




American Concrete Institute®
Advancing concrete knowledge

Shrinkage-Compensating Concrete—Past, Present, and Future, Part 2

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WEB SESSIONS



Kyle R. Renevier, Sstudent, University of Oklahoma, Norman, OK

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The Use of Shrinkage Compensating Concrete in an Underground Water Tank



Kyle Renevier
Chris Ramseyer
Ph.D., P.E

ACI Oct 2012

In-situ testing of Shrinkage Compensating Concrete



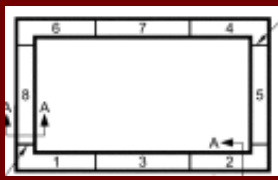
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Investigation of Shrinkage Compensating Concrete

- Research Locations
 - Restrained Tank (Springfield, IL)
 - Unrestrained slab on ground (Los Angeles, CA)
 - Restrained slab on ground (Fears Lab, Norman, Oklahoma)
- Testing
- Results
- Conclusion

Purpose of Research

- Investigate behavior of concrete tank walls & slabs
- Review ACI 223 notes on shrinkage compensating concrete SCC cast wall sequence

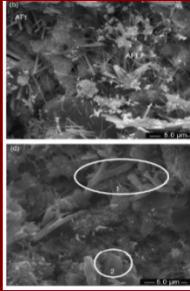


Purpose of Research

- Strain evaluations of walls during construction
 - Should the wall be designed to slide or
 - Is typical tank detailing ok i.e. high fixity
- Long term shrinkage


Previous Research

- JingJing (2011)
 - Temperature impact on SCC
- At 100°F
 - Expansion increases in SCC
 - Faster strength gain
- At 160°F
 - SCC becomes unstable
 - Ettringite degrades
 - Strength and expansion does not occur




Previous Research

- Eskildsen et al. (2004)
 - Vibrating wire strain gages (VWSG)
 - Post-tensioned SCC
- Performance
 - Max Expansion 140µε
 - Max Shrinkage 120µε
 - Out performed Portland Cement



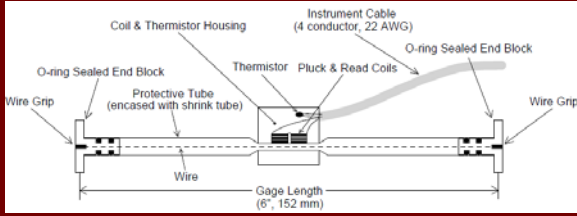
Previous Research

- Xia et al. (2009)
 - VWSG to monitor construction of skyscraper
 - Installation of VWSG
 - Noise in the first 5 days



Equipment

- Geokon Vibrating Wire Strain Gages
 - Model 4200 (with 100' of cable)
 - Measures microstrains
 - Measures temperature



Equipment

- Geokon Data Acquisition System
 - Model 8002-16 (16 Channels)






Testing Set Up

- Wires fed through form work




Testing Set-Up

- Cables run to Data Acquisition System



Testing

- System ran for 170 days
 - Interval of 15 minutes between each reading
- After initial set up
 - Adjoining tank walls were poured 23 days later



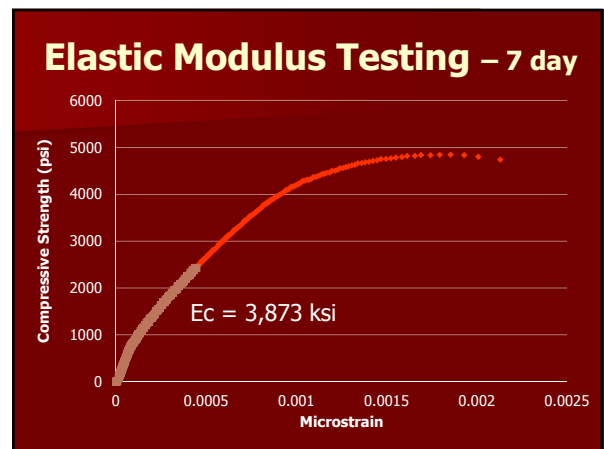
Testing

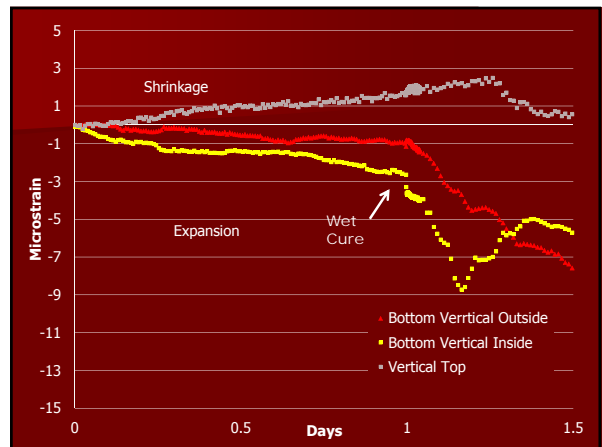
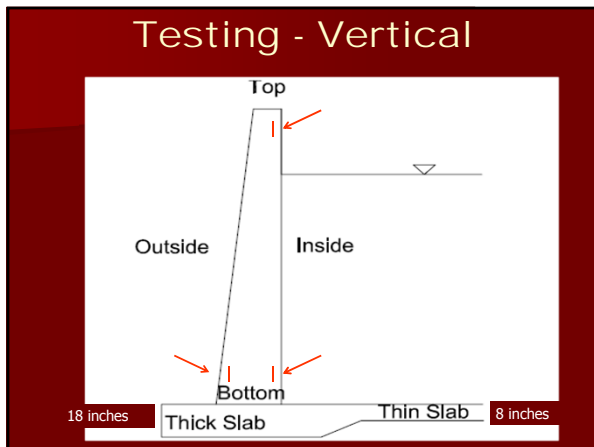
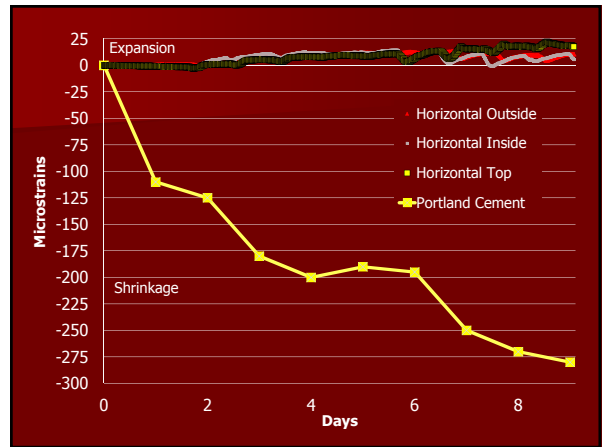
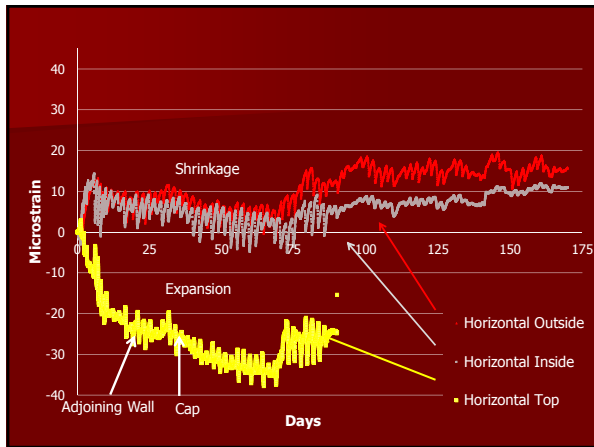
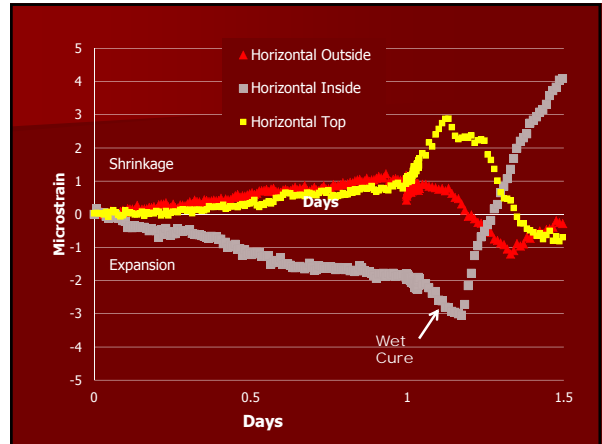
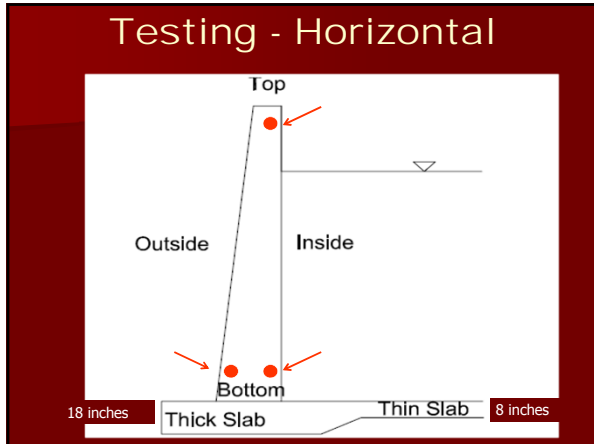
- A cap was poured around day 35

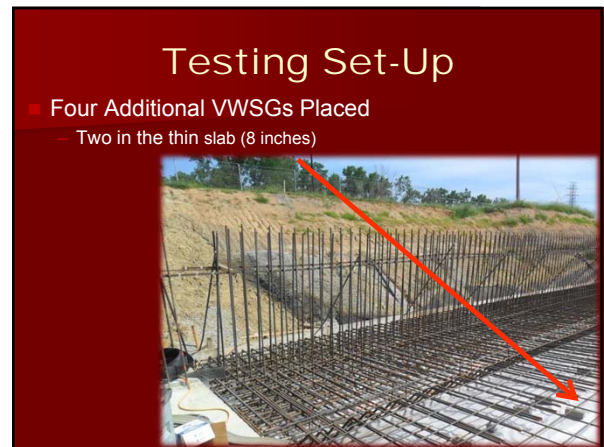
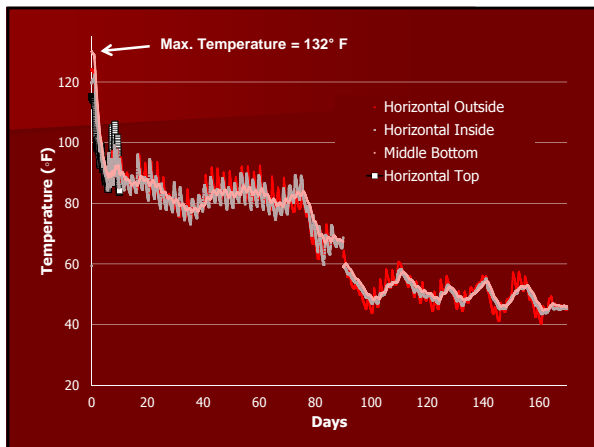
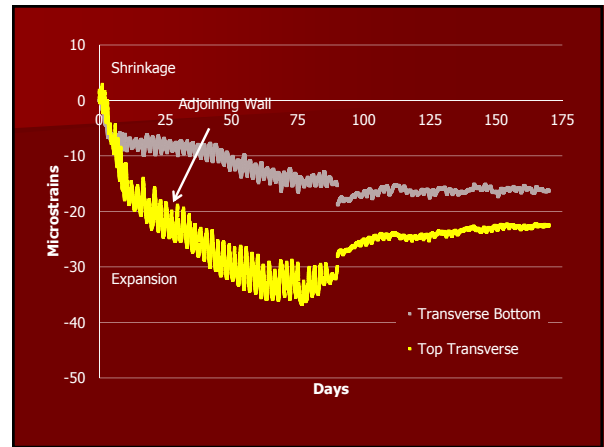
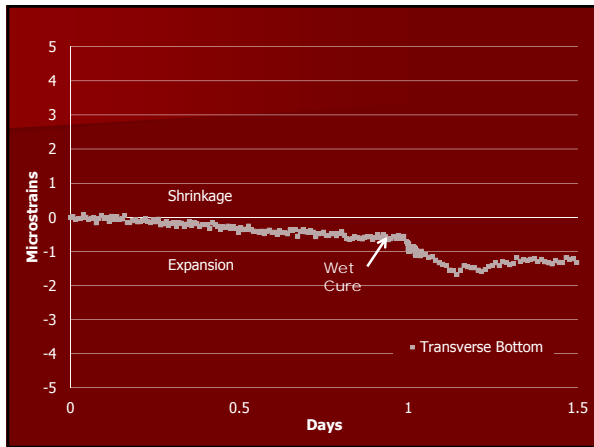
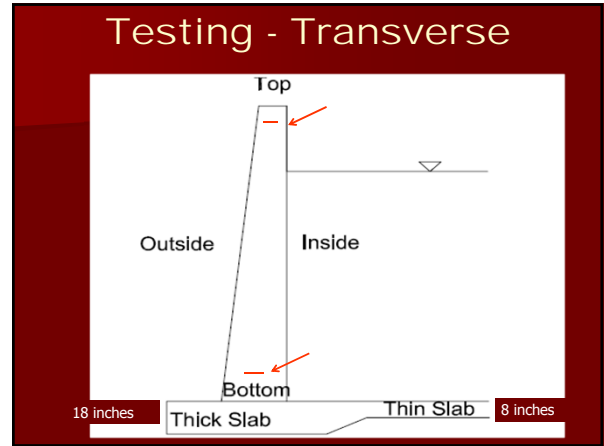
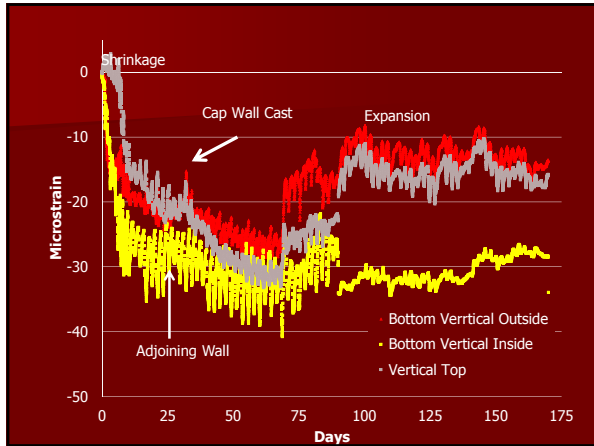


Springfield Mix

- CSA cement = 90 lbs/yd
- Portland type I = 418 lbs/yd
- Type C Fly Ash = 57 lbs/yd
- w/cm = 0.46 to 0.48
- MRWR
- Air entraining = 4% - 4.5%
- #67 Aggregate
- Sand
- ASTM C 878 = 0.07% expansion



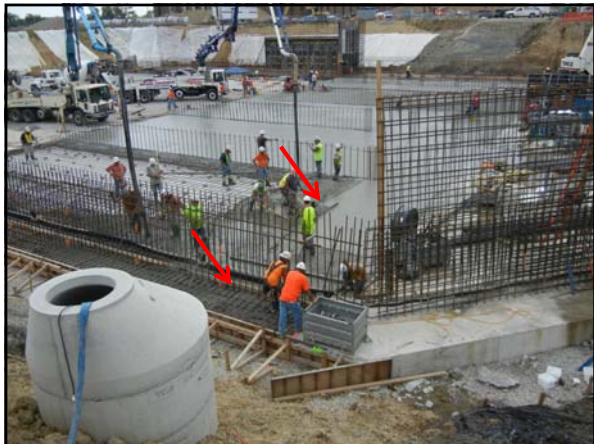


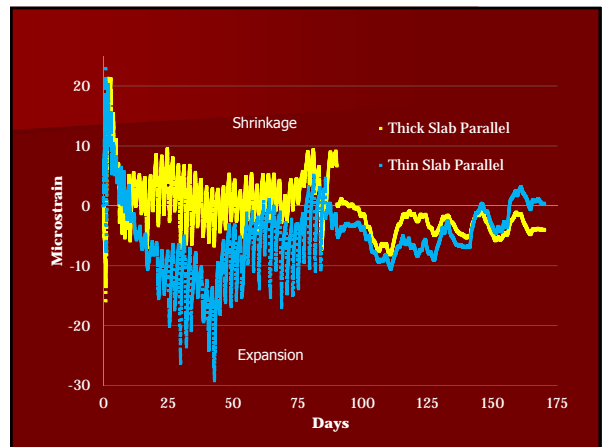
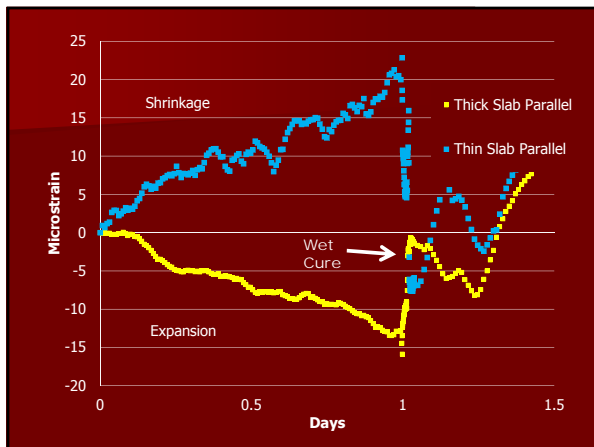
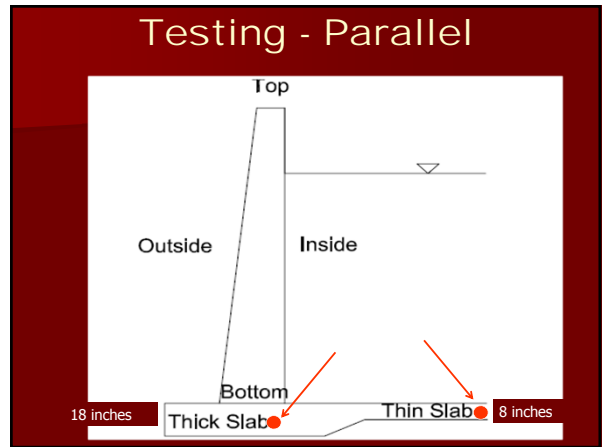
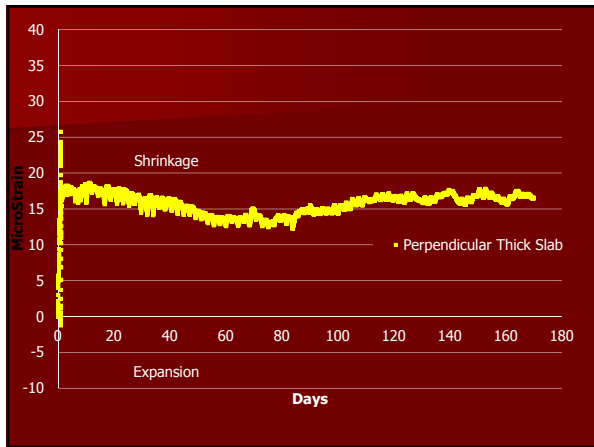
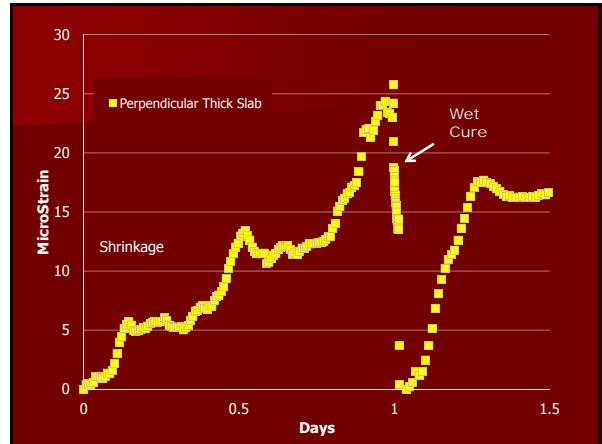
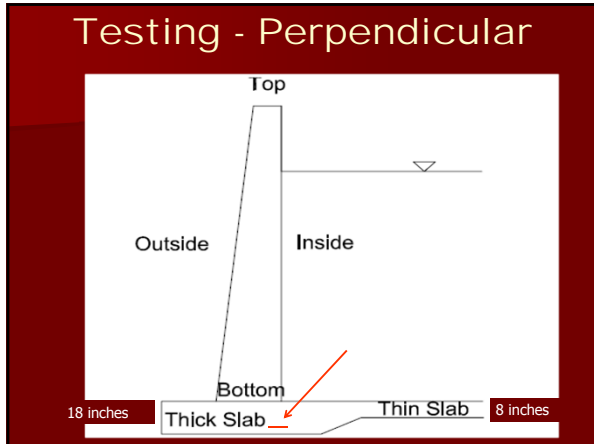


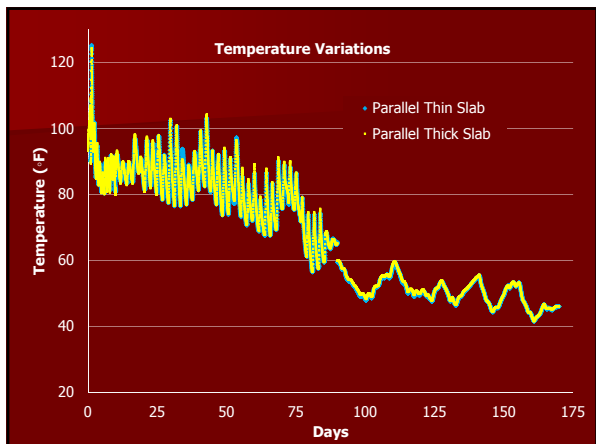


Testing Set-Up

- Four Additional VWSGs Placed
 - Two in the thick slab (18 inches)

A wide-angle photograph of the testing set-up. A large rebar grid is visible on a concrete slab. A red arrow points to a sensor placed on the slab. The background shows a construction site with a hillside.





Restrained Testing Tank Wall Results

| Highest Microstrain Value for Each Direction | | |
|--|-------------|---------------------|
| Location | Microstrain | Expansion/Shrinkage |
| Vertical Interior Bottom | 41 | Expansion |
| Vertical Outer Bottom | 29 | Expansion |
| Vertical Top | 32 | Expansion |
| Horizontal Interior Bottom | 13 | Shrinkage |
| Horizontal Outer Bottom | 20 | Shrinkage |
| Horizontal Top | 38 | Expansion |

Restrained Testing Slab on Ground Results

| Highest Microstrain Value for Each Direction | | |
|--|-------------|---------------------|
| Location | Microstrain | Expansion/Shrinkage |
| Thick Slab Perpendicular | 26 | Expansion |
| Thick Slab Parallel | 24 | Shrinkage |
| Thin Slab Parallel | 23 | Shrinkage |
| Transverse Bottom | 19 | Expansion |
| Transverse Top | 33 | Expansion |

Why do we not see 0.07% expansion? And why does it expand beyond 7 days?

- Slab to grade restraint
- Wall to slab restraint
- Difference in surface area to volume ratio

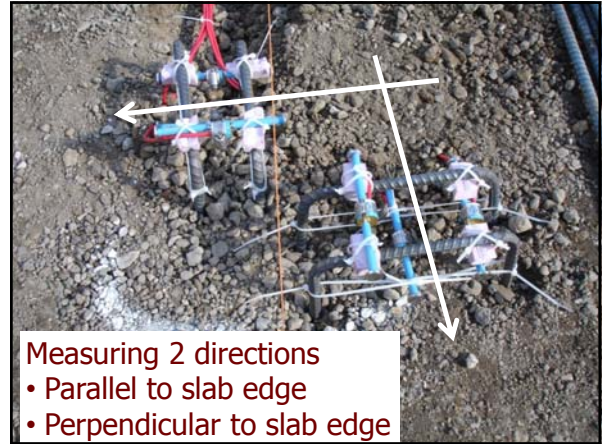
| | Exposed Surface Area (ft ²) | Total Volume (ft ³) | Surface Area Volume |
|--------------|--|------------------------------------|------------------------|
| ASTM C878 | 0.8750 | 0.0625 | 14.000 |
| Wall Segment | 2322 | 2160 | 1.075 |

Unrestrained Testing

- Los Angeles, California
 - No rebar placed in the slab
 - Testing for 70 days

LA Mix

- CSA cement = 90 lbs/yd
- Portland type I = 408 lbs/yd
- w/cm = 0.46 to 0.48
- #3 & 4 Aggregate = 1782 lbs/yd
- Sand = 1458 lbs/yd
- MRWR = 59.6 oz/yd

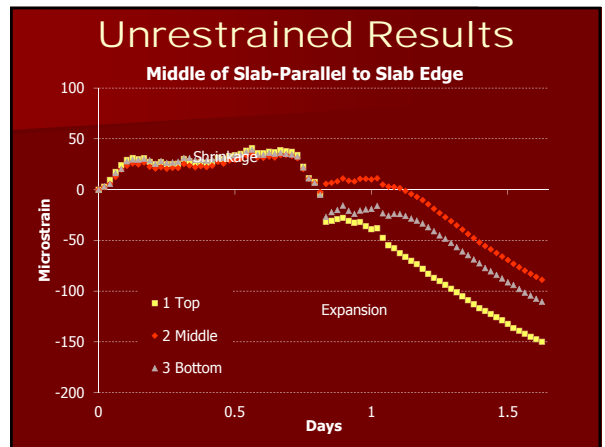
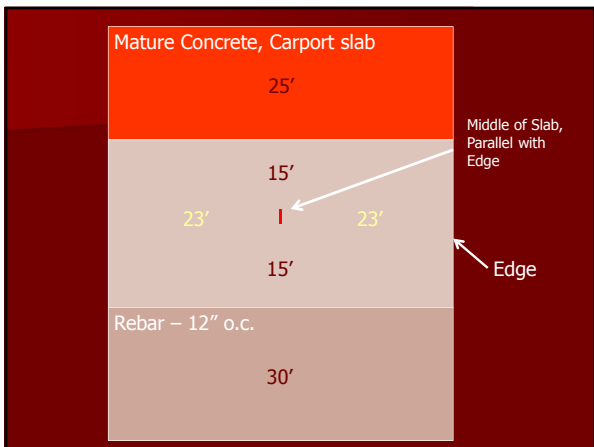


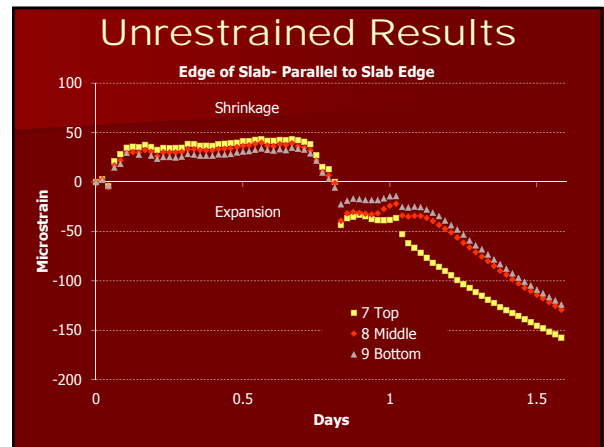
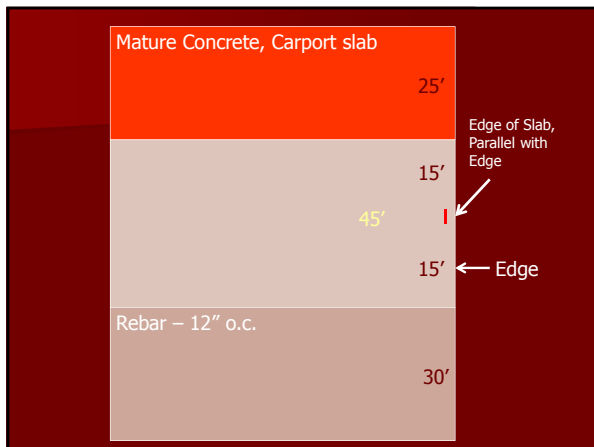
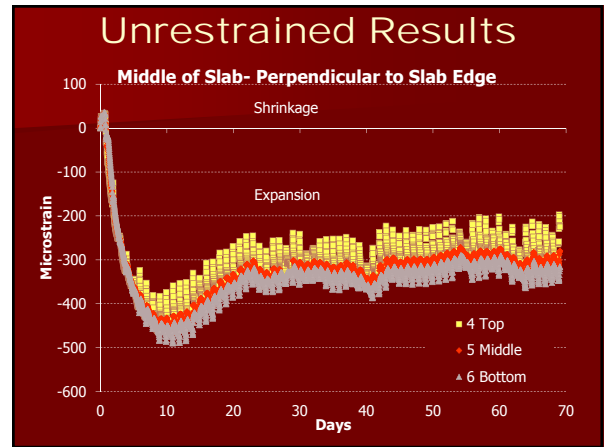
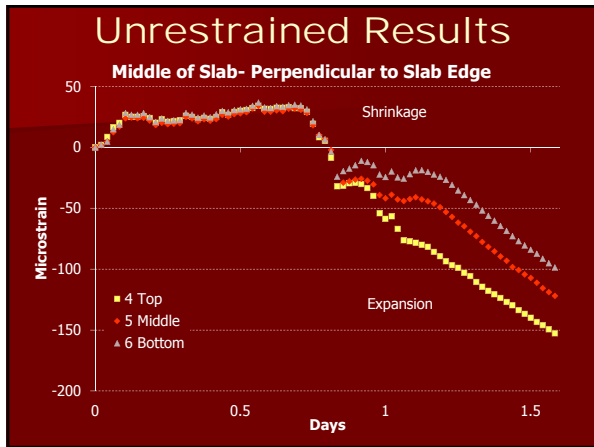
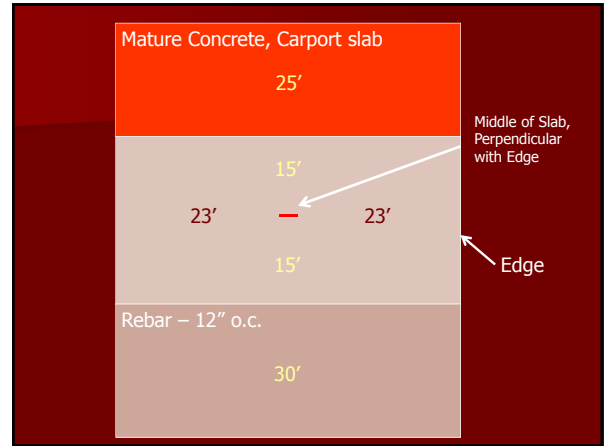
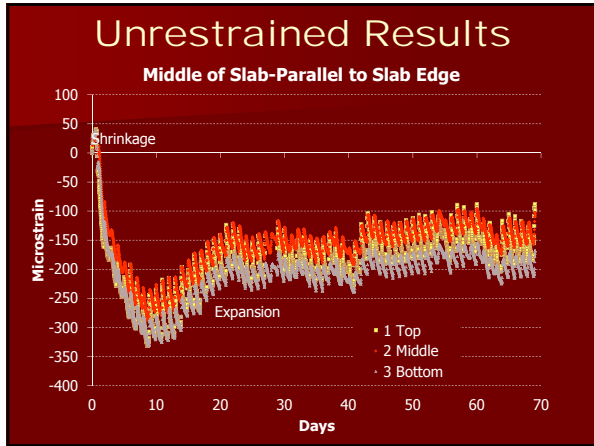
Measuring 2 directions

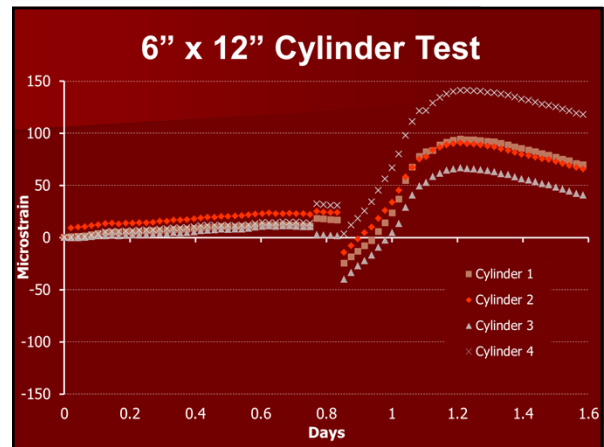
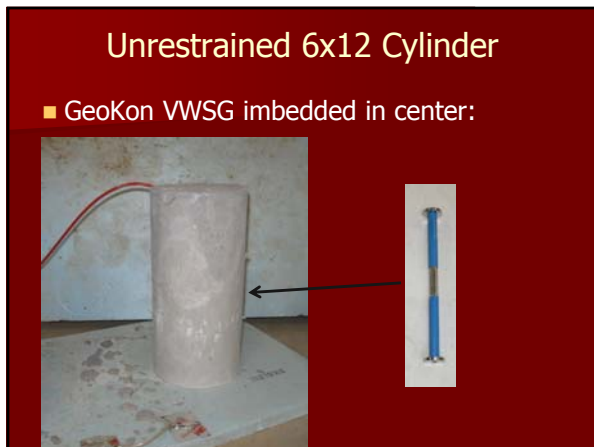
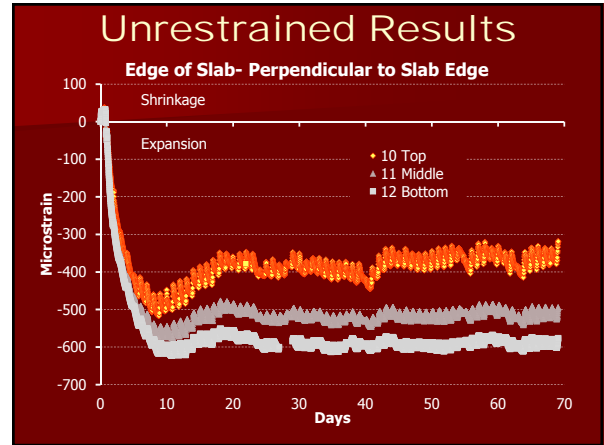
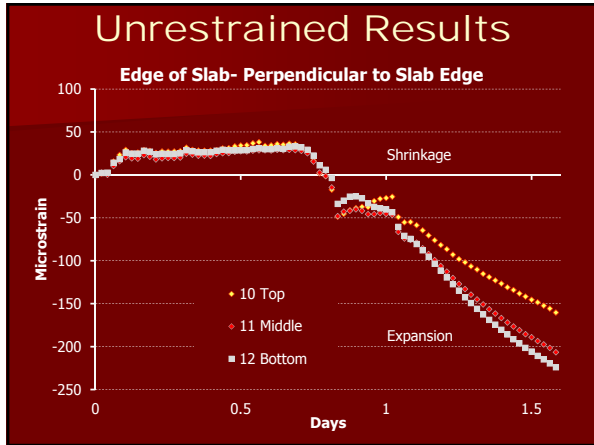
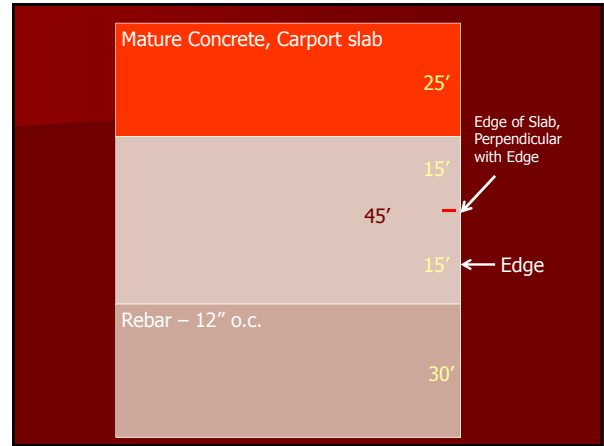
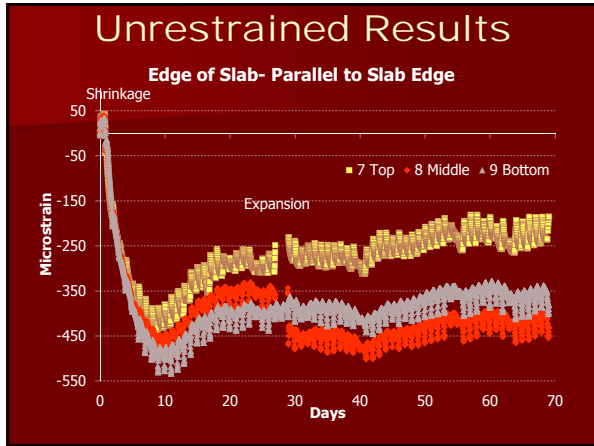
- Parallel to slab edge
- Perpendicular to slab edge

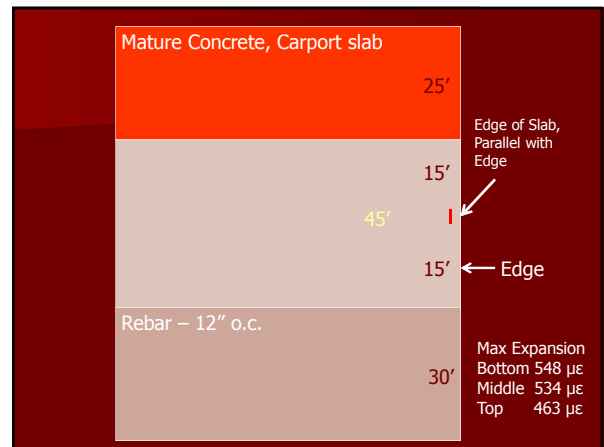
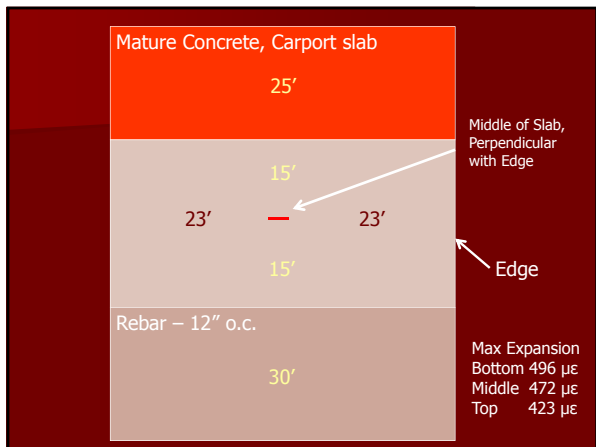
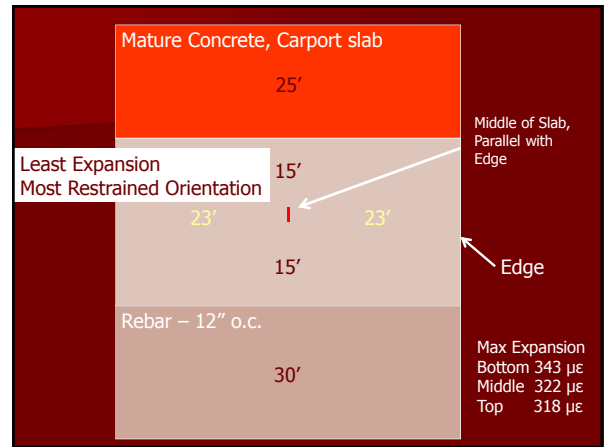
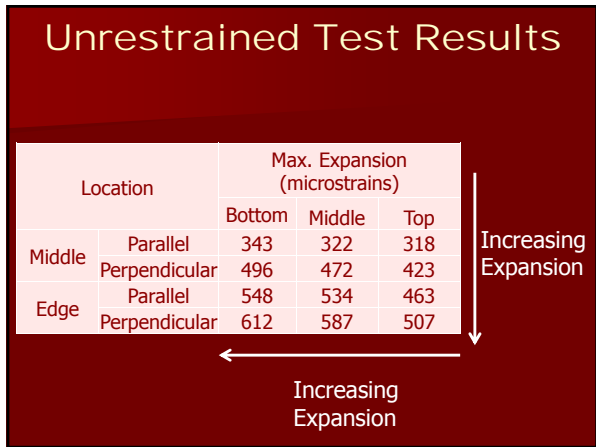
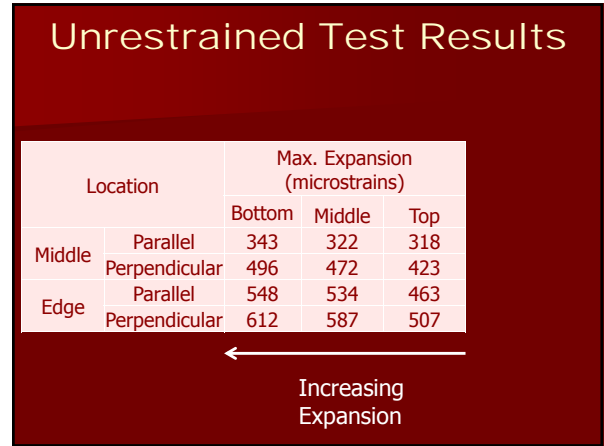
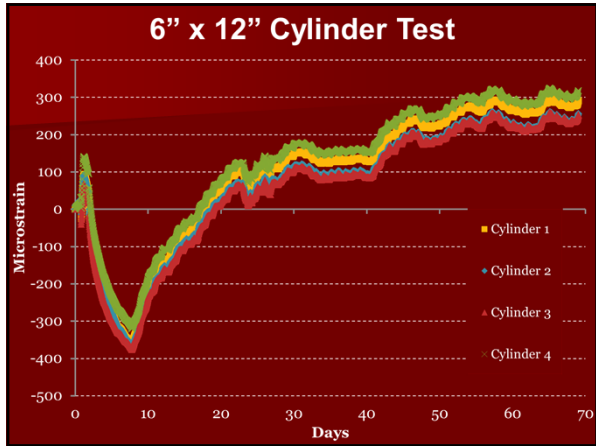
Unrestrained Testing Set Up

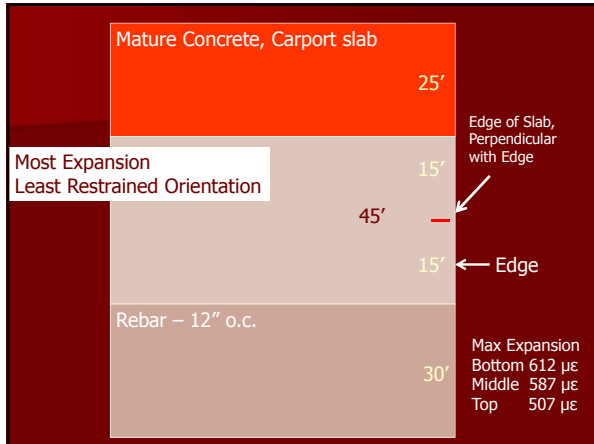
- Three depths
 - Top (4.5 inches from the ground)
 - Middle (3 inches from the ground)
 - Bottom (1.5 inches from the ground)





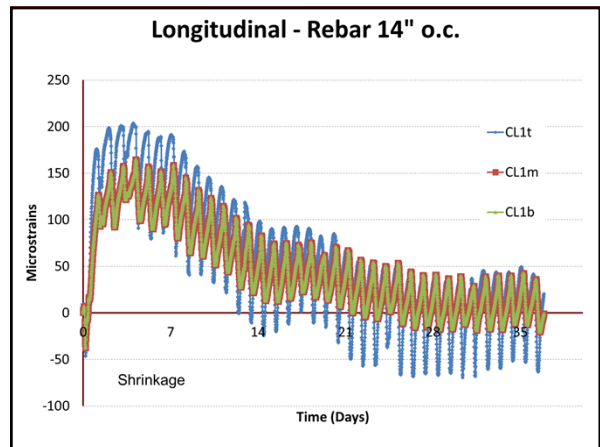
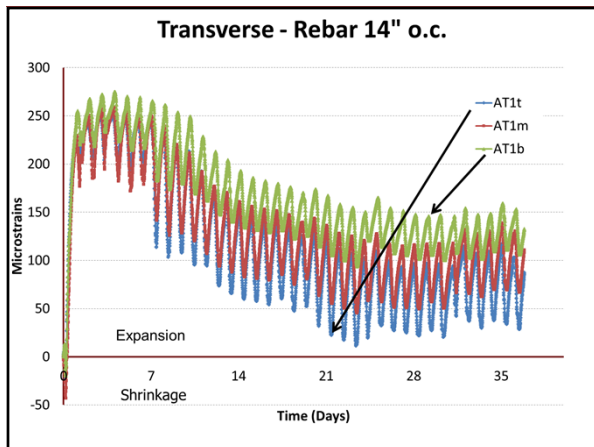
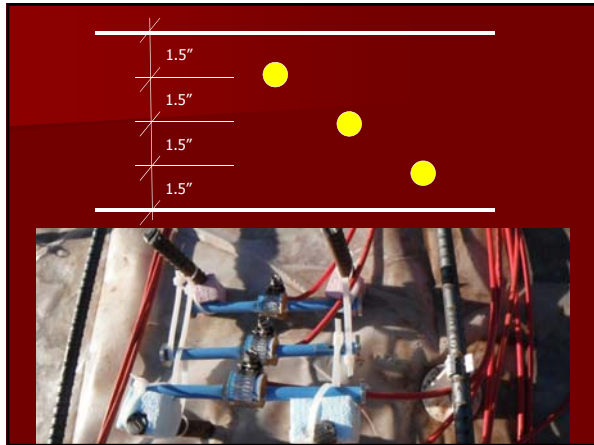


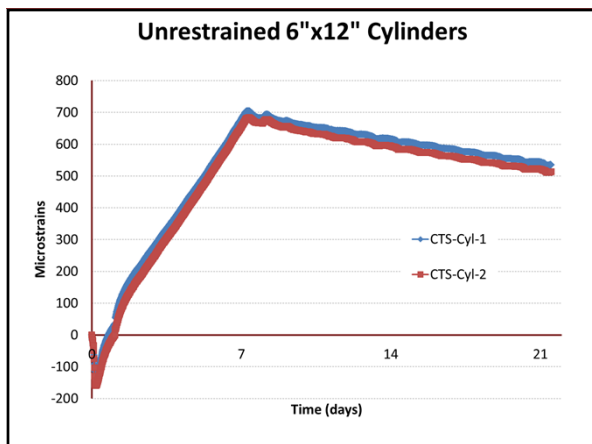
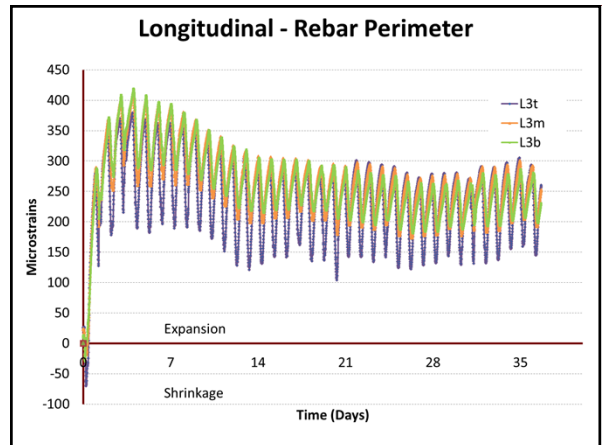
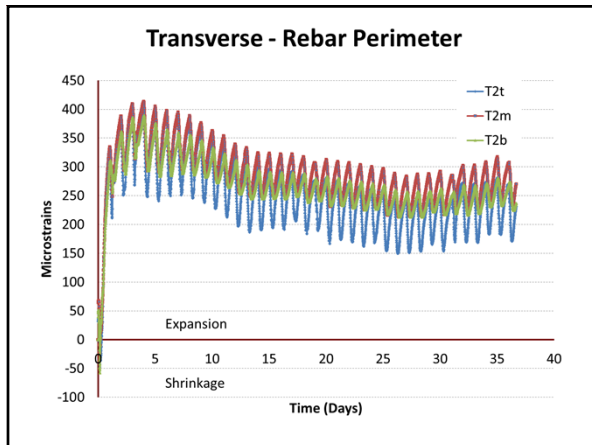
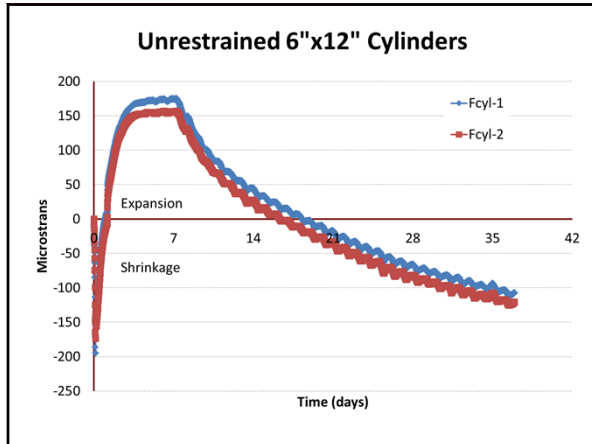




Restrained Testing

- Fears Lab, Norman, Oklahoma
- (4) 15' x 50' x 6" slabs
 - (2) #4 rebar @ 14" o.c.
 - (2) w/ (2) #5 rebar at perimeter





Conclusion

- Restraining Type K, Shrinkage Compensated Concrete in one direction does Not restrain the expansion in other directions.
 - Restraining σ_1 does not restrain σ_2 or σ_3

Conclusion

- Type K, Shrinkage Compensated Concrete will not self destruct at the expansions acceptable to ACI 223 if there is no rebar
- Highly restrained placement of Type K, Shrinkage Compensated Concrete will have minimum expansion and shrinkage

Conclusion

- VWSG are a suitable measuring tool for SCC
 - Durable, Accurate and not prone to bias
- Scale of the project affects SCC
 - Greater surface area verse volume of the prism or wall may cause discrepancies between lab and in-situ testing

Acknowledgement

- City of Springfield
- CTS
- University of Oklahoma
- Geokon
- ACI 223

Thank You!



Questions ?

