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Shrinkage-Compensating Concrete—Past, Present, and Future, Part 1

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Acknowledgments

- University of Oklahoma
- Fears Structural Engineering Laboratory
- Advisor: Dr. Chris Ramseyer
- Sponsor: CTS Cement Manufacturing

Topics

- Background/Theory
- Method
- Results
- Conclusions

Restraint of Slabs: ACI 223

- Slab-on-ground surrounded by existing: "infinite restraint"
- "...there can be no movement"
- "...high compressive stress in concrete but may provide little compensation"



Restraint of Slabs: ACI 223

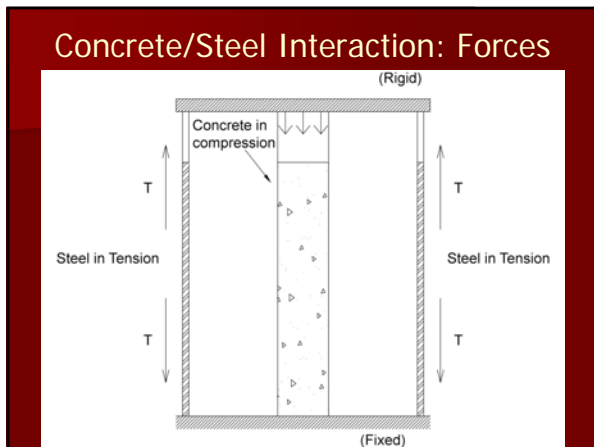
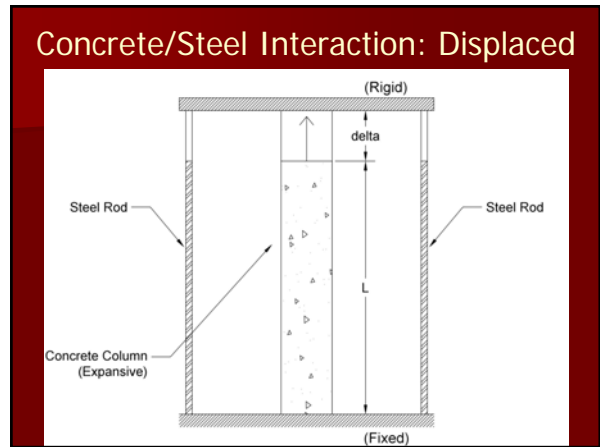
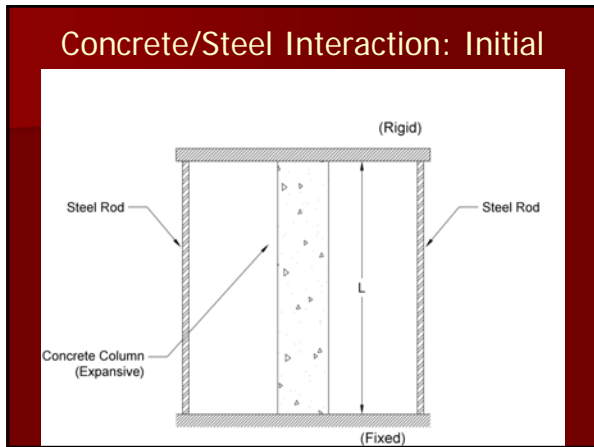
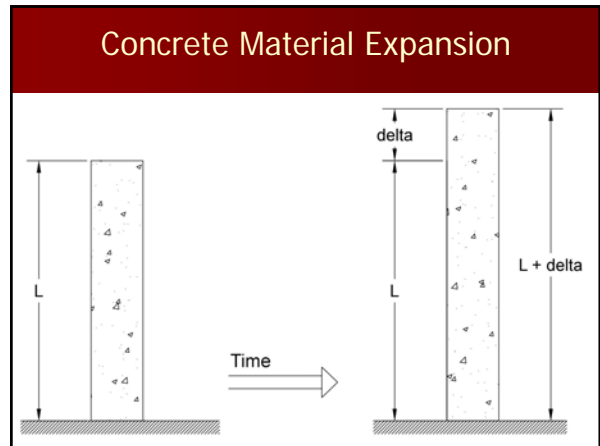
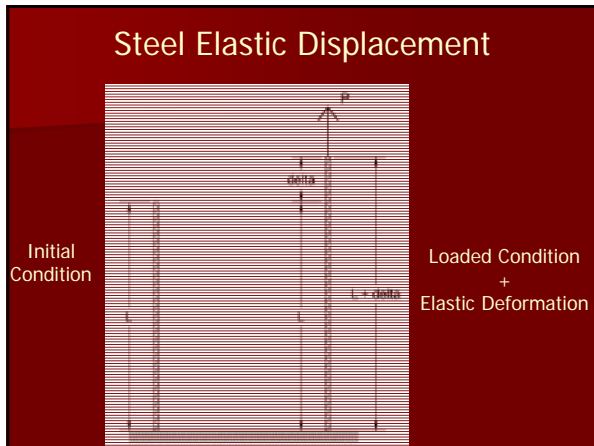
...high compressive stress $\sigma = \frac{P}{A}$ but little compensation" $\Delta = \frac{PL}{AE} \approx 0$



Does Total Restraint Exist?

- Classical Mechanics → Hooke's Law
- Applied force must be accompanied by material deformation (whether large or small)
- Concrete is elastic over a small range and therefore cannot be a perfect boundary condition

Concrete Elastic Displacement

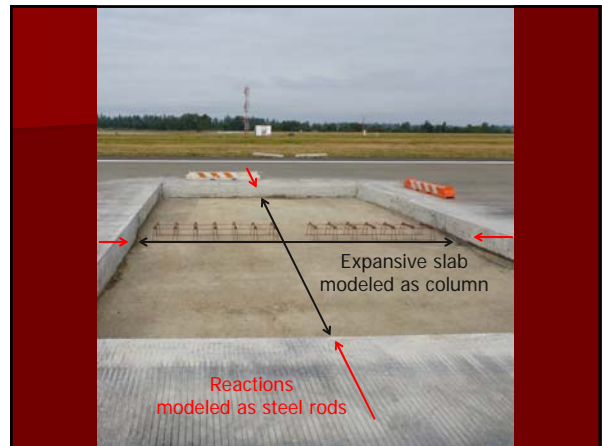
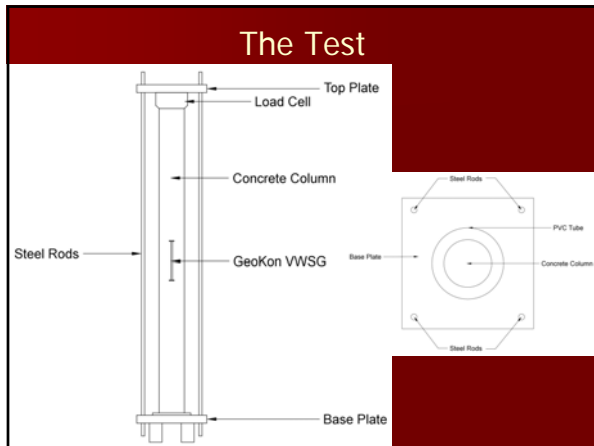


Equivalent Stiffness

- Axial stiffness defined by: $\frac{EA}{L}$

$$\frac{E_s A_s}{L_s} = \frac{E_c A_c}{L_c}$$

- Result: Steel area required is roughly equal to a group of (4) 5/8" bars
- Additionally, test with (4) 1/2" and (4) 3/4" bars
- Provides 36% to 44% range, respectively



Mixes

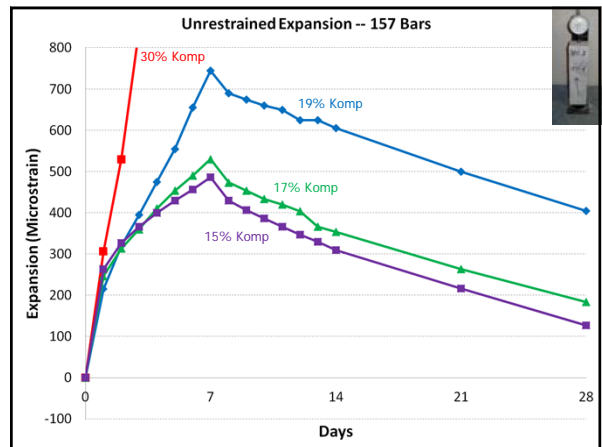
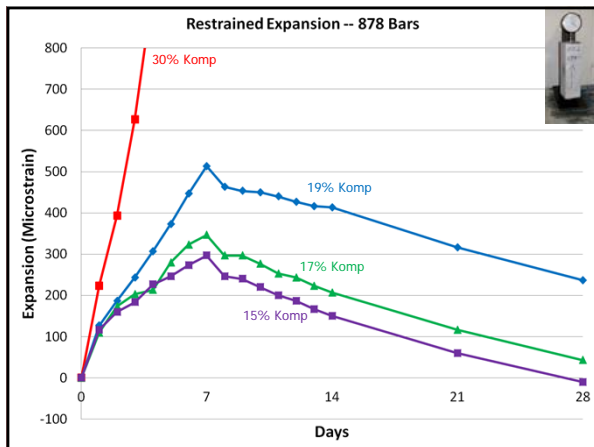
	30%	19%	17%	15%
PC Type I	406	470	481	493
Komponent	174	110	99	87
Total Cementitious	580	580	580	580
Rock	1776	1776	1786	1780
Sand	1377	1383	1392	1369
Water	275	275	256	287
W/C Ratio	0.5	0.5	0.5	0.5

(Lbs. per cubic yard)

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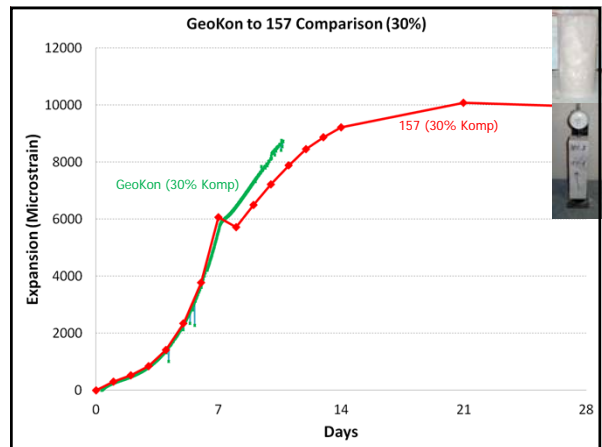
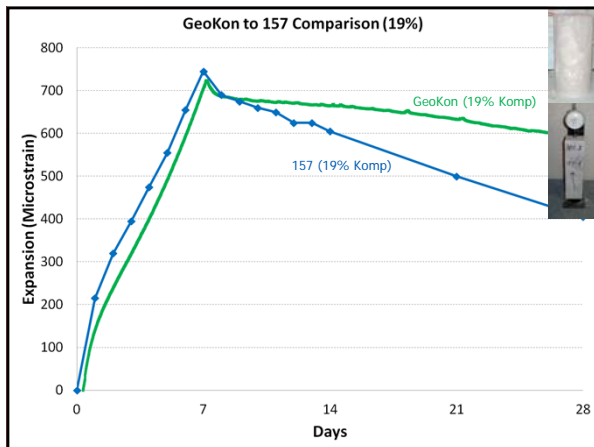
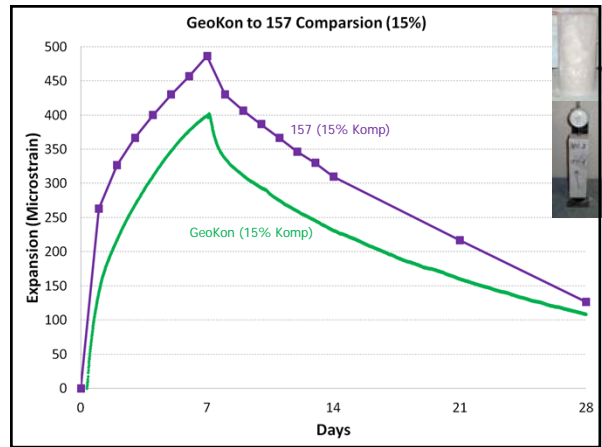
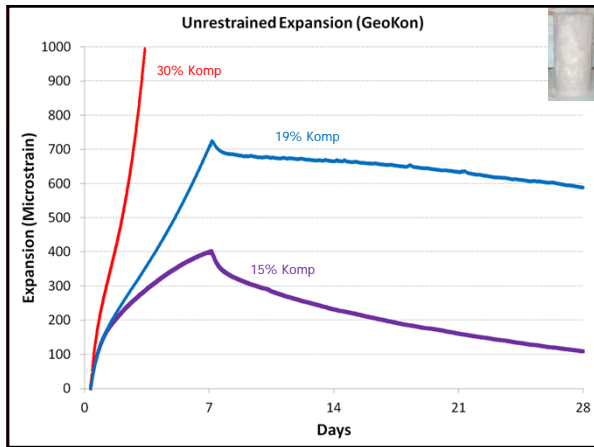
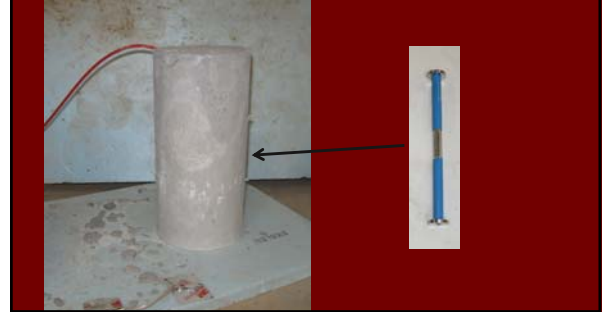
Instrumentation

- GeoKon VWSG:



Unrestrained 6x12 Cylinder

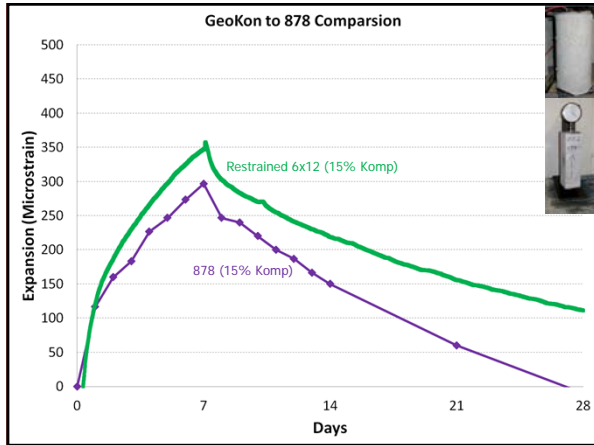
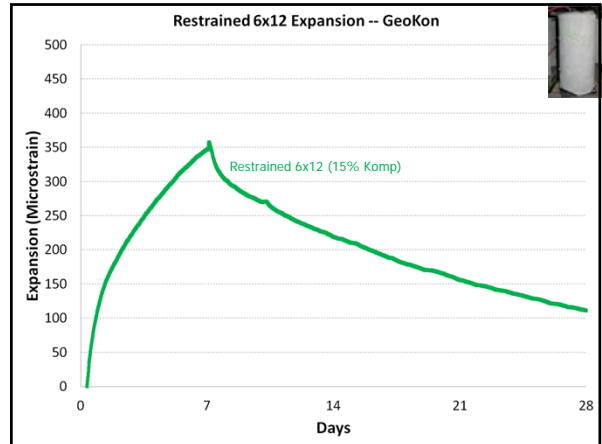
- GeoKon VWSG imbedded in center:




Restrained 6x12 Cylinder

- GeoKon VWSG imbedded in center:

$$\rho_{\text{cylinder}} = \rho_{878} = 0.17\%$$




Test Frames



- Somat eDAQ
- GeoKon Loggers
- 1/2" Frame
- 5/8" Frame
- 3/4" Frame

Wet Curing Condition

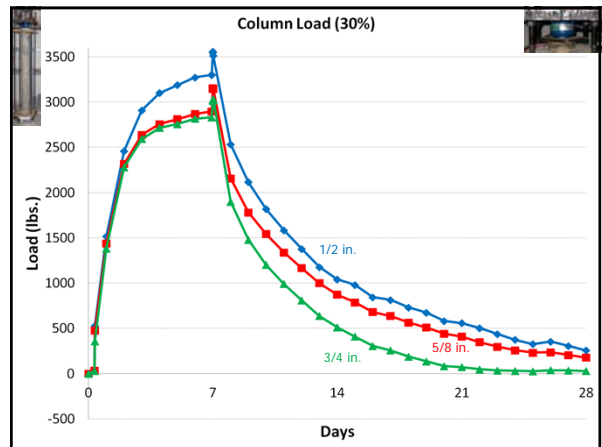
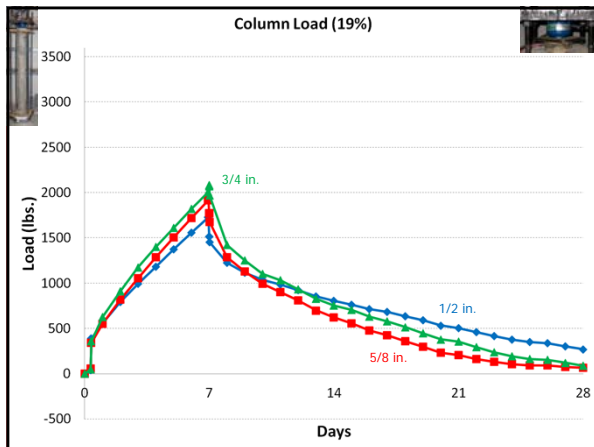
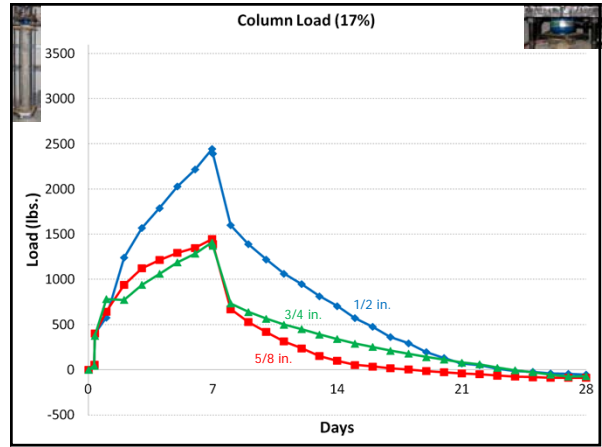
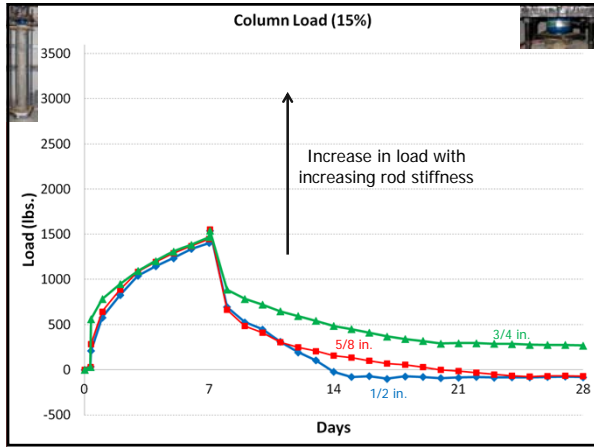
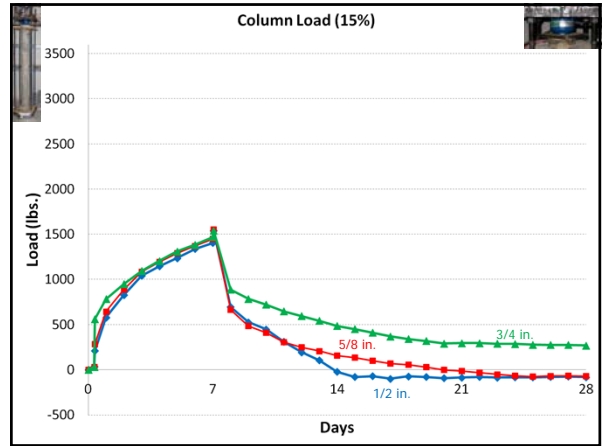


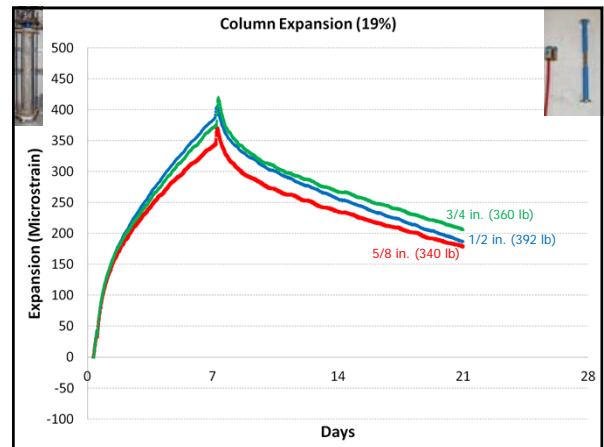
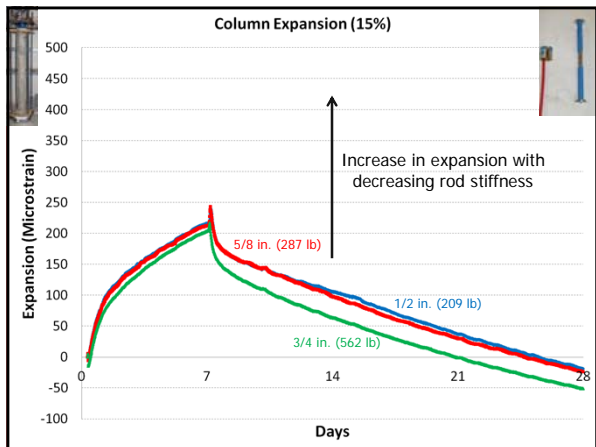
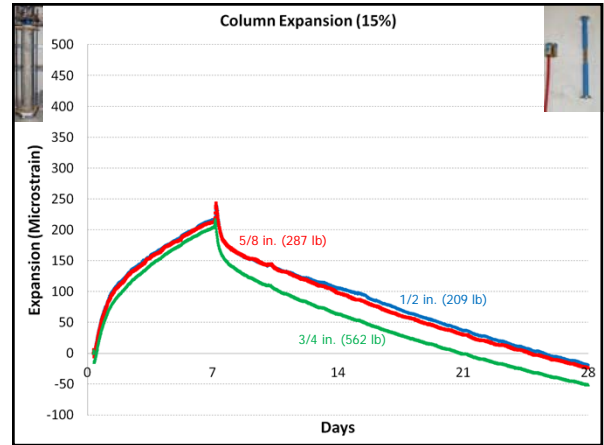
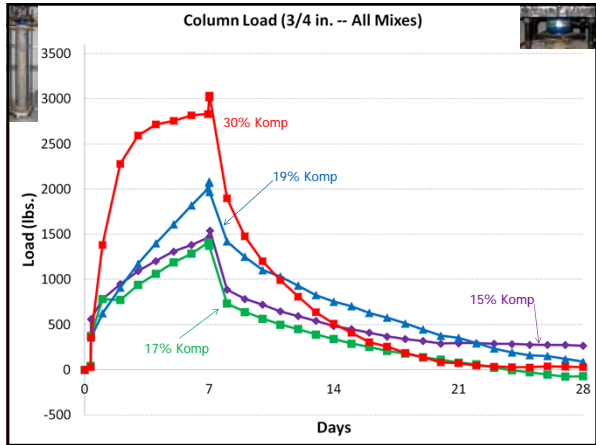
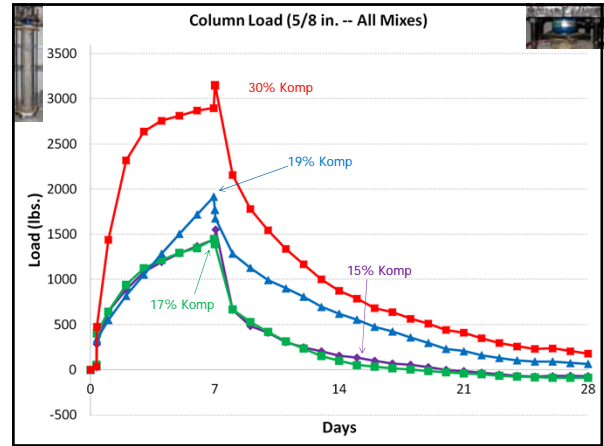
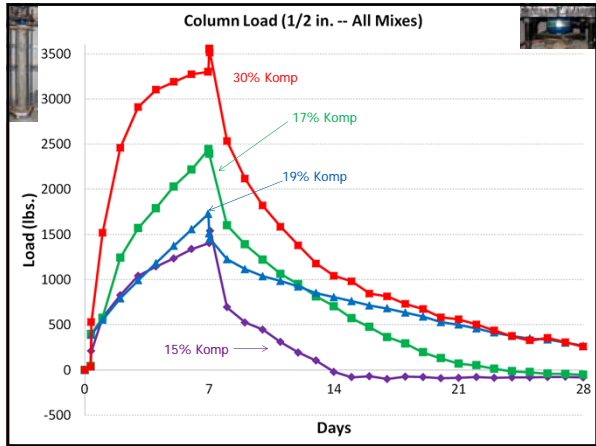
PVC Water Jacket

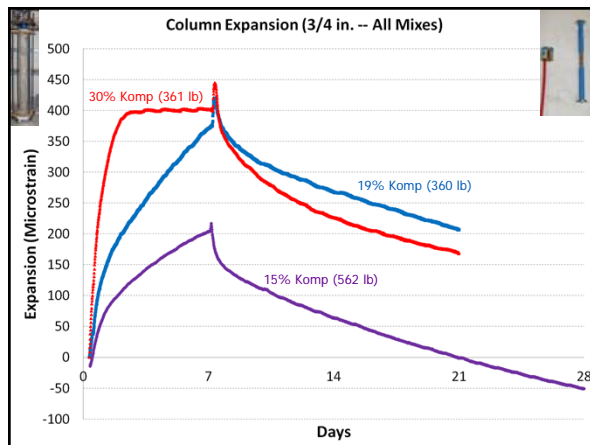
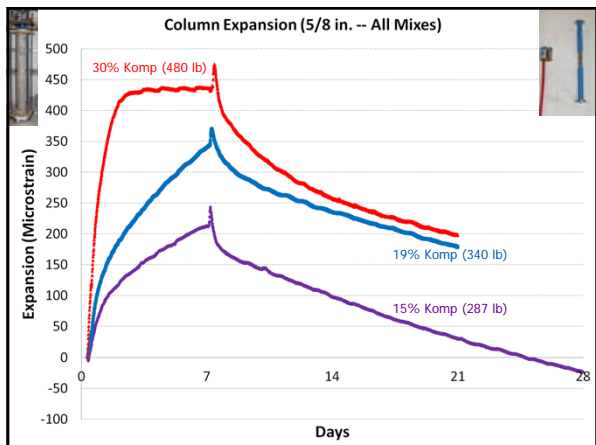
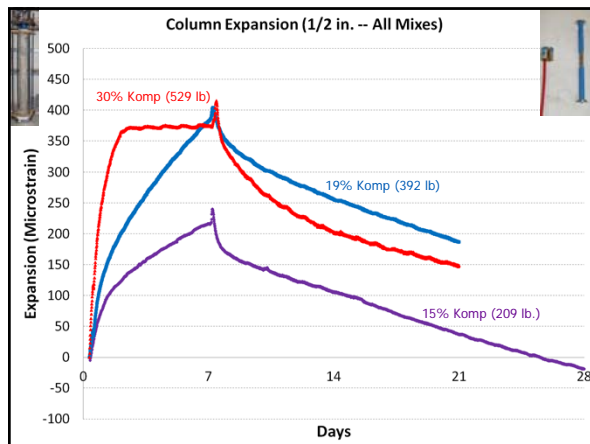
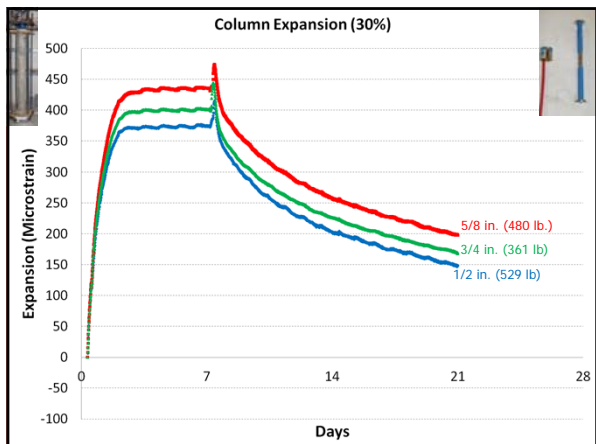
Wet Curing Condition



Columns Curing with PVC Water Jackets







- ### Instrumentation Conclusions
- GeoKon VWSG converges consistently with ASTM-standardized tests
 - VWSG generates smoother, more complete data sets than length-comparator tests
 - Overall behavior better characterized due to finer interval of readings

- ### Instrumentation Conclusions
- VWSG 6x12 specimens less vulnerable to environmental variation:
 - Higher thermal mass than ASTM bar tests
 - Lower surface-area-to-volume ratio than ASTM bar tests

Material Conclusions

- Bracketing the stiffness problem:

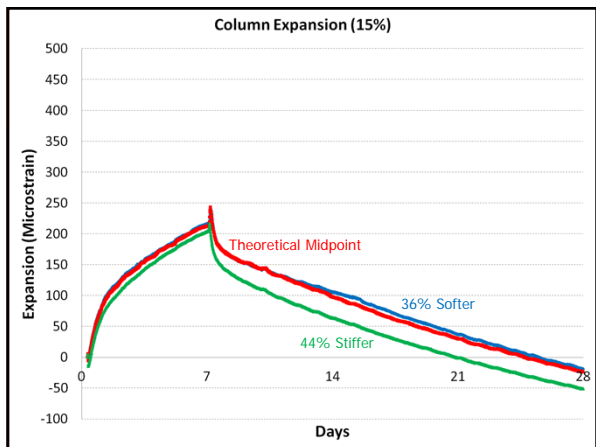
Frame Size: 1/2" → 5/8" → 3/4"

Material Conclusions

- Bracketing the stiffness problem:

Frame Size: 1/2" → 5/8" → 3/4"

Stiffness Variance: 36% 44%



Material Conclusions

- Large increase in restraint stiffness does not cause a large gap in shrinkage compensation
 - All column expansion data sets are tightly clustered
- A very stiff boundary condition will not prevent shrinkage-compensating expansion
 - Type K shrinkage compensating concrete is not sensitive to a mature concrete boundary condition

Material Conclusions

- Compressive stress is accompanied by significant expansion
- In general, higher loads are generated by stiffer restraint
- Both load and expansion are influenced by amount of pre-compression in the columns
 - Work in progress: perform a range of tests with carefully controlled low pre-compression values

Questions?