Ultrathin Bonded Wearing Course as a Pavement Preservation Treatment for Jointed Concrete Pavements

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ABSTRACT

This paper reports on use of ultrathin bonded wearing course (UTBWC) as a pavement preservation strategy for jointed plain concrete pavements. This strategy has been used in North Carolina on both urban and rural sections. One of the benefits of the ultrathin bonded wearing course is that the elevation change is very small, typically 5/8 inch. Expenses associated with thick overlays, like adjustments to signs, guardrails, bridge clearances, and shoulders are minimized. The effectiveness of the UTBWC in improving ride quality and extending pavement life is evaluated for 5 projects.

North Carolina performs pavement condition surveys every year on the interstate system, and every other year on other systems. On jointed concrete pavements, a sample of 39 to 41 slabs is used for each mile ($1/10^{th}$ mile). Asphalt surfaced roadways are evaluated using 100% coverage in a windshield survey. Application of the ultrathin bonded overlays resulted in a dramatic "bump" of the Pavement Condition Ratings. The rate of decline of the PCR after resurfacing with UTBWC is between 0.8 and 3.0 points per year based on 2 sites. Most of the decline in PCR to date is associated with reflection cracking, which does appear, but does not degrade rapidly. Faulting ultimately results in decreased ride quality over time as indicated by increases in International Roughness Index (IRI). The rate of increase in IRI ranged from 0.5 to 2.1 points per year. Based on our experience with UTBWC on poor quality jointed PCC, a life of 6 to 10 years is attainable, and is supported by the projections of performance curves from two of the sites.

Key Words: pavement preservation, ultrathin bonded wearing course, jointed plain concrete pavement

INTRODUCTION

North Carolina constructed significant mileage of jointed plain concrete pavement in the 1960s and 1970s. Both doweled and undoweled segments were constructed. Some of the jointed PCC pavement is on the primary system, but the majority is part of the interstate. Base type varies from 4 inches of dense graded aggregate, to 4 inches of bituminous base course to cement treated base (1). The standard thickness of jointed concrete pavement during that period was 9 inches. Typical slab length was 30 feet, so mid slab and third point breaks are present on many projects. Traffic, particularly heavy truck traffic, increased rapidly and pavement distresses have developed. With many sections "aging out" at nearly the same time, a treatment has been sought to prolong the life of these roadways wherever pavement condition indicates that this is possible.

This paper will focus on five projects where an ultrathin bonded wearing course was placed on an existing jointed plain concrete pavement. For each project, the distresses on the JPCC pavement will be described and the results of the pavement condition survey before the ultrathin bonded wearing course (UTBWC) will be shown. Survey results and other test results following the preservation treatment will be used to assess the effectiveness of the UTBWC for that project.

The five sites to be discussed in this paper are listed in Table 1. Three are in the Raleigh metropolitan area. I-40 in Burke County is rural and located in the foothills of NC. The I-95 site is located in a rapidly developing area, and is heavily trafficked by north/south tourists and shipping on the interstate connecting Florida to New York.

North Carolina conducts a Pavement Condition Survey annually on Interstate Routes and biannually on the primary and secondary systems. For jointed PCC pavements, the first 0.1-mile of every mile is evaluated for transverse and longitudinal cracking, pumping, spalling, joint sealant condition and blowups. For asphalt surfaced roadways (including composite sections), the pavement is divided into "similar" sections and a windshield survey is performed. Distresses reported include transverse, longitudinal and fatigue cracking, bleeding, patching, and sealing. Pavement condition is expressed as a Pavement Condition Rating (PCR) that varies between 0 and 100 with 100 being a roadway in perfect condition.

Ride quality is measured using high-speed laser profilers and is reported every $1/10^{th}$ mile as IRI. IRI is obtained for both the inner and outer wheel paths and these values are averaged. Most primary roadways, including interstates, are tested every other year unless they are under construction activities. Other routes are tested on an as needed or as requested basis, with less historical data available. The profilers run from county line to county line, so distance is generally measured as within county milepost. NCDOT takes IRI measurements continuously, so readings include bridge decks and approach slabs that may not be part of IRI profiles in other agencies.

ULTRA THIN BONDED WEARING COURSE

Ultra thin bonded wearing course consists of a thin high-quality gap-graded hot mix layer that is placed on a polymer-modified tack coat/membrane using a specialized piece of equipment. The hot mix is placed immediately behind the membrane allowing the emulsion rate to be increased. The close proximity of the hot mix to the emulsion distributor assures that the emulsion breaks and rises within the hot mix layer (2). North Carolina uses a lift thickness for UTBWC of 5/8 inch; the normal range is 0.5 to 1.0 inch (3). A complete copy of the NCDOT specification for ultra-thin bonded wearing course is available on the project services website: http://www.ncdot.org/doh/preconstruct/ps/specifications/english/web6a.pdf in Section 661.

The hot mix is spread over the lane width with a heated screed. Rolling of the wearing course is done with two passes of a double steel drum roller that seats the aggregate (2). California specifies that static and steel drum rollers only should be used and drums must be 12 tons (4); Colorado uses a minimum weight of 11 tons (5).

Hanson (6) reported on one of the initial U.S. UTBWC applications in Pennsylvania where the IRI went from 173 to 120 following application of the UTBWC. The IRI at this site rose to 138 within 5 years of placement of the wearing course. A second site

where UTBWC was placed on jointed concrete went from an IRI of 150 to 77, and increased to 96 after 5 years. Hanson also conducted visual surveys of UTBWC placed on existing concrete pavements in Alabama and Missouri, but did not quantify their performances. Cooper and Mohammad reported on performance of UTBWC placed on asphalt surfaces (2).

SITE SELECTION FOR UTBWC

US-1, CARY: RALEIGH METROPOLITAN AREA

As shown in Table 1, the US-1 site in Cary was the first UTBWC site in North Carolina. The US 1 site leads to the towns of Cary and Apex and is a heavily traveled commuter route to the city of Raleigh. At the time of placement of the UTBWC, the undoweled concrete pavement was over 30 years old, was in poor condition with numerous transverse cracks and severe faulting. Most slabs were stable. Prior to the overlay, badly broken slabs and unstable slabs were removed and patched with hot mixed asphalt. The purpose of the project was to improve ride quality and to test the performance of UTBWC under difficult conditions (7). NCDOT expectations were to get no more than 2 to 3 years of service from the UTBWC.

Figure 1 shows the before and after IRI for the US 1 Cary project. The figure also shows the progression of roughness over time. In this figure and all other IRI figures in this paper, the pre-UTBWC values are shown in black; post-UTBWC values are shown with white filled shapes. The average IRI for this segment went from 201.3 to 115.9, an improvement in IRI of 85.4. In looking at the post-UTBWC lines from 1998 and 2000, no consistent trend of increasing or decreasing IRI between these two test cycles is noted. Some inconsistency is due to the variability in the vehicle alignment in running successive tests, seasonal effects on pavement smoothness, and slight variations in locating the starting and ending points for testing and for locating the project limits (tests are run from county line to county line).

Prior to the UTBWC, the average PCR for the northbound lanes of US 1 was less than 30. PCRs for the US 1 Cary section following placement of the UTBWC are shown on Figure 2. In 2000, Wu (7) reported that reflection cracking appeared but did not degrade. Four years later, that remained largely the case. This is attributed to the ability of the highly viscous tack to hold the thin lift of high quality material. This segment of roadway is currently under reconstruction, but up until the time of reconstruction, the UTBWC remained bonded with no more than moderate transverse cracking. The reconstucted and widened project is expected to be complete in November 2006.

SITE 2: I-440 RALEIGH BELTLINE

The I-440 site is a portion of the Raleigh inner beltline located west of downtown Raleigh. The section is a four-lane divided highway with a narrow grass median. While it is a controlled access facility, it has many closely spaced exit and entrance ramps. The pavement was more than 30 years old and pavement conditions had deteriorated to a pre-

UTBWC PCR of 36.6. Presence of curb and gutter in some sections restricted final elevation of an overlay. The UTBWC was placed in July 2000. Figure 3 shows the change in PCR for milepost 1.5 with time before and following the UTBWC. A significant jump in PCR occurred following placement of the UTBWC, and the PCR has declined from 100 to 80 in five years since placement. This figure shows one milepost only. The average rate of change of PCR for the inner and outer directions of travel are 3.5 and 3.2 points per year respectively. A performance curve for the UTBWC, shown in Figure 4, indicates that 6.2 years will be required for the pavement condition to reach a PCR of 70.

The pre-UTBWC IRI was significantly lower than the US-1 site, averaging 115.1 for both directions as opposed to almost 200 in Cary. Even with the relatively smooth pre-resurfacing ride, average IRI was decreased by 33. The pre- and post-resurfacing IRI is shown on Figure 5. Note that only small changes to the post-UTBWC IRI have occurred since placement. This site did have some post UTBWC issues in one relatively short section. Construction documents suggest a brief problem at the asphalt plant that resulted in some early removal and patching.

SITE 3: I-40 BURKE COUNTY

I-40 in Burke County was constructed in 1961 and consists of 23 miles of jointed PCC. Joint spacing was 30'. The terrain becomes increasingly mountainous from east to west as you approach the eastern continental divide west of Burke County. 2004 traffic counts were around 20,000 vehicles per day with 14 to 18 percent trucks. Complaints about ride quality prompted the division to seek treatment.

A site visit showed that while some slabs had mid-slab cracking, no slabs were unstable or shattered. Shallow spalling at the joints was present at almost 100% of the slabs and was responsible for the poor ride quality. The PCR at the time of the site visit was around 64.

Funding limitations caused the repair work to be conducted over a 2-year period. During the first year, all of the shallow spalls were cleaned and replaced with hot mixed asphalt. The UTBWC was applied the next year, along with permanent markings. The results were an increase in pavement condition rating of more than 35 points and a decrease in IRI of 100 points. Figure 6 shows the change in IRI for the westbound direction.

Six years of pavement condition survey data was available for I-40 Burke County since placement of the UTBWC. Figure 7 shows the average PCR for each year since resurfacing for both eastbound and westbound directions. The best-fit trend line was obtained for a polynomial, as shown on Figure 7. Based on this trend line, it will take 10.7 years for the pavement to reach a PCR of 70.

SITE 4: CAPITAL BOULEVARD, RALEIGH

Capital Boulevard is an urban street with many business driveways, cross streets and utilities. Traffic is estimated at more than 40,000 vehicles per day. Dual tire uni-body trucks outnumber tractor-trailer trucks by a factor of 2 to 1 on Capital Boulevard. The section is from 4 to 8 lanes wide, with asphalt widening and asphalt turn lanes into businesses and side streets. Curb and gutter is present throughout the UTBWC section, which extends from the Raleigh Beltline to downtown. An active railroad bridge with limited clearance crosses the roadway and limits treatment alternatives. Portions of the roadway had a thin hot mixed asphalt overlay, which had partially debonded. The concrete was very old, built in the 1950's. Only limited grading was done for the original construction; the roadway follows the contours of the natural ground and has significant dips and bumps.

Despite its age, the concrete was in remarkably good condition, with 20 slabs requiring replacement prior to resurfacing. Ride quality was poor, but the concrete still provided an adequate structure. Moderate to severe faulting was the dominant distress.

Prior to placing the UTBWC, the old asphalt overlay was milled off. Leveling was done in areas with dips and shattered slabs were removed as replaced with hot mixed asphalt. The UTBWC was place in summer 2003 and improvement to ride quality was immediately noted.

Noise issues about traffic on Capital Boulevard were also raised just before the improvement project was undertaken. Three ambient noise readings were taken at three locations along the roadway before and after the resurfacing project. Each reading was made with a Gen Rad calibrated noise reader using a microphone located 25' from the edge of the outside lane and elevated to a height of 4 feet. All measurements were made for a period of 20 minutes, after which the device was recalibrated to assure that drift during the measurements was not excessive. The pre-UTBWC Leq readings were 74.4, 78.0, and 78.1. Post-UTBWC values were 71.3, 69.4, and 69.8. This 6.7 dB average drop in noise level is a noticeable improvement (changes of 3 dB or less are not reliably detectable to the human ear).

Reflection cracking has occurred in the UTBWC, but the reflection cracks remain low severity and narrow. No debonding has occurred and ride quality remains good.

SITE 5: I-95 IN JOHNSTON COUNTY

I-95 is a major north-south corridor for both tourists and truckers between New York and Florida. The section in Johnston County is a four-lane divided sections with grass median. The 9-inch thick concrete was constructed in 1959. Pre-resurfacing PCR is highly variable along the length of the roadway, as shown in Figure 8. The average pre-UTBWC PCRs are 33.0 and 37.5 for the northbound and southbound directions respectively, but the northbound direction is less variable than that in the southbound direction.

Prior to placement of the UTBWC, severely distressed concrete slabs were removed and replaced with full-depth hot mixed asphalt. Spalls were repaired with a poly-fiber product, and a leveling course of hot mixed asphalt was placed on the outside lane. Shoulder drains were installed throughout most of the project.

Ride quality was improved measurably by the resurfacing project, with an improvement of 62.6 and 40 points in the northbound and southbound directions respectively. Figure 8 demonstrates this improvement along the southbound direction.

OVERALL RESULTS

Table 2 summarizes the improvements realized from placement of UTBWC for four of the sites reported here. Positive improvement was found for all sites. Ride quality improved for even the roadway with the smoothest pretreatment ride quality, and the roughest roadways improved by more than 80 points.

Since most of the sites remain in service with the UTBWC in place, only a few observations can be made about the ability of the treatment to extend pavement life. US 1 in Cary, the first UTBWC placed in North Carolina, is now undergoing reconstruction. That UTBWC was placed on pavement in highly distressed condition, and still served for 10 years. Performance curves for the UTBWC were developed for I-440 in Raleigh and for I-40 Burke County. These curves indicate that it will take 6.2 and 10.7 years respectively, to reach a PCR of 70.

It was only possible to look at rate of decline of pavement condition rating and rate of increase in IRI for the sections having multiple post-resurfacing surveys. The two sites resurfaced in 2003 did not meet this criterion, and primary routes are not surveyed regularly. It was hoped that a relationship could be developed between pre-treatment PCR and the rate of decline in post-treatment PCR or the rate of increase in post-treatment IRI. There was insufficient data to support this activity. PCR details report for all sites that reflection cracking appears within a few years, but remains narrow and of low severity. Ride quality degrades gradually over time, not because of the UTBWC but because of pavement issues beneath the wearing course.

CONCLUSIONS

We evaluated the performance of five sites of UTBWC placed on old PCC pavement in North Carolina using pavement condition ratings, IRI, and for one site, noise level measurements. Condition improvements occurred for all sites, regardless of initial condition of the pavement. On all except the roughest roadway, the post-UTBWC average IRI was reduced to less than 90. The roughest roadway had an 85-point reduction in IRI to 115.9.

Slabs that are shattered or unstable under load should be removed and replaced prior to placement of the UTBWC. Ideally this would be a concrete replacement, however, all slab replacements for the 5 sites reported here had shattered slabs replaced with hot mixed asphalt. UTBWC will improve ride quality, but is essentially a thin resurfacing. If

the profile of the roadway needs to be reshaped to remove dips or reestablish cross slope, a leveling course should be applied prior to the UTBWC.

Reflection cracking did appear, usually within 1 or 2 survey cycles, but the UTBWC remained fully bonded to the underlying concrete pavement. Reflection cracking remained narrow and of low severity. No maintenance activities were associated with any of the UTBWC sites, except one that had a plant problem during construction.

Using time to reconstruction and performance curves developed in this study, results suggest a life of the treatment of 6 to 10 years. We consider this to be an excellent life extension for PCC pavements that are already more than 30 years old.

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LIST OF TABLES

LIST OF FIGURES

Route	County	Length (miles)	Curb and Gutter?	Concrete Thickness (in)	Base Type	UTBWC Year
US 1, Raleigh metro area	Wake	1.5	N	9	ABC	1996
Capital Blvd, Raleigh	Wake	2	Y	8	Soil	2003
I-40	Burke	23	N	9		2000
I-440, Raleigh	Wake	3.2	Y	9	ABC	2000
I-95	Johnston		N	9	ABC	2003

Table 1: Sites of ultrathin bonded wearing course to be described.

Site	Pre-PCR	Initial Δ PCR	Post UTBWC PCR rate of decline (pts/yr)	Pre-IRI	Δ IRI (decrease)	Post UTBWC IRI rate of increase (pts/yr)
I-40 Burke Eastbound	64.1	35.9	0.83	189.1	103.1	2.1
I-40 Burke Westbound	63.8	36.2	2.47	182.9	99.6	2.1
US 1 Cary	<30.1	>65		201.3	85.4	
I-440 Raleigh Inner	36.6	63.4	3.5	115.2	34.4	1.26
I-440 Raleigh Outer	11.4	88.5	3.2	115.0	32.4	0.54
I-95 Johnston Northbound	33.0	62.0		150.7	62.6	
I-95 Johnston Southbound	37.5	58.2		123.9	40.0	

Table 2: Summary of PCR and IRI results for UTBWC sections.

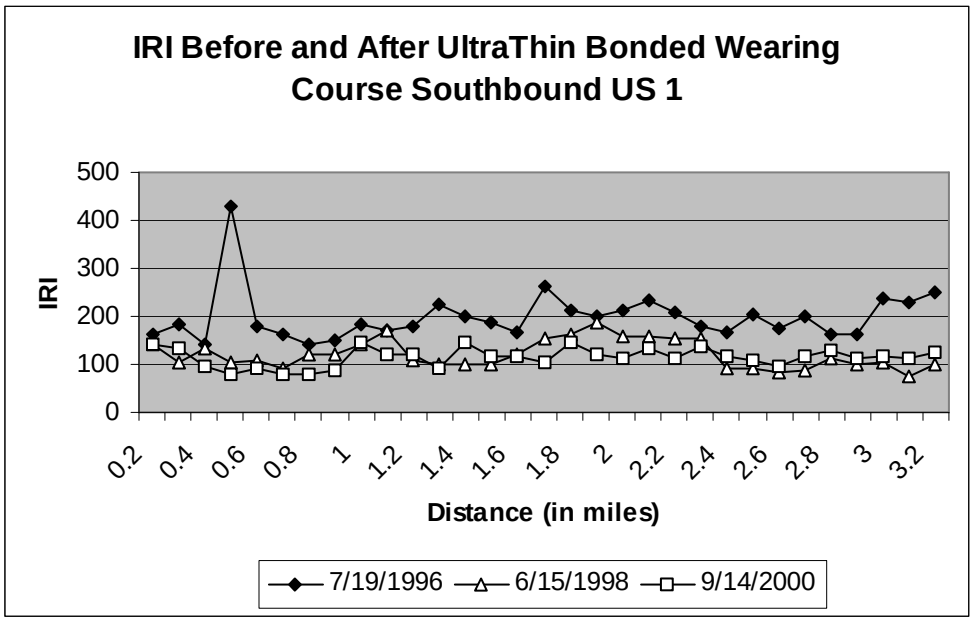

Figure 1: IRI before and after UTBWC on US-1 in Cary

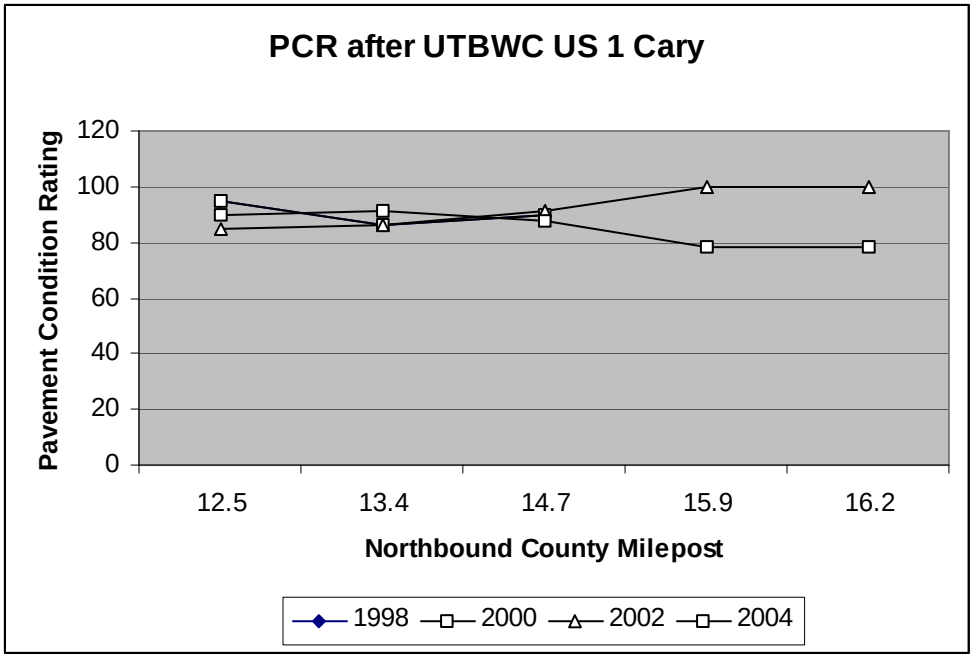

Figure 2: Pavement Condition Ratings after placement of UTBWC on US 1 in Cary.

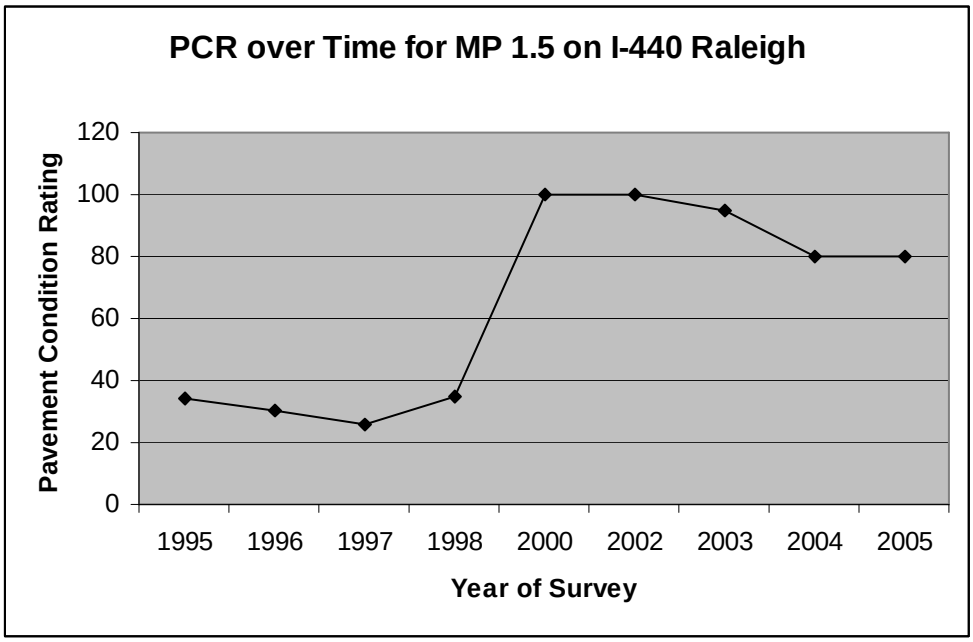

Figure 3: PCR at milepost 1.5 from four years before to five years after placement of UTBWC on I-440.

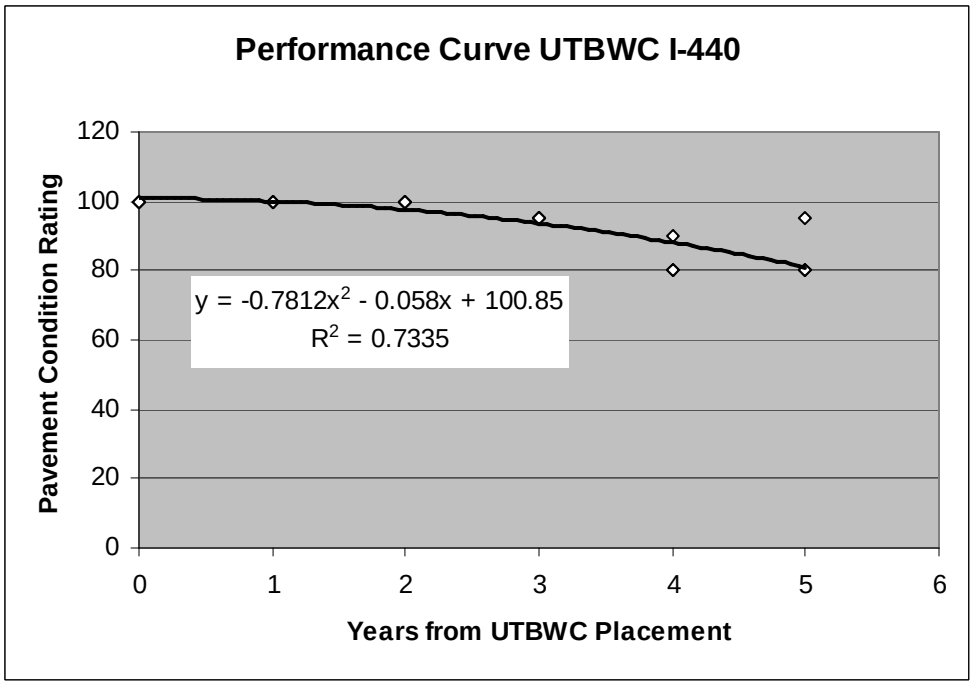

Figure 4: Performance curve for UTBWC on I-440, both directions combined.

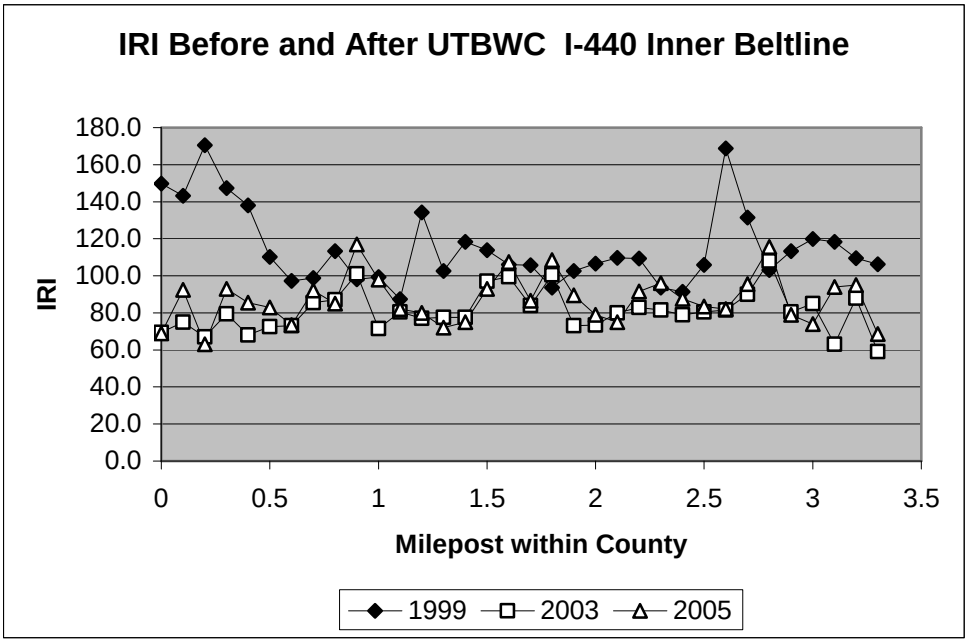

Figure 5: IRI before and after UTBWC on I-440 Raleigh Beltline.

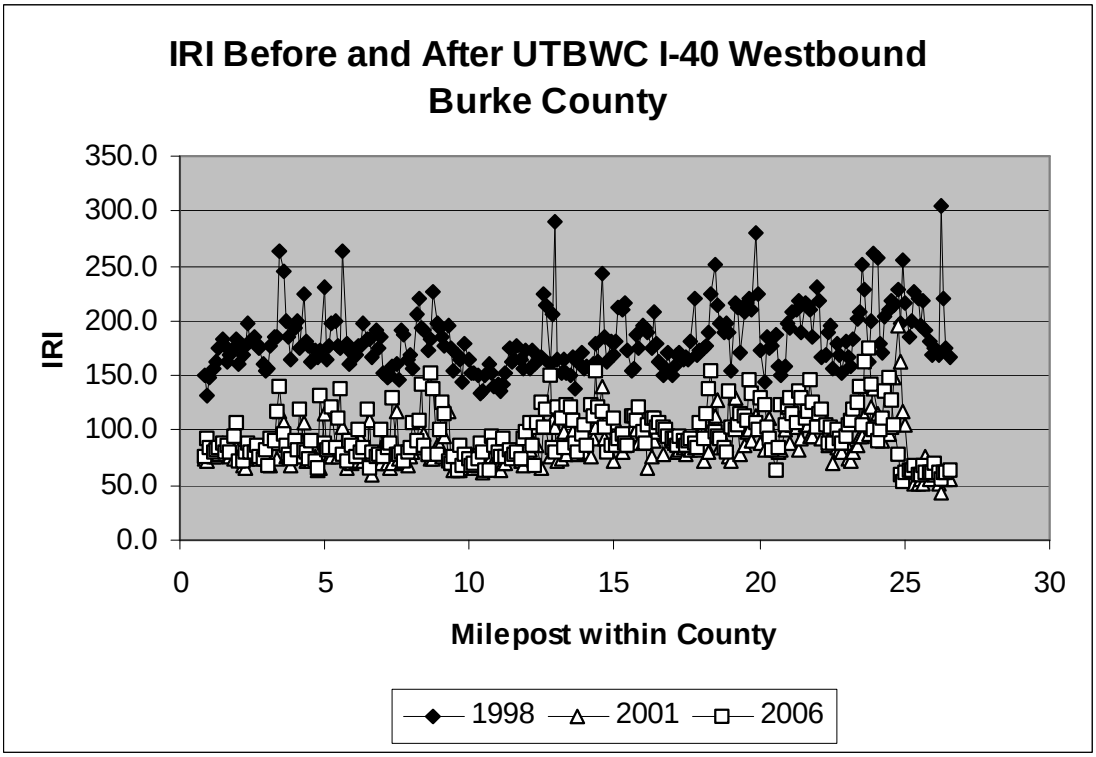

Figure 6: IRI Before and After UTBWC on I-40 Burke County.

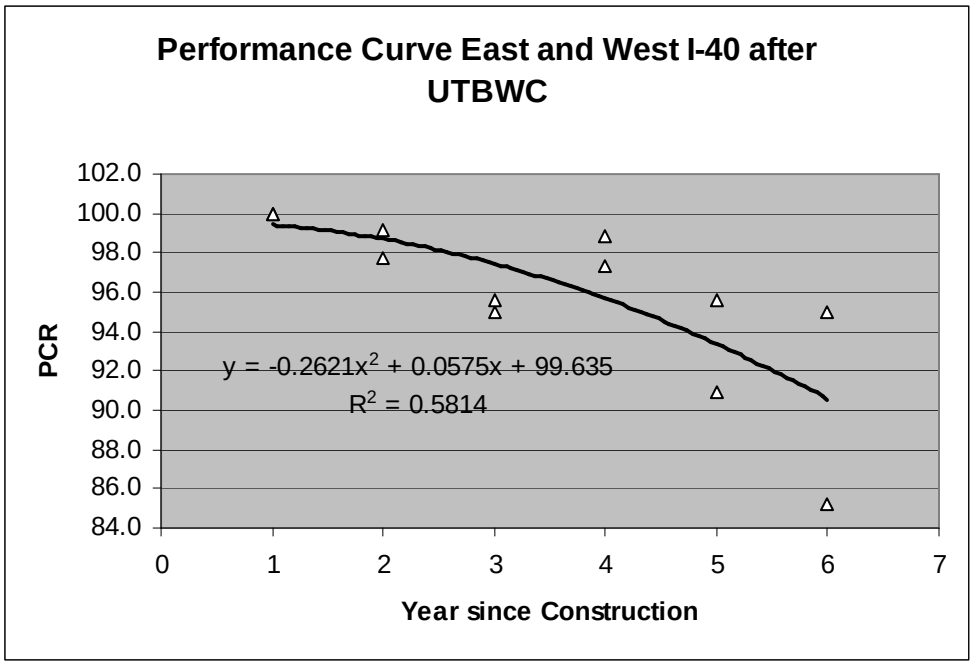

Figure 7: Performance Curve after placement of UTBWC on I-40 Burke County.

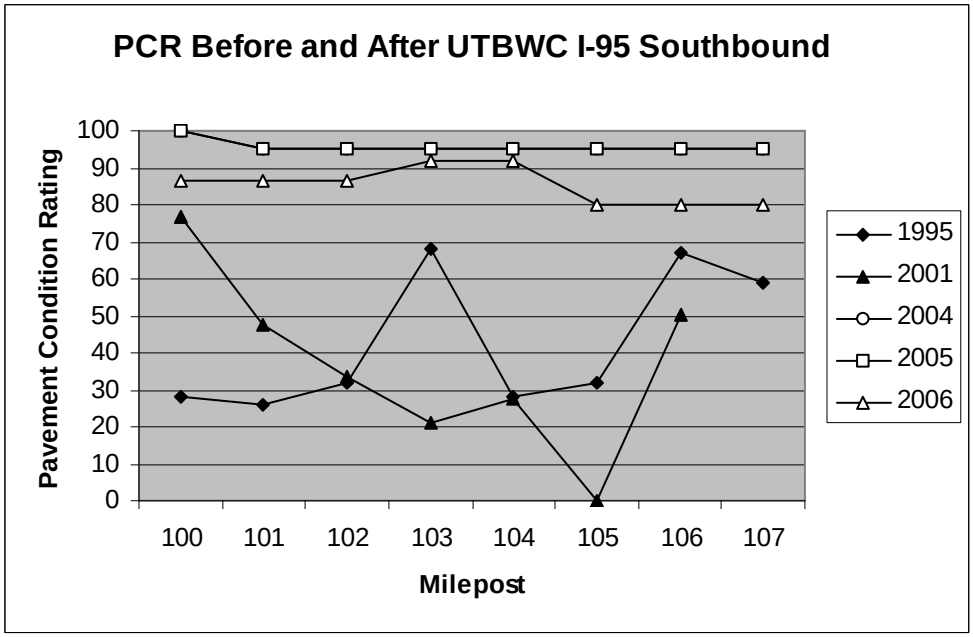

Figure 8: Pavement Condition rating before and after UTBWC on I-95 in Johnston County.

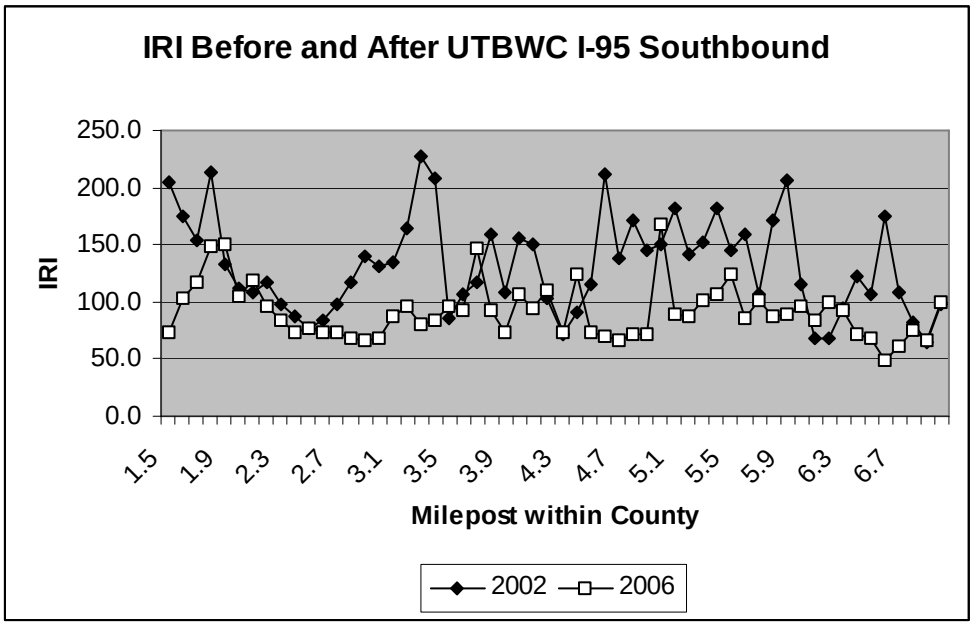

Figure 9: IRI before and after UTBWC on I-95 in Johnston County.