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United States
Department of Transportation

SUMMARY REPORT

US 23, Future I-26
New Interstate Concrete Paving

Madison County, North Carolina
Summer 2002

FHWA MCL Project # 0205

Federal Highway Administration
Office of Pavement Technology
HIPT, Room 3118
400 7th Street, SW
Washington, DC 20590

This report summarizes the findings from a concrete materials test program conducted by FHWA's Mobile Concrete Laboratory on new concrete interstate paving on US Route 23 between Mars Hill, North Carolina and Sam's Gap at the Tennessee State line (North Carolina State Project No. 8T842401, MCL Project # 0205). The project traverses extremely rugged mountain terrain in the Smokey Mountains north of Asheville. The project required the excavation of 37 million cubic yards of material with cuts as high 600 feet and embankments as high as 220 feet. The majority of the project is on 5 and 6% vertical grade. During the summer of 2002, approximately 9 miles of new concrete interstate pavement was placed. The pavement consists of six lanes of jointed plain concrete pavement (JPCP) 10" in depth over a 3" asphalt base layer. The joints were doweled and spaced at 18, 19, 21 and 22 feet. Figure 1 shows a section of the project after the completion of concrete paving.

Figure 1. Completed concrete pavement on Future I-26, Madison Co., NC.

The subject test program focused on three primary objectives: 1) Demonstrating the advantages of maturity testing in terms of opening pavements to construction traffic earlier, 2) demonstrating the Air Void Analyzer (AVA) as a tool to characterize the concrete's air void system for freeze thaw durability, and 3) demonstrating a simplified impact-echo technique (Concrete Thickness Gauge, CTG-1) for determining pavement thickness nondestructively. These objectives were established based upon requests by and discussions with NCDOT (Sam Frederick), and FHWA's North Carolina Division Office (Jim Phillips) prior to our arrival on-site in July 2002. In an effort to accomplish these objectives, a test plan was developed and agreed upon that involved both laboratory and field testing of the paving concrete during a two week period in July and

August of 2002. This test plan included on-site construction monitoring, quality control testing, as well as sampling and casting of test specimens. A summary of the test data is included in the Appendix. Results from onsite and subsequent laboratory testing indicate the following:

1. Use of maturity to assess in-place pavement strengths would have allowed construction traffic on the pavement 2-days earlier. For the specific site conditions encountered during our test program, the pavement reached the 550psi NCDOT opening to strength criteria in 5 days, while the companion beams took over 7 days. Typical time savings may be less or greater, depending on the environmental conditions during and subsequent to concrete placement. Figure 2 illustrates how the maturity of the pavement (in-place concrete) is increasing at a greater rate than that of the quality control beams.

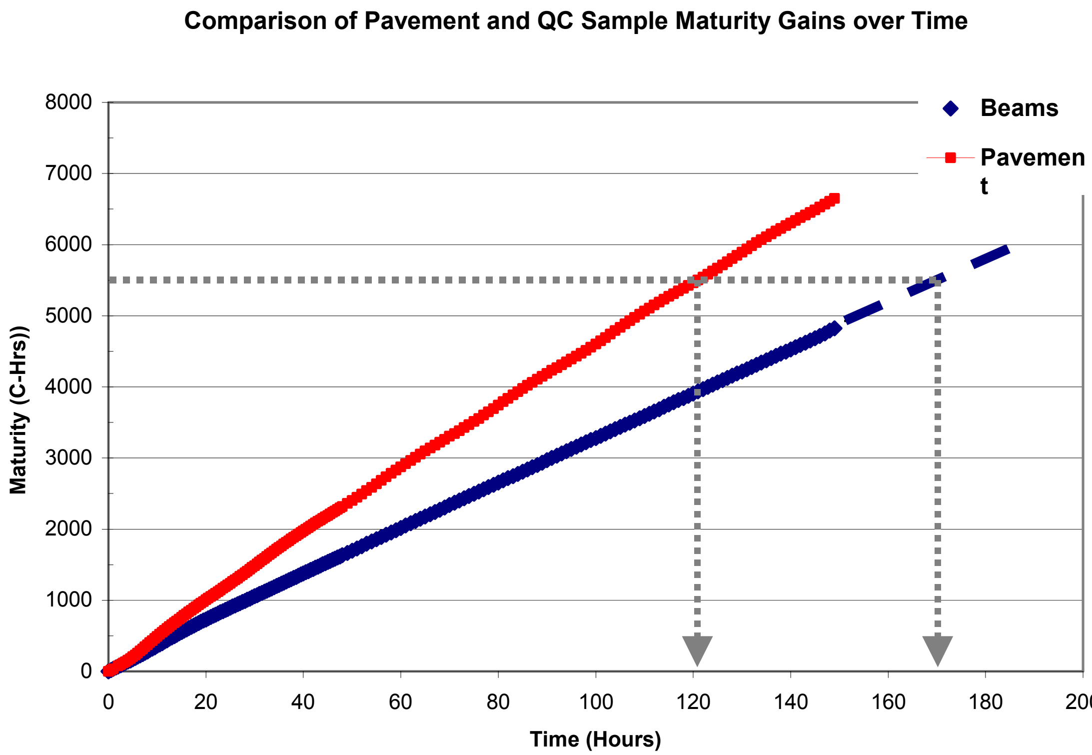

Figure 2. Maturity gain of pavement and QC specimens over time.

Test results also show how the maturity relationships are reproducible during the course of a project. Maturity-strength relationships were generated for concrete placements taking place on July 24, 2002 and July 26, 2002. Figure 3 shows how the relationships are very similar, even with significant slump differences and changes in air content.

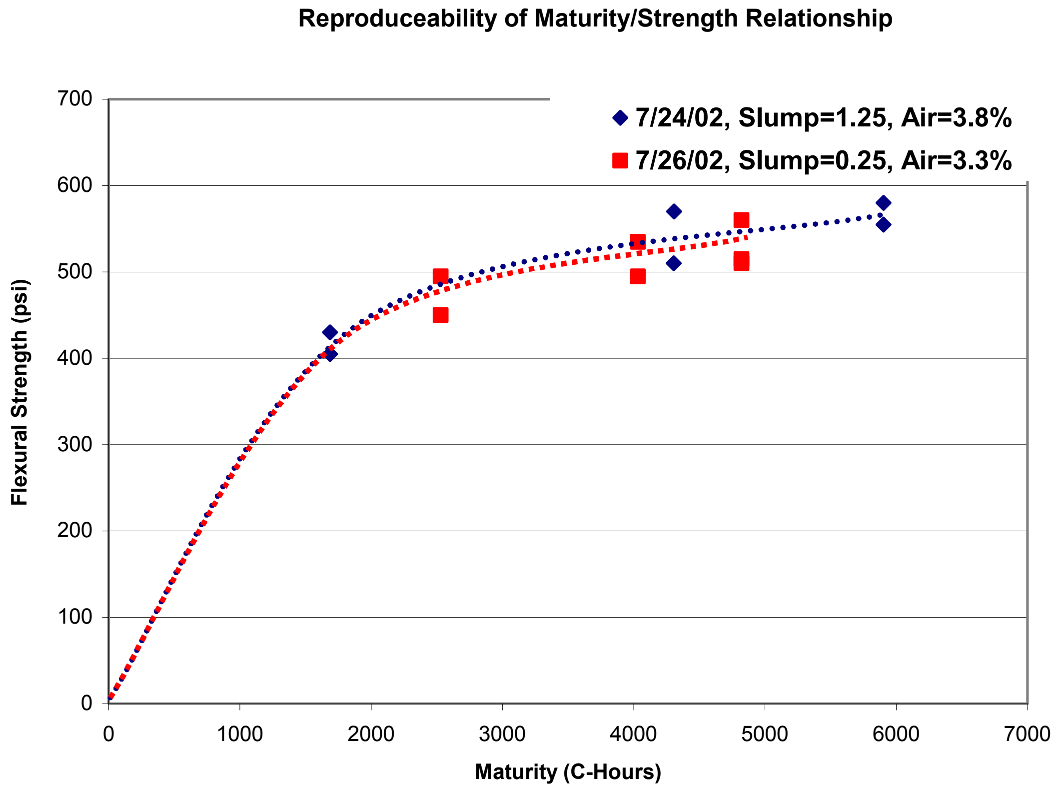

Figure 3. Maturity/strength relationships for two separate placements.

2. Air void analysis of the plastic concrete sampled at the batch plant indicates that the air void system is marginal to inadequate when the slump is less than 1 ½ inches. Of the six samples tested, three exhibited spacing factors (SF) greater than 0.010 inches (the generally accepted maximum limit). Without exception, the spacing factor was greater than 0.010 inches when the slump was less than 1 ½ inch. In addition, the specific surface (SS) was less than 600 (the generally accepted minimum limit) in those same instances. In summery, the air voids are too coarse and spaced too far apart when the slump is less than 1 ½ inch. This may be related to less efficient mobilization of the air-entraining admixture in the lower-slump mixtures (due to lower amounts of water). Figure 4 shows the Air Void Analyzer used for this analysis. Table 1 summarizes the AVA data.

Figure 5. Air Void Analyzer being prepared for testing

Table 1. Summary of Air Void Analyzer results.

Sample Number	Slump (Inches)	C 231 (%)	AVA		
			Avg Vol (%)	Avg SF(in)	Avg SS(/in)
1	0.50	3.1	1.2	0.022	410
2	1.50	5.0	3.5	0.010	712
3	0.25	3.3	1.2	0.019	504
4	1.00	4.6	1.9	0.014	569
5	1.75	4.0	2.4	0.010	732
6	1.50	4.8	2.2	0.009	772

Note: NCDOT specifications require an air volume of 3.5% to 6.5%

3. The Concrete Thickness Gauge (CTG-1) does not determine concrete pavement thickness accurately (within ¼ inch) when the concrete pavement is bonded intimately to an asphalt base. The concrete pavement at this site bonded very well to the underlying asphalt base, possibly as a result of the young age of the asphalt base (a few weeks to months) and the high temperatures during construction (80-90F). The lack of a clear boundary at the bottom of the concrete slab reduces the amount of energy that is reflected back to the surface of the pavement as a result of a surface impact. Accurate CTG results are dependent on this reflected portion of the signal. CTG measurements in six locations differed with core thicknesses by as much as ½ inch. All tests showed a poor signal integrity, indicating the lack of a clear boundary at the bottom of the concrete pavement. Figure 6 shows the CTG-1 used for this testing.

Figure 6. The CTG-1 impact-echo unit.

In an attempt to verify the CTG's capability on concrete pavements that are not bonded to an asphalt base, tests were performed on an 11 inch thick 4 foot by 4 foot concrete slab that had previously been removed from the pavement for unrelated reasons. The slab was positioned on a dense aggregate surface along the roadway shoulder. All CTG tests conducted on this slab were within ¼ inch of the actual slab thickness, as determined with a measuring tape. The signal integrity for all these test was high, confirming the presence of a clearly defined boundary at the bottom of the slab.

Based upon results from the test program conducted by FHWA's Mobile Concrete Laboratory at this project, we draw the following conclusions:

1. Implementing the use of maturity will allow the contractor and State to realize significant time savings (and cost savings) associated with measuring the in-place pavement strength. Schedules may be significantly accelerated by allowing construction traffic on the pavements much earlier.

2. Careful attention should be paid to the amount and quality of air in paving concrete. Using volumes of entrained air near the lower boundary of the specification (3.5%) may result in marginal to inadequate air void systems, particularly when slumps are below 1.5 inches. Better control of the batch-to-batch uniformity will minimize the significant variability in the volume and quality of the air void system. The Air Void Analyzer is a useful method to characterize the air void system during construction, allowing for rapid on-site adjustments to ensure a freeze-thaw durable concrete pavement.

3. The CTG-1 impact-echo unit is suitable for use as a non-destructive pavement thickness measurement device only when the concrete pavement has a clearly defined boundary at the bottom of the pavement. When the concrete is intimately bonded to the material below, accuracy suffers significantly.

If you have any comments or questions about these findings/results, please contact Leif Wathne, Concrete Materials Engineer with the Mobile Concrete Laboratory at (202) 366-1335.