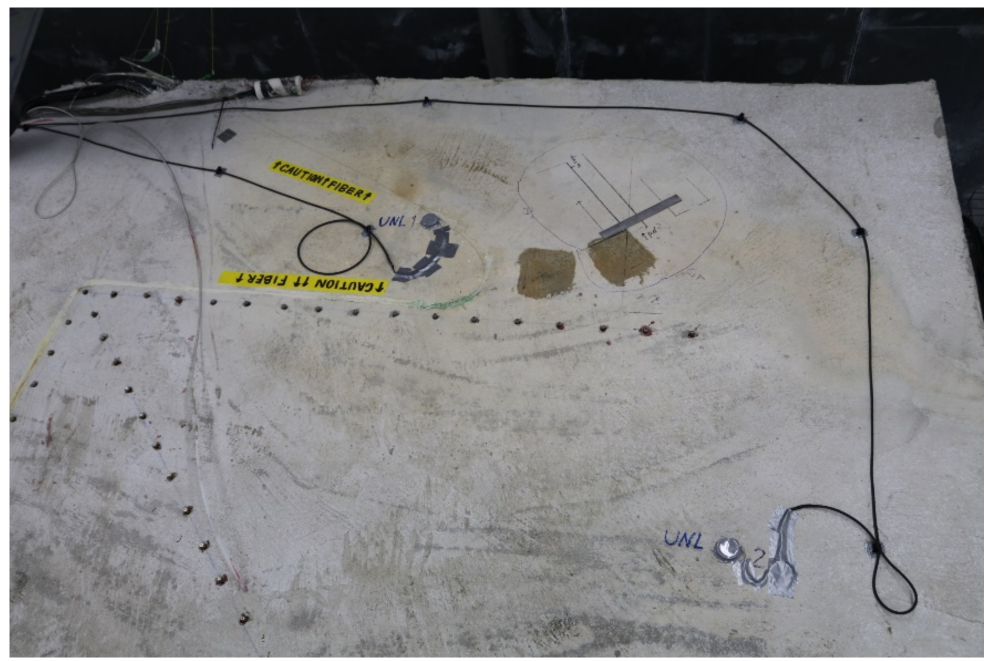
8 possible wave paths in each specimen

ASR MONITORING SYSTEM



Experimental setup

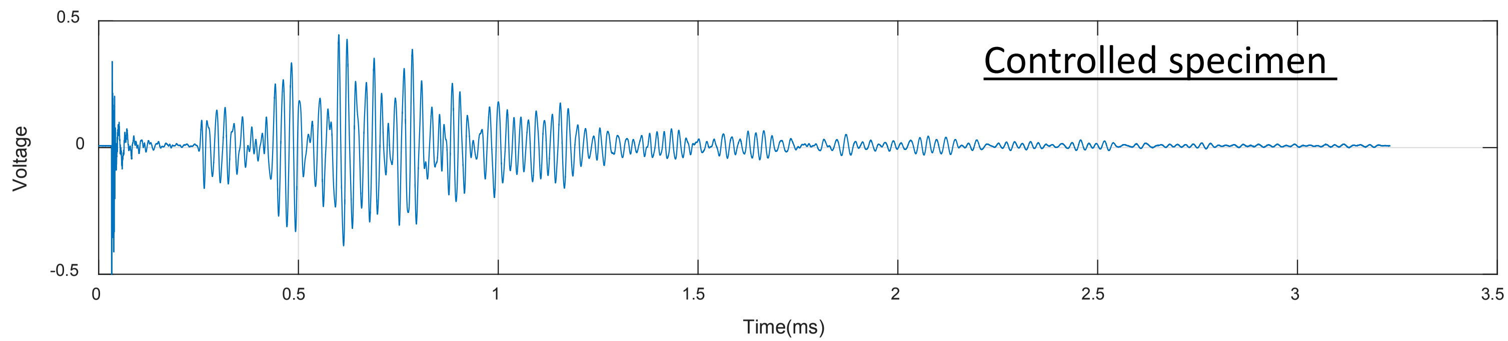
- University of Nebraska (UNL) team installed sensors (April 21) on ORNL/UTK large scale ASR specimens, and start to receive data
- Collect data around 2:15AM daily. The information was also shared acoustic emission research team.



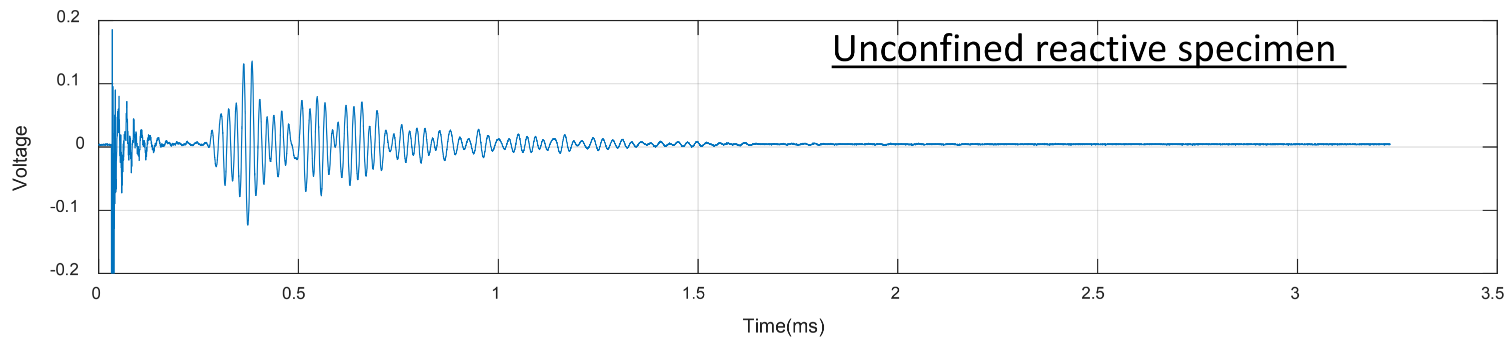
Ultrasonic remote monitoring system and sensors

Sample Time Domain Signals on 3 specimens

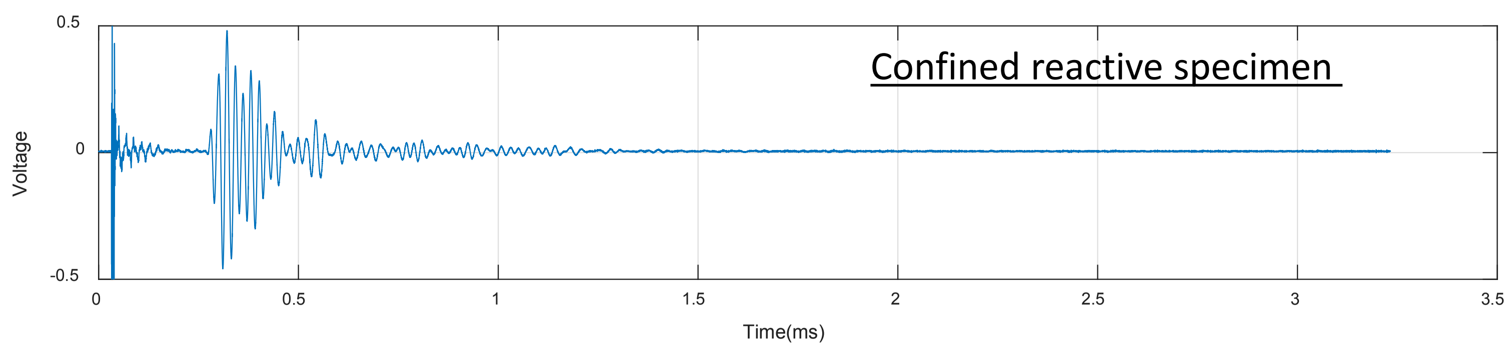
High amplitude
Slow decay



Low amplitude
Slow decay



High amplitude
Fast decay



Temperature effect

- Velocity change can be caused by
  - Temperature change
  - Microcracking
  - Shrinkage, continuing hydration induced strength increase
- Temperature variation has significant effect on CWI analysis, much larger than microcracking effect
- Relative wave velocity change dV/V is inversely proportional to temp change
- Temperature effect is typically compensated by a reference specimen in the same temp condition

Future work

- Improve understanding on temperature effect on opening/closing of microcracks, and the effect of which on diffuse wave analysis.
- Start detailed monitoring and analysis on medium size ASR specimens by December 2017
- Collaborate with U South Carolina to analyze data recorded by the AE sensors – feasibility to develop a dual function system using the AE and ultrasonic sensors.

Acknowledgements

- DOE NEUP program
- University of Tennessee Knoxville and ORNL for providing access to the large scale specimens
- Collaborators (U S Carolina, U Alabama, Gatech, INL)
- University of Nebraska for cost share and space allocation