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CONCRETE SHRINKAGE ANALYSIS OF BRIDGE DECK CONCRETE

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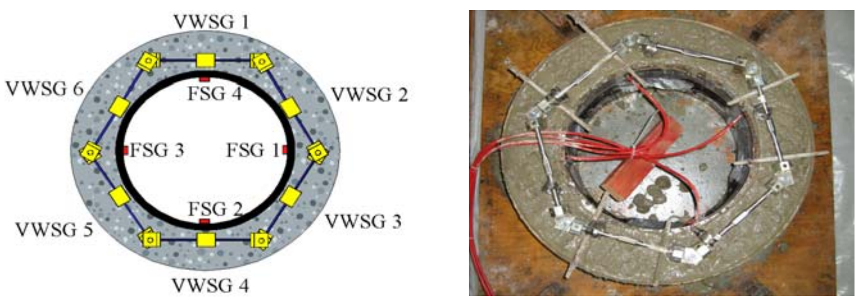
WHY WE ARE DOING THIS…

Over the last decade, the use of High Performance Concrete (HPC) has emerged as an important alternative to deal with deteriorating infrastructure. The Federal Highway Administration (FHWA) has initiated programs for the design and construction of HPC bridges and pavements with the aim of reducing both initial construction costs and long-term maintenance costs. However, a number of bridge decks have exhibited cracking due to various causes including shrinkage. There is a need to assess the cracking potential of concrete mixes used in bridge decks under restrained shrinkage conditions.

A testing method, developed by AASHTO (PP 34-99, The Passive or Restrained Ring Test) as shown in Figure 1, is employed to compare the relative cracking potentials of concrete mixtures. This cracking tendency was performed on 15 concrete mixes used for bridge decks by NJDOT to identify those that would exhibit high potential for cracking. Vibrating Wire Strain Gages (VWSG) have been installed on the concrete ring to measure the strain directly as shown in Figure 1. Although cracking of bridge decks can be attributed to various causes, this study provided a comparative classification of the cracking potential of each mix. A correlation of cracking potential with various parameters is also established. Results show that mixes with high Coarse Aggregate (CA) to Fine Aggregate (FA) ratio (i.e., CA/FA >1.48) and a CA minimum weight of 1800 lb/cu.yd have lower potential for cracking. It is also shown that the rate of free shrinkage correlates directly with the rate of restrained shrinkage, and a limit of 450 micro strain for free shrinkage at 56 days is recommended to reduce the cracking potential of concrete mixes.



(a) (b)

Figure 1. a) Schematic Diagram of Six VWSGs, and b) picture of the Six VWSG Restrained Shrinkage Test Setup.

OBJECTIVES

The primary objectives of this research project are: 1) evaluate the restrained shrinkage properties of HPC mixes currently used for bridge deck applications in New Jersey using the AASHTO PP34-99 test method and 2) provide a comparison of their relative cracking potential.

HERE IS WHAT WE DID…

A total of 15 mixes from various bridge deck projects were provided by NJDOT and tested as shown in Figure 2. The water to binder ratio ranges between 0.34 – 0.40 and the majority of the mixes have slag as a replacement for cement. Mixes are grouped according to the cement replacement percentages. Two main groups are 30% and 40% slag replacement. Remaining mixes have varying percentages of slag, silica fume and fly ash as cementitious replacements. Also, the source of coarse and fine aggregates, as well as the type and manufacturer of chemical admixtures are varied within groups of mixes. This forms a complex matrix of variables by which the effects of the most sensitive parameters can be determined.

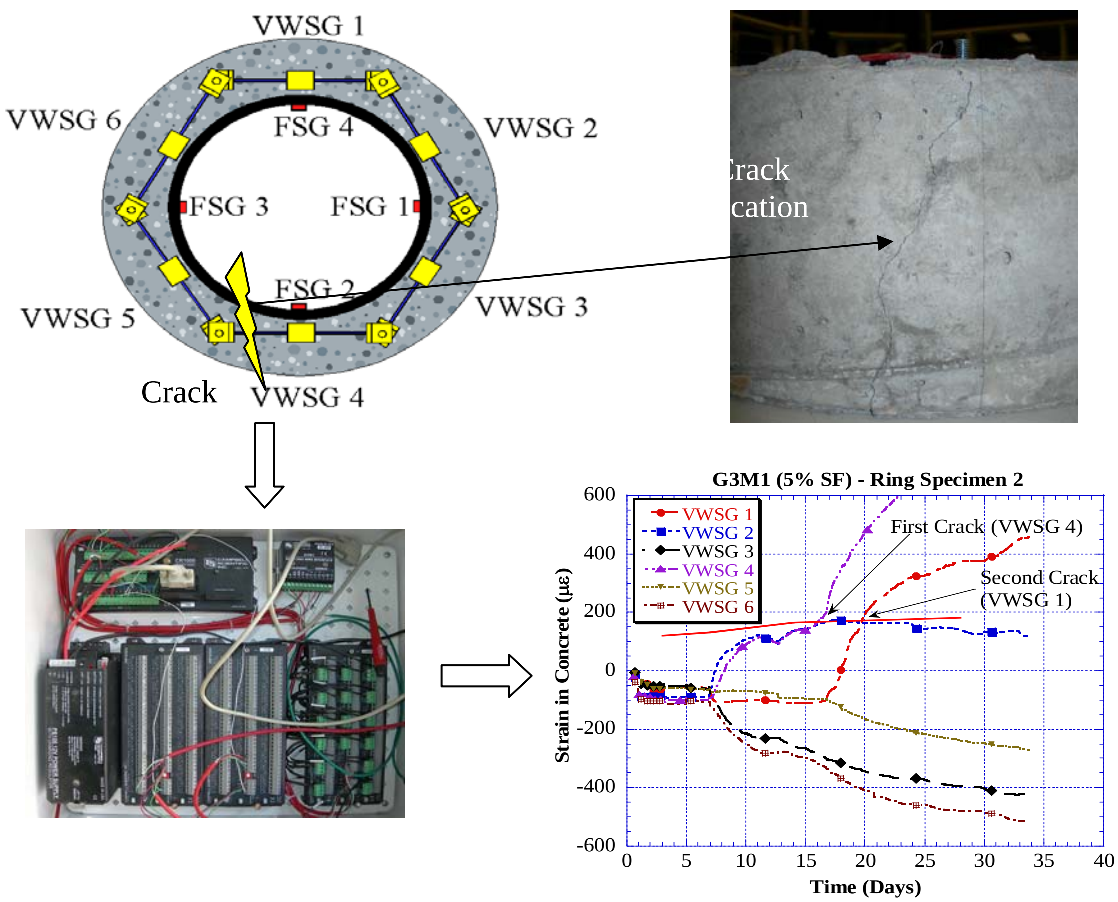


Figure 2. Schematic of the restrained shrinkage test setup, data collection schemes, and test results.

Table 1 shows the test results for all 15 mixes. Out of the fifteen mixes tested, nine were observed to crack under restrained shrinkage. To identify the causes of cracking as well as the effects of the many variables that contribute to shrinkage cracking, various comparisons were made. These comparisons include, correlation of restrained shrinkage cracking with the coarse aggregate to fine aggregate (CA/FA) ratio, total coarse aggregate content in a mix, total cementitious materials used in a mix, mechanical properties of a mix, and most importantly the rate and total amount of shrinkage of each mix.

Table 1–Comparison of Cracked and Uncracked Mixes with Respect to Coarse Aggregate Content and CA/FA Ratio.

Group	Mix	Cracking*		CA/FA	CA Content (lbs/cu.yd)	Cement Content (lbs/cu.yd)	Rank
		Avg. Percent of Tensile Strength	Avg. No. of Days				
1	G1M1	100%	9	1.33	1650	800	15
	G1M2	100%	13	1.42	1700	658	11
	G1M3	37%	Not Cracked	1.57	1875	660	1
2	G2M1	100%	45.5	1.42	1700	658	9
	G2M2	100%	9.5	1.42	1700	658	13
	G2M3	44%	Not Cracked	1.48	1850	657	2
	G2M4	100%	18	1.5	1850	658	10
	G2M5	100%	48	1.56	1825	661	8
	G2M6	63%	Not Cracked	1.57	1811	683	3
3	G3M1	100%	9.5	1.45	1725	735	14
	G3M2	76%	Not Cracked	1.37	1750	705	4
4	G4M1	94%	Not Cracked	1.48	1850	667	6
	G4M2	100%	12	1.43	1700	658	12
	G4M3	86%	Not Cracked	1.48	1850	707	5
	G4M4	100%	62.5	1.46	1800	690	7

FINDINGS……

The following conclusions can be made:

1. The results show that total coarse aggregate content and the CA/FA ratio has the greatest effect on both free and restrained shrinkage. There was a significant

reduction in free shrinkage of mixes with high CA/FA ratios and coarse aggregate contents compared to similar mixes with lower ratios and lower total coarse aggregate content. The two best performing mixes, G1M3 and G2M3, utilized less than 50% of their tensile strength. Both mixes, G1M3 and G2M3, had coarse aggregate contents of 1875 and 1850 lbs/cu.yd while their CA/FA ratio was equal to 1.57 and 1.48, respectively. Moreover, seven out of the nine mixes that cracked under restrained shrinkage had a CA/FA ratio of less than 1.48 and six of these mixes were observed to have low coarse aggregate content (less than 1725 lbs/cu.yd).

2. Free shrinkage rate prior to cracking was found to correlate directly with the restrained shrinkage rate prior to cracking and time to cracking for a given mix. Mixes which had lower ultimate shrinkage values experienced lower shrinkage rates overall. All five mixes that did not experience cracking were observed to have less than 400 microstrains of free shrinkage at 56 days. The two mixes that experienced cracking after 28 days were observed to have a free shrinkage value in between 400 and 500 microstrains at 56 days. Five out of the six remaining mixes, which experienced cracking before 28 days, had more than 500 microstrains of free shrinkage at 56 days. It is recommended that the free shrinkage at 56 days be limited to 450 microstrain.

3. Other factors that were found to increase cracking potential were high cementitious material contents (two mixes with the highest cementitious content were observed to crack earliest), and the properties of the coarse aggregate used in mix design (Mix G3M1 has deposits of argillites within its coarse aggregate source which significantly affected its performance). It is recommended that the amount of cementitious material be limited to 700-lb/cu yd. Also, maximum percentage of silica fume utilized in a mix should be limited to 5 percent.

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A final report is available online at
http://www.state.nj.us/transportation/research/research.html

If you would like a copy of the full report, please FAX the NJDOT, Division of Research and Technology, Technology Transfer Group at (609) 530-3722 or send an e-mail to Research.Division@dot.state.nj.us and ask for:

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