Report on Evaluation of Thin Hot Mix Asphalt Overlays and SR 164 Case Study

Prepared by:

Thomas R. Tate, P.E.
Trenton M. Clark, P.E.
VDOT Materials Division
Pavement Design and Evaluation Section

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Pavement Design and Evaluation
Designing Today for Tomorrow's Strains

Virginia Department of Transportation

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EXECUTIVE SUMMARY

The purpose of this evaluation was to summarize past use and performance of thin hot mix asphalt concrete overlays (example - NOVA Chip®) in Virginia and North Carolina, and to document pavement conditions before and after application of a thin hot mix asphalt concrete overlay (THMACO) on SR 164 in Portsmouth, Virginia.

In general, the North Carolina Department of Transportation (NCDOT) has been using thin hot mix asphalt concrete overlays (THMACO's) since 1997 on some of their high volume jointed concrete pavements. NCDOT does minimal repairs to the jointed concrete pavement before placing the THMACO's and are looking for 6 to 10 years of service life from the surface placed depending on the project. The NCDOT THMACO applications observed during a trip by VDOT representatives in June 2003 appeared to be performing very well given the traffic conditions observed (high volume) and the reported condition of the underlying jointed concrete (fair to poor).

Five THMACO applications have been placed in the Commonwealth of Virginia prior to 2003, four for municipalities in the Hampton Roads area, and one on Interstate 81. The THMACO's were applied over two different pavement types (jointed concrete and asphalt concrete) and in varying traffic conditions. The oldest applications were placed in 1999 with the more recent ones occurring in 2002. Two sites were on asphaltic concrete pavements in subdivisions that had relatively low traffic volumes; one was on jointed concrete pavement through an urban area; one was on jointed concrete pavement that was an entrance to a port facility (heavy truck traffic); and one was on an asphaltic concrete Interstate. Based on observations made in April 2003, the projects constructed in 1999 (City of Norfolk and City of Hampton) were performing better than the projects constructed in 2001 and 2002 (City of Chesapeake and City of Newport News). The 1999 projects contained a limited number of reflective cracks and the 2001/2002 projects contained a greater frequency of reflective cracks that also appeared to be wider. For the THMACO surface placed on I 81 in Wythe County, roughness measurements were obtained in the travel lane in 2000, 2002, 2003 and 2004. The IRI averaged 70 inches per mile in 2000 after application of the THMACO and averaged 73 inches per mile when measured in 2004. This was not a significant change in roughness.

In June 2000 a preliminary evaluation was performed on the continuously reinforced concrete pavements (CRCP) of SR 164 in Suffolk and Portsmouth, Virginia. The evaluation was initiated due to an increasing number of failures in the 8-inch CRCP. After completion of the preliminary evaluation a more detailed evaluation was completed in August 2001. Procedures used to evaluate the existing pavement included: a visual condition survey, FWD (falling weight deflectometer) testing, cutting of cores, drilling soil test borings, laboratory concrete compressive strength tests, and a laboratory concrete petrographic evaluation. The results of these evaluations characterized the existing 8-inch thick CRCP as being in poor condition due to spalling along transverse cracks and numerous punchouts in relation to the short period of time the pavement had been in service. In addition to the punchouts, evidence of base or subgrade materials being "pumped" from beneath the pavement was noted on the asphalt concrete shoulders. The 9-inch thick CRCP was providing good service and generally did not exhibit the distresses observed in the 8-inch CRCP.

Major rehabilitation of the 9-inch CRCP was not considered necessary because it appeared to be performing adequately. Several rehabilitation alternatives were considered for the 8-inch CRCP portion of the roadway. Alternatives considered for the 8-inch CRCP included:

1. Remove Concrete and Construct New CRCP
2. Remove Concrete and Construct New Asphalt Pavement
3. Install Edge Drain, Patch Concrete Pavement, and Construct Thick Asphalt Overlay
4. Install Edge Drain and Patch Concrete Pavement
5. Install Edge Drain, Patch Concrete Pavement, and Construct Thin Hot Mix Asphalt Overlay

Although Alternatives 1 and 2 could preserve existing grades, due to maintenance of traffic issues and cost, they were not considered feasible alternatives. Alternative 3, while significantly lower in estimated cost, was considered unfeasible because of the significant changes to roadway (and shoulder) elevation that would result. Potential changes in elevation were also why un-bonded and bonded concrete overlays, and rubblization with an asphalt overlay were not considered. Alternative 4 addressed the failures that had occurred and one of the potential sources of the pavement failures observed (water in the pavement structure). Alternative 5 was recommended because it provides for repair of existing failures and correction of conditions that probably initiated these failures.

In July 2003, a contract for installing edge drains, sealing pavement joints, full-depth patching of CRCP failures, and construction of a THMACO was awarded. The THMACO was constructed on the 8-inch CRCP but not on the 9-inch CRCP, providing a surface with which to compare performance of the THMACO.

After completion of the pavement rehabilitation work in the Fall of 2003, non-destructive testing (NDT) of the pavement was performed. Non-destructive testing included FWD, skid, roughness, and visual surveys. The NDT data obtained after completion of the pavement rehabilitation was compared to previous data available. Testing of the THMACO and CRCP surfaces indicate that they have similar skid (friction) qualities, and there has been no increase in the overall stiffness of the 8-inch CRCP. However, there was a significant increase in ride quality after placement of the THMACO on the 8-inch CRCP.

The pavements have been through one winter season since rehabilitation with no new distresses observed. Continued monitoring of the sections for roughness, skid resistance, and visual distresses will be performed so that the potential benefit of THMACO's can be assessed. Satisfactory performance of the THMACO surfaced pavements would be no failures in this section in the next three years, and that it perform comparably with respect to rideability and number of failures requiring repair to the 9-inch CRCP after 8 years. After eight to ten years (2011 to 2013), provided there are no significant increases in traffic volume, we would expect the wearing surface to require replacement. These expectations are based on comparing the performance of the THMACO section to the 9-inch CRCP, and current asphalt pavement surface lives.

PURPOSE AND SCOPE

The purpose of this evaluation was to summarize past use and performance of thin hot mix asphalt concrete overlays (example - NOVA Chip®) in Virginia and North Carolina, and to document pavement conditions before and after application of a thin hot mix asphalt concrete overlay (THMACO) on SR 164 in Portsmouth, Virginia. Information on past use of THMACO's was obtained by reviewing previous reports and test data on various pavement sections. For SR 164, pavement evaluation test data performed before application of the THMACO was reviewed and compared to post rehabilitation/construction test data and observations.

BACKGROUND INFORMATION

The following paragraphs summarize what thin hot mix asphalt overlays (THMACO's) are, and their past use and performance in North Carolina and Virginia.

Thin Hot Mix Asphalt Concrete Overlays

THMACO's are comprised of a thin hot mix asphalt concrete layer (less than one inch thick) and a binder material/tack coat. The binder material/tack coat is an asphalt emulsion modified to provide excellent adhesion of the hot mix asphalt concrete to the surface being overlaid. THMACO's are placed in a single lift at 3/8" to ¾" thick, making it an ultra-thin overlay. THMACO's can be used as preventative maintenance on a roadway or as a new surface during construction. Several uses for this material are to improve ride quality, restore skid resistance, seal the pavement surface, and extend the pavement structure's life.

The following were four suggested uses for THMACO's. One possible use was as a preventative maintenance activity. For roads experiencing limited functional surface distresses and that are structurally sound, THMACO's should extend the pavement's life. THMACO's may also be beneficial in areas where curb and gutter exist and the curb reveal must be maintained for drainage. The minor increase in pavement elevation from application of a THMACO should not adversely affect the drainage. In addition to curb and gutter locations, routes with guardrails at or near the minimum height could be candidate sites. Again the minimal increase in elevation should not significantly affect the guardrail height requirements. Second, THMACO's should be effective in reducing noise and water spray. For roads that have these problems, application of a THMACO may be a solution. Third, for sound PCC pavements THMACO's could be used to seal the pavement's surface and prevent water infiltration. Fourth, when placed properly THMACO's could be used to restore friction in areas of low friction.

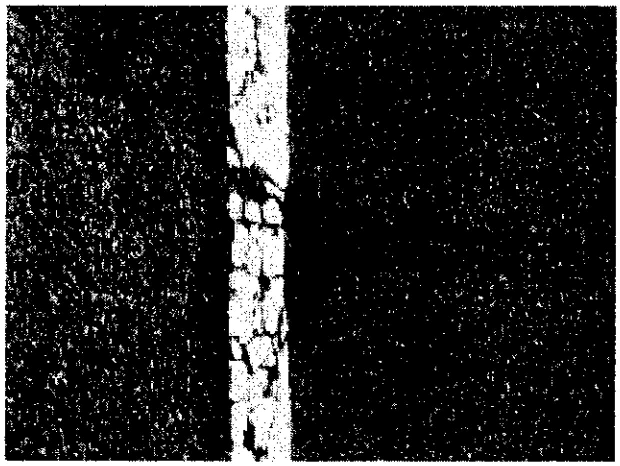
THMACO's in North Carolina

On June 5, 2003, Mr. Andy Mergenmeier, Mr. George Boykin, Mr. Trenton Clark, and Mr. Tom Tate of VDOT drove to Raleigh, North Carolina to meet Dr. Judith Corley-Lay - NCDOT State Pavement Management Engineer. The purpose of this trip was for the VDOT representatives to view some of NCDOT's THMACO (NOVA Chip®) projects. The following is a summary of information obtained on this trip.

In general, NCDOT has been using THMACO's since 1997 on some of their high volume jointed concrete pavements. These pavements typically are reinforced and have joints 30 feet on center. NCDOT does minimal repairs to the jointed concrete pavement before placing the THMACO's and are looking for 6 to 10 years of service life from the surface placed depending on the project. Most THMACO applications have been 5/8-inch thick. NCDOT reports reduced water spray on THMACO surfaced roads with respect to Superpave surfaced roads.

The NCDOT THMACO applications observed appeared to be performing very well given the traffic conditions observed (high volume) and the reported condition of the underlying jointed concrete (fair to poor). Reflective cracks were visible in the older applications (2 to 3 years old). However, generally not observed was adjacent cracking and raveling of the THMACO from the reflective crack, which commonly occurs with VDOT's hot mix asphalt overlays on jointed concrete pavements (see photograph No.s 1 & 2 below). Overall the VDOT representatives were impressed with the performance of the THMACO for the conditions observed and reported.

Photograph No. 1: Reflective crack (I 440 in Raleigh).



Photograph No. 2: Reflective crack seeping water (US 1 in Cary).

NCDOT project sites visited:

1. US 1 in Cary (THMACO placed 1997/1998)
2. I 440 in Raleigh, between SR 54 and I 40/440 Split (THMACO placed 2001)
3. US 401 (Capital Boulevard) in Raleigh (THMACO placed 2003)

NCDOT project sites not visited but discussed:

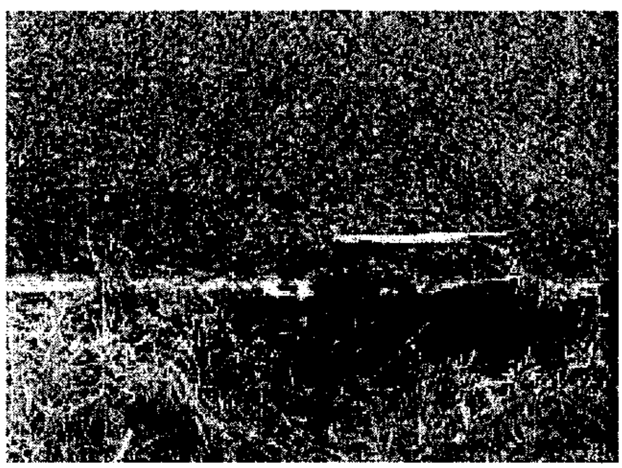
1. I 40 in Burke County, between Hickory and Morganton (THMACO placed 2000/2001)
2. US 311 (Main Street) in High Point (in planning stages in 2003)
3. I 85 Randolph & Davidson Counties, Mile Post 81 to Business I 85 Split near Lexington (THMACO placed 2002)
4. I 85 Business in High Point (THMACO placed 2002)

THMACO's in Virginia

Five THMACO applications placed in the Commonwealth of Virginia, four for municipalities and one Interstate, were reviewed. The THMACO's were applied to two different pavement types (jointed concrete and asphalt concrete) and in varying traffic conditions. The oldest applications were placed in 1999 with the more recent ones occurring in 2002. The following paragraphs summarize information obtained on these sites.

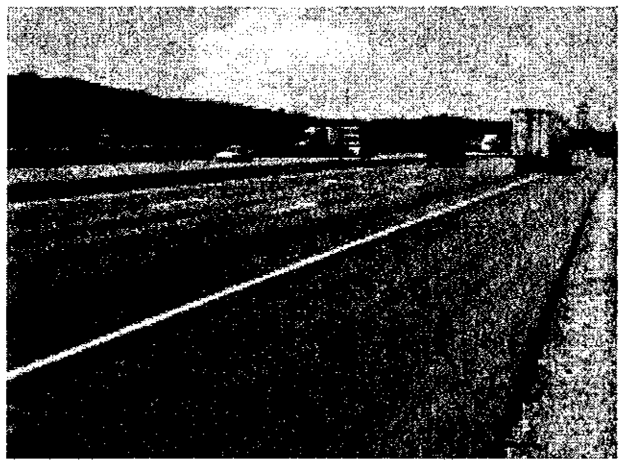
Four municipalities in the Southeastern part of Virginia (Cities of Chesapeake, Hampton, Newport News, and Norfolk) have placed a THMACO surface. Two sites were on asphaltic concrete pavements in subdivisions that had relatively low traffic volumes; one was on jointed concrete pavement through an urban area; and one was on jointed concrete pavement that was an entrance to a port facility (heavy truck traffic). THMACO quantities placed ranged from approximately 5,000 square yards to 32,000 square yards for a project.

Based on observations made in April 2003, the projects constructed in 1999 (City of Norfolk and City of Hampton) are performing better than the projects constructed in 2001 and 2002 (City of Chesapeake and City of Newport News). The 1999 projects contained a limited number of reflective cracks. These reflective cracks were typically tight with no raveling of crack edges or formation of adjacent cracks. The City of Hampton project was in a subdivision on an asphalt concrete pavement and the City of Norfolk project was on a jointed concrete road into the coal terminals. The 2002 and 2001 projects in the City of Newport News and City of Chesapeake, respectively, contained a greater frequency of reflective cracks that also appeared to be wider than those in the 1999 projects. The City of Newport News project was on jointed concrete. On this project spalling crack edges and cracking parallel to the original reflective crack were also observed. The City of Chesapeake project was in a subdivision on asphalt concrete pavement.



Photograph No. 3: Reflective crack over a greater than one inch joint (Redgate Avenue in Norfolk).

In July 2000, a THMACO surface was placed on I 81 in Wythe County, by Virginia Maintenance Services, Inc. as a part of their Interstate maintenance contract with VDOT. The overlay project was on all three lanes of I-81 southbound from county relative mile point 21.52 to 16.60, 4.92 miles. The 2002 estimated traffic volume for this section of I 81 Southbound was 25,000 average annual daily traffic (AADT) with 29 percent trucks. Roughness measurements for this pavement segment were obtained in the travel lane in 2000, 2002, 2003 and 2004. The average IRI in 2000 after application of the THMACO was 70 inches per mile. When last measured in Spring 2004 the average IRI in the travel lane was 73 inches per mile. This was not a significant change in roughness. During a cursory visual survey in May 2004, the following distresses were noted: apparent patching of the center lane approximately 300 feet long, and isolated patches from the dislocation of snow plowable pavement markers. In general the surface of the THMACO appeared to be in good condition (see Photograph No. 4 below).



Photograph No. 4: I 81 in Wythe County, shoulder was not overlaid.

CASE STUDY OF STATE ROUTE 164

Background Information

State Route 164 (Western Freeway) starts west of I 664 in Suffolk, Virginia and goes 6.45 miles east to its terminus at Bayview Boulevard in Portsmouth. The majority of the roadway was completed in 1991 to 1993, with the eastern most portion being completed in 1978 as a part of the West Norfolk Bridge. Generally, SR 164 is a four lane divided highway with a grass median and asphalt shoulders. Continuously reinforced concrete pavement (CRCP) was used for approximately 3.9 miles of the roadway with the remainder being asphalt concrete. Approximately 2.11 miles of the concrete pavement is 9-inch thick CRCP and approximately 1.79 miles is 8-inch CRCP. The designed base for the CRCP was 6-inches of soil stabilized with 10 percent cement. The 1997 traffic volumes for SR 164 range from 19,945 average annual daily traffic (AADT) with 5.2 percent trucks for the pavement east of Town Point Road, to 23,660 AADT with 5.2 percent trucks for the pavement around the I 664 interchange. The 2002 traffic volumes for these locations are 34,000 AADT near the I 664 interchange and 28,000 AADT east of Towne Point Road. The location of SR 164 and pavement sections constructed are presented on Figure 1.

Existing Pavement Evaluation

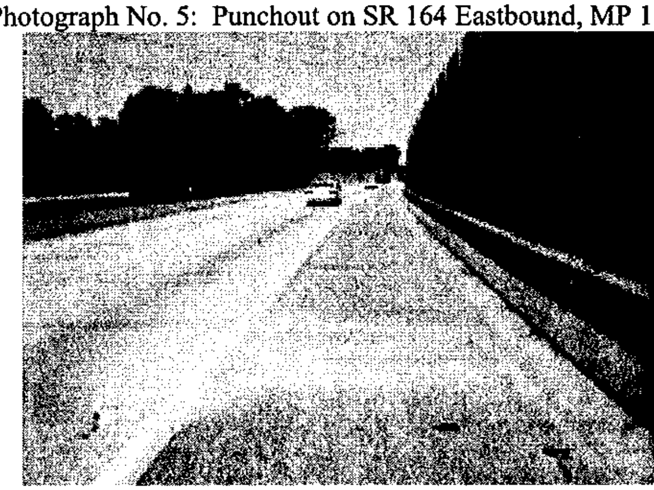
In June 2000 a preliminary evaluation was performed on the continuously reinforced concrete pavements, which lead to a more detailed evaluation that was completed in August 2001. The following paragraphs present the evaluation procedures used, their results, and a summary of the maintenance/rehabilitation activities that were recommended.

Visual Condition Survey

On June 1 and 2, 2000, a visual condition survey of the east and westbound lanes of SR 164 was performed by Thomas R. Tate, P.E., Hampton Roads District Pavement Management Engineer. The purpose of the survey was to document the types, frequency, and severity of pavement distresses visible. This information was presented in a Memorandum (report) dated July 10, 2000 and is summarized below.

In June 2000 the pavements varied in condition relative to their thickness. The 9-inch thick CRCP appeared to be in good condition with limited "Y" cracking and no failures observed. The 8-inch CRCP appeared to be in poor condition for its age, approximately 8 years old when surveyed in 2000, due to the observed frequency of patches and punchout failures. The majority of the failures (punchouts) in this pavement had occurred within a 0.4-mile long section of the 8-inch CRCP (see Photograph No. 5). The punchouts indicated a structural failure within the CRCP system. These failures may have been caused by a failure of the concrete or the pavement's supporting layers. The presence of fines on the asphalt shoulders indicated that water was getting into the pavement system and has washed out material from the supporting layers (see Photograph No. 6). Possible sources for this water were the open longitudinal joints between the concrete pavement and asphalt shoulders, and the unpaved portion of the inside shoulders which sloped (drained) towards the pavement. Additionally, low severity spalling of the transverse cracks was noted.

Photograph No. 5: Punchout on SR 164 Eastbound, MP 1.46.



Photograph No. 6: Fines on shoulder near punchout shown in Photograph No. 5.

Cores and Soil Test Borings

Pavement coring and soil test borings were performed at ten locations on January 10, 2001. Pavement core/soil test boring locations were selected based on FWD deflection basin results obtained in August and September 2000. Approximate pavement core and soil test boring locations are shown on Figure 2.

Concrete and soil cement core samples were obtained from the pavement using a four-inch diameter, water-cooled diamond bit. Seven of the concrete core samples obtained from the CRCP contained reinforcing steel. The 8-inch CRCP contained No. 5 size reinforcing steel with a concrete cover that ranged from 4.5 inches to 5.6 inches. The 9-inch CRCP contained No. 6 size reinforcing steel with a concrete cover that ranged from 3 inches to 3.8 inches. The 8-inch CRCP thicknesses ranged from 7.6 to 8.9 inches and averaged 8.2 inches. The 9-inch CRCP thicknesses ranged from 8.6 to 9.5 inches and averaged 9.2 inches. Soil cement was encountered beneath the CRCP. The soil cement ranged in thickness from 4 to 9 inches and averaged approximately 5.5 inches. Individual core thicknesses and locations are presented in the attached Table 1, Summary of Concrete and Soil Cement Core Information.

Standard penetration resistance tests (AASHTO T 206) were conducted at regular intervals at each of the core locations and encountered a fine sand fill material with some clay in borings 1, 2, 5, and 9. The consistency of the sandy fill was variable with standard penetration resistances (N) ranging from 41 to 86 blows per foot (bpf) in the upper foot of subgrade. At boring locations 3, 4, 6, 7, 8, and 10 a clay material with some sand was encountered beneath the pavement. The consistency of the clayey material was also variable with standard penetration resistances ranging from 8 to 30 bpf in the upper foot of subgrade. At borings 6, 7, and 10 organic material was encountered at depths of 6 ft, 7 ft, and 3 ft, respectively, in the borings. More detailed descriptions of the subsurface conditions encountered are presented in the attached Engineering Geology Reports (Appendix).

No ground water was encountered in the borings during drilling or upon removal of drilling tools. The borings were backfilled and patched immediately after boring and no long-term observations for ground water were made.

Based on the standard penetration resistances, soil classifications, and experience with similar materials, it was estimated that the sandy subgrade, in its current condition, was providing a resilient modulus (M_r) of greater than 10,000 psi and a subgrade reaction (k) value of 500 pci on top of the soil cement. The clayey subgrade, in its current condition, was providing a resilient modulus (M_r) of less than 5,000 psi and a subgrade reaction (k) value of less than 200 pci on top of the soil cement.

FWD Testing

On August 8 & 9, and September 12 & 13, 2000, the subject pavements were tested using a Dynatest falling weight deflectometer (FWD). The Dynatest FWD is a trailer mounted pavement-testing device capable of measuring pavement deflections under various impulse forces ranging from 3,000 to approximately 30,000 pounds. The resulting load and deflection data were used to backcalculate the in-situ layer properties for the pavement structure. In addition, the NDT data was used to calculate the load transfer efficiency of transverse cracks in the CRCP. Deflections were measured on the "loaded" slab and adjacent "unloaded" slab. The load transfer efficiency (expressed as a percentage) was calculated as the ratio of the deflection of the unloaded slab to the deflection of the loaded slab. The pavements were tested at load levels of approximately 9,000 and 16,000 pounds. The load was applied to the pavement structure through a circular load plate. Deflections were measured under the center of the load plate and at radial offsets of 8, 12, 18, 24, 36, 48 and 60 inches.

A total of 334 basin and 513 load transfer tests were performed to estimate the pavement layer moduli and load transfer efficiency, respectively. Basin tests were performed approximately 150 ft. on center in the travel lanes and 500 ft. on center in the passing lanes. Load transfer tests were performed approximately every 75 feet on center in the travel lanes.

The FWD data was used to estimate the modulus of elasticity of the existing pavement layers and subgrade soils underlying the pavement. Data reduction and analysis was performed using equations published in the Supplement to the AASHTO Guide For Design of Pavement Structures, Part II – Rigid Pavement Design and Rigid Pavement Joint Design, dated 1998. Elastic properties were determined using backcalculation methods that matched computed deflections to the deflections measured at each test point.

To accurately backcalculate elastic properties, the thicknesses of the various pavement layers were required. Layer thicknesses used in backcalculation were based on thickness data from the corings/borings. A summary of the layer thicknesses used in backcalculation and of elastic properties indicated for each section is presented below.

CRCP Thickness, inches	Composite* Thickness, inches	Composite Elastic Modulus (E)	Subgrade Resilient Modulus (M_r)	Subgrade Reaction (k)
8	13	4.9 x 10^6psi	3,000	150
9	14	6.5 x 10^6psi	4,000	200

* Composite Thickness: Thickness of CRCP plus thickness of soil cement.

The elastic modulus values presented above are based on the combined thickness of CRCP and soil cement. Backcalculation values when the CRCP and soil cement were separated into two layers provided unreasonable results. The composite modulus values however correlate well with other testing performed (see Laboratory Testing). However, the subgrade values predicted by the AASHTO equations appear to be low when compared to the high N values recorded for the fine sand fill material under the 9-inch CRCP.

The theoretical limits of load transfer efficiency are zero for no load transfer and 100 percent for full load transfer across transverse cracks. Values of load transfer greater than 70 percent are generally considered to indicate good load transfer. The load transfer for all cracks tested was greater than 80 percent, indicating good load transfer. However at 51 locations tested in the 8-inch CRCP pavement, high deflections (greater than 10 mils) were measured. These high deflections indicate a loss of base or subgrade support for the pavement.

Laboratory Testing

Samples of the concrete and soil cement cores obtained were returned to the laboratory for testing. The compressive strength of five concrete cores and three soil cement cores were measured in accordance with AASHTO T 24. The measured compressive strength (corrected for specimen height) of the concrete cores ranged from 5,750 psi to 8,380 psi and averaged approximately 6,520 psi. The measured compressive strength (corrected for specimen height) of the soil cement cores ranged from 1,230 psi to 1,490 psi and averaged approximately 1,340 psi. Individual compressive strength results are presented in the attached Table 1, Summary of Concrete and Soil Cement Core Information.

A petrographic evaluation was performed on two concrete cores obtained from the pavements, cores C-4 and C-10. The purpose of the evaluation was to determine if the scaling and white precipitate noticed during the visual survey were indications of larger or possible more widespread material problems. The complete petrographic report submitted by Stephen Lane with the Virginia Transportation Research Council is summarized here.

> The petrographic evaluation indicated that the distresses observed at core location C-10 were primarily the result of a high water to cement ratio. No indications of alkali-silica reactions (ASR) were noted, however minor deposits of ettringite were observed in some voids. While the formation of ettringite in excess does cause the disruption of concrete, minor deposits are commonly found within the voids of a concrete structure exposed to the elements. Therefore the minor deposits observed in the samples evaluated do not appear to indicate a larger concrete durability problem with ettringite formation.

Pavement Analysis

Traffic and pavement thickness requirements were based on information provided, conditions encountered during the evaluation, and standard pavement evaluation and design procedures. Pavement evaluation and design procedures used included: the American Association of State Highway and Transportation Official's (AASHTO) Guide for Design of Pavement Structures, dated 1993; the Supplement to the AASHTO Guide For Design of Pavement Structures, Part II – Rigid Pavement Design and Rigid Pavement Joint Design, dated 1998; DARWin 2.0 pavement evaluation and design software; and typical pavement design variables issued by VDOT's Central Office Pavement Design and Evaluation Section on March 3, 2000.

Traffic

The 1997 average annual daily traffic (AADT) for SR 164 ranged from 19,545 AADT for the eastern half of the route to 25,212 AADT near the Towne Point Road interchange. The traffic count by traffic class and the ESAL factor by class presented in the attached Appendix were used to calculate the yearly total ESAL's. Using a lane distribution of 80 percent of the traffic being in the design lane, and 300 days of traffic per year, yielded a maximum traffic volume of approximately 281,400 ESAL's per year in 1997. If 3.0 percent growth in traffic occurs, the number of ESAL's per year in 2001 and 2031 will be 307,500 and 768,700, respectively. This translates into approximately 8×10^6 ESAL's for a 20-year design life and 16×10^6 ESAL's over a 30-year design life. Although transportation upgrades are planned for the area (Third Tunnel Crossing), these upgrades have not been used for this analysis because they were to be completed later in the life of the pavement.

Existing Pavement Capacity

The information obtained from the visual survey, FWD testing, cores, soil test borings and laboratory testing were used to estimate the capacity of the existing pavement. Based on the evaluation parameters used, allowable ESAL's to failure were calculated using DARWin 2.0. The allowable total capacity of the 8-inch CRCP was estimated as 2.3 x 10^6 ESAL's and the total capacity of the 9-inch CRCP was estimated as 4.4 x10^6 ESAL's. These calculations indicated that the 8-inch CRCP was at the end of its service life and that the 9-inch CRCP had approximately 10 years of remaining service life.

Pavement Rehabilitation Alternatives

Major rehabilitation of the 9-inch CRCP was not considered necessary because it appeared to be performing adequately. Several rehabilitation alternatives were considered for the 8-inch CRCP portion of the roadway. Alternatives considered for the 8-inch CRCP included:

1. Remove Concrete and Construct New CRCP (estimated initial construction cost of $6,315,000)
2. Remove Concrete and Construct New Asphalt Pavement (estimated initial construction cost of $3,253,000)
3. Install Edge Drain, Full-Depth Patch Concrete Pavement, and Construct Thick Asphalt Overlay (estimated initial construction cost of $1,067,000)
4. Install Edge Drain and Full-Depth Patch Concrete Pavement (estimated initial construction cost of $409,000)
5. Install Edge Drain, Full-Depth Patch Concrete Pavement, and Construct Thin Hot Mix Asphalt Concrete Overlay (estimated initial construction cost of $770,000)

Note: Initial construction costs were based on 2001 and 2002 dollars and bid prices, and did not include incidental items (traffic control, pavement markings, guardrail, etc.). Construction of "New" pavements to be on existing soil cement base.

Although Alternatives 1 and 2 could preserve existing grades, due to maintenance of traffic issues and cost, they were not considered feasible alternatives. Alternative 3, while significantly lower in estimated cost, was considered unfeasible because of the significant changes to roadway elevation (and shoulder) that would result. The 8-inch CRCP portion of the roadway passes under one bridge, ties into several ramps, and has a jersey wall with sound barrier at the edge of the outside shoulder which constrained changes in pavement elevation. Potential changes in elevation were also why un-bonded and bonded concrete overlays, and rubblization with an asphalt overlay were not considered. Alternative 4 addresses the failures that had occurred and one of the potential sources of the pavement failures observed (water in the pavement structure). Alternative 5 addresses water infiltration further by sealing the pavement and shoulder surfaces with an asphalt overlay that does not dramatically change the surface elevation of the pavement.

Based on the conditions observed, planned increases in traffic, and existing grade constraints, it was recommended that Alternative 5 (full-depth patch failures, install edge drains, seal joints, and placement of a thin hot mix asphalt concrete overlay on the 8-inch CRCP) be performed. This alternative provides for repair of existing failures, correction of the conditions that probably initiated these failures, and an overlay to further reduce the intrusion of water through the pavement surface. Not placing an overlay can allow infiltration of surface water into spalled transverse cracks.

SR 164 Pavement Rehabilitation Results

In July 2003, a contract for installing edge drains, sealing pavement joints, patching CRCP failures, and construction of a thin hot mix asphalt concrete overlay (THMACO) was awarded. After completion of this work in the Fall of 2003, non-destructive testing (NDT) of the pavement was performed. Non-destructive testing performed included FWD, skid, roughness, and visual surveys. The NDT data obtained was compared to previous data where available. The following sections present a comparison of data obtained before the pavement rehabilitation and after.

Photograph No. 7: Application of THMACO on SR 164, October 2003 (MP 2.34, WBL).

FWD Testing

On February 10 and 11, 2004, the subject pavements were again tested using a Dynatest falling weight deflectometer (FWD). The pavements were tested at load levels of approximately 9,000 and 16,000 pounds. The load was applied to the pavement structure through a circular load plate. Deflections were measured under the center of the load plate and at radial offsets of 8, 12, 18, 24, 36, 48 and 60 inches. The resulting load and deflection data were used to backcalculate the in-situ layer properties for the pavement structure and compare these results to FWD data collected in August and September of 2000. The following table summarizes a comparison of the backcalculation and deflection data.

Direction	Lane	CRCP Thickness	Data Year	Composite E, psi x 10^6		M_r, psi		D_0, mils	
				Average	STD	Average	STD	Average	STD
EB	1	9"	2000	6.5	5.1	3,900	1,000	4.95	1.43
EB	1	9"	2004	4.4	2.7	3,800	700	5.56	1.08
EB	1	8"	2000	4.9	2.4	3,300	800	6.58	1.73
EB	1	8"*	2004	4.0	3.0	3,900	700	6.37	1.49
WB	1	8"	2000	4.6	2.4	3,200	900	7.43	3.03
WB	1	8"*	2004	3.4	2.0	3,700	800	6.68	1.35
WB	1	9"	2000	6.9	4.6	3,600	900	5.28	1.53
WB	1	9"	2004	5.5	3.1	3,600	700	5.58	1.35

Notes: Composite E – Composite modulus of CRCP and soil cement (soil cement 5-inches thick)
D_0 – Deflection at sensor 0, which is at load plate
M_r – Subgrade modulus
* - Testing performed on THMACO surface.

The above backcalculation and deflection data indicate the following:

- Even though the data was segmented by pavement structure (8-inch CRCP and 9-inch CRCP), there was high variability in the data. Some standard deviation values were over 50 percent of the average value.
- The change in average subgrade modulus (M_r) from 2000 to 2004 was approximately 15 to 18 percent higher for the 8-inch CRCP and less than 5 percent different for the 9-inch CRCP.
- An approximate 18 to 33 percent drop in composite modulus (E) from 2000 to 2004 was indicated.
- Changes in average deflections at D_0 were less than 1.0 mil. The average deflections for the 9-inch CRCP were slightly higher in 2004 and the average deflections for the 8-inch CRCP were slightly lower in 2004.

The FWD data indicates there was reduction in concrete stiffness in the CRCP pavement structures between 2000 and 2004. This difference in response may be due to pavement deterioration with traffic, but is most likely the result of the 2000 testing being performed at the end of summer and the 2004 testing being performed in the winter. Increased pavement stiffness would not be uncharacteristic given the higher pavement temperatures of summer which should have increased load transfer at transverse cracks. Slight increases in subgrade stiffness and slight reductions in deflections at D_0 for the 8-inch

CRCP may be an indication that the edge drains are removing excess water from the subgrade and that the THMACO has reduced surface infiltration. There was no increase in pavement stiffness indicated after application of the THMACO to the 8-inch CRCP, which was expected. The thickness and stiffness of the THMACO is small with respect to the CRCP and soil cement layers.

Skid Testing

Skid numbers were collected in general accordance with ASTM E274, "Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire" using a VDOT skid unit before pavement rehabilitation in June 2003 and after pavement rehabilitation in January 2004. Measurements were obtained using a smooth (bald) tire test. The following table summarizes a comparison of the skid test data.

Direction	Lane	CRCP Thickness	Date Tested	Skid Number		
				Average	Max	Min
EB	1	9	Jun 2003	46.8	59.5	31.5
EB	1	9	Jan 2004	43.9	57.0	27.5
EB	2	9	Jun 2003	45.7	63.9	33.5
EB	2	9	Jan 2004	45.4	60.7	31.5
EB	1	8	Jun 2003	45.2	61.6	31.4
EB	1	8	Jan 2004	47.8	50.6	45.0
EB	2	8	Jun 2003	46.6	66.5	32.0
EB	2	8	Jan 2004	48.0	52.6	43.0
WB	1	8	Jun 2003	36.1	50.8	23.5
WB	1	8	Jan 2004	46.7	48.4	42.2
WB	2	8	Jun 2003	44.2	57.7	31.7
WB	2	8	Jan 2004	49.2	52.6	46.7
WB	1	9	Jun 2003	47.7	63.0	30.2
WB	1	9	Jan 2004	48.1	59.9	35.7
WB	2	9	Jun 2003	51.2	62.9	33.4
WB	2	9	Jan 2004	49.7	60.0	35.2

With one exception, there was not a significant change in the average skid number for individual segments and lanes from test data collected in June 2003 and January 2004. The concrete surfaced pavements were providing adequate skid resistant in 2003, and continued to do so when tested in 2004.

Placement of the THMACO increased significantly the average skid number of one segment, lane 1 of the 8-inch CRCP WB. The average skid number for this segment increased from 36.1 to 46.7 with placement of the THMACO. Data collected indicates that the THMACO was providing a minimum skid number of approximately 42 when tested in January 2004.

Roughness Testing

Pavement roughness test data was collected using a VDOT pavement profiler (South Dakota Type) in accordance with VTM-106, "Determining Pavement Roughness and Rut Depth Using an Accelerometer Established Inertial Profile Referencing System." Roughness data was collected in the eastbound travel lane in February 2003 as a part of data collection for VDOT's HPMS effort. Roughness data was collected for this report in May 2004. The following table summarizes a comparison of the pavement roughness test data.

			IRI, inches per mile			
		CRCP	Feb 2003		May 2004	
Direction	Lane	Thickness	Average	STD	Average	STD
EB	1	9"	80	24	92	23
EB	2	9"	*	-	84	25
EB	1	8"	140	37	86	21
EB	2	8"	*	-	72	18
WB	1	8"	*	-	86	28
WB	2	8"	*	-	74	28
WB	1	9"	*	-	90	20
WB	2	9"	*	-	82	21

* Sections did not require ride data collection for HPMS

Unfortunately more roughness information was not available for conditions before pavement rehabilitation. Data collected indicates that before pavement rehabilitation the 9-inch eastbound CRCP had a "good" average ride quality (see chart below) and the 8-inch westbound CRCP had a "poor" average ride quality. From 2003 to 2004 there was a slight increase in the average roughness on the 9-inch eastbound CRCP. Construction of concrete patches and placement of a THMACO on the 8-inch eastbound CRCP reduced the average roughness from poor (140) to good (86), which is a significant reduction. In 2004 all pavement segments had a good ride quality. With continued usage we would expect increases in roughness in future years until another pavement maintenance or rehabilitation activity is performed.

Qualitative Category	IRI Range (inches/mile)
Excellent	< 60
Good	60 – 100
Fair	100 – 140
Poor	140 – 200
Very Poor	>200

Reference: "Roughness on Virginia's Roads, 2004 Annual Interstate Roughness Report," VDOT's Pavement Design and Evaluation Section, May 2004.

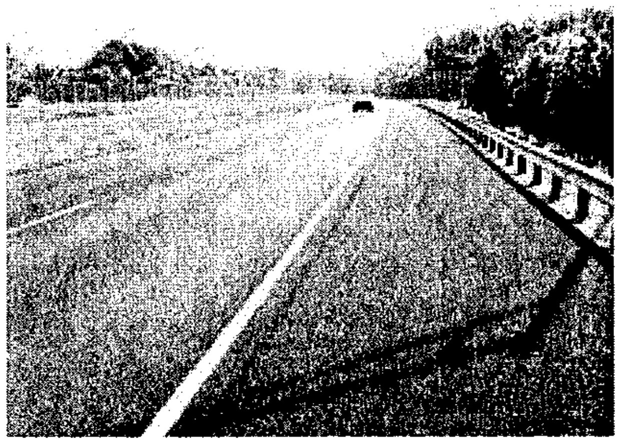
Visual Survey

In April 2003 CGH Pavement Consultants based in Harrisburg, Pennsylvania performed a visual condition survey of the concrete pavements in the Commonwealth of Virginia using continuous pavement images. Continuous images for a random tenth of a mile in every mile (10% sampling) were selected and rated for distress quantification. For CRCP a concrete distress rating (CDR) and concrete punchout rating (CPR) indices were calculated for every section rated. Distress conditions and severities were quantified using the guidelines published by VDOT in "A Guide to Evaluating Pavement Distress Through the Use of Video Images," dated 1998. In March 2004 the condition of the THMACO (asphalt) surfaced pavement sections were surveyed using VDOT's Windshield Rating procedures and software dated January 2002. VDOT's Windshield Rating procedures generate a LDR (load related distress) and NDR (non-load related distress) number that quickly quantifies the condition of the pavement for comparison purposes. The table below summarizes condition-rating indices for the pavement segments. Additional site visits were made by pavement engineers to verify conditions reported.

			Condition Rating Indices					
		CRCP	2003		2004			
Direction	Lane	Thickness	CPR	CDR	CPR	CDR	LDR	NDR
EB	1	9	97	92	+	+	*	*
EB	1	8	75	87	**	**	100	100
WB	1	8	96	97	**	**	100	100
WB	1	9	93	97	+	+	*	*

Notes: + - 2004 condition data not available.
* - Concrete surfaced pavement, see CPR, CDR.
** - Asphalt surfaced pavement, see LDR, NDR.

The initial post rehabilitation condition survey of the 8-inch CRCP indicates that there were no visible surface distresses in the THMACO at the time of the survey. The 9-inch CRCP had not been surveyed since completion of the rehabilitation project. However, cursory observations indicate that it is still providing good service. This table of information should be updated as additional years of data are collected.



Photograph No. 8: SR 164 THMACO surface after one winter, May 2004 (MP 1.10, EBL).

Conclusions

On SR 164 the THMACO was constructed on the 8-inch CRCP after full depth patching of failures, installation of an edge drain, and sealing of open longitudinal joints. The adjacent 9-inch CRCP was also patched and open joints were sealed. However, edge drains and a THMACO were not constructed on the 9-inch CRCP section, providing a surface with which to compare performance of the THMACO. Initial testing of the THMACO and CRCP surfaces indicate that they have similar skid (friction) qualities, and there has been no increase in the overall stiffness of the 8-inch CRCP with application of the THMACO. However, there was a significant increase in ride quality after placement of the THMACO on the 8-inch CRCP.

The pavements have been through one winter season since rehabilitation with no new distresses observed. Continued monitoring of the sections for roughness, skid resistance, and visual distresses will be performed so that the potential benefit of THMACO's can be assessed. `Satisfactory performance of the THMACO surfaced pavements would be no failures in this section in the next three years, and that it perform comparably to the 9-inch CRCP after 8 years with respect to rideability and number of failures requiring repair. After eight to ten years (2011 to 2013), provided there are no significant increases in traffic volume, we would expect replacement of the wearing surface. These expectations are based on comparing the performance of the THMACO section to the 9-inch CRCP, and current asphalt pavement service lives.

CONCLUSIONS

Thin hot mix asphalt concrete overlays (THMACO's) have been used in North Carolina and Virginia since 1997 to provide a new wearing surface for concrete and asphalt pavements. North Carolina Department of Transportation (NCDOT) was applying the THMACO's to obtain another 6 to 10 years of service life from the existing pavements depending on the project. Some of NCDOT's earlier applications are approaching this expected service life and appear to be performing well. On SR 164 a THMACO was applied to an 8-inch CRCP section after extensive patching, sealing of open joints, and retrofitting of edge drains. The adjacent 9-inch CRCP was also patched and open joints sealed, however, edge drains and a THMACO were not constructed on the 9-inch CRCP section. The THMACO has improved the rideability of the 8-inch CRCP and there were no failures in this section after one winter. However, the success of the THMACO will be judged by its performance in future years. For comparison purposes, the future performance of the THMACO should be compared to that of the 9-inch CRCP that will receive similar traffic and environmental conditions. As a minimum, we would expect no failures in the THMACO section before 2006 (three years) and replacement of the surface not until after 2011 (eight years).

APPENDIX

FIGURES

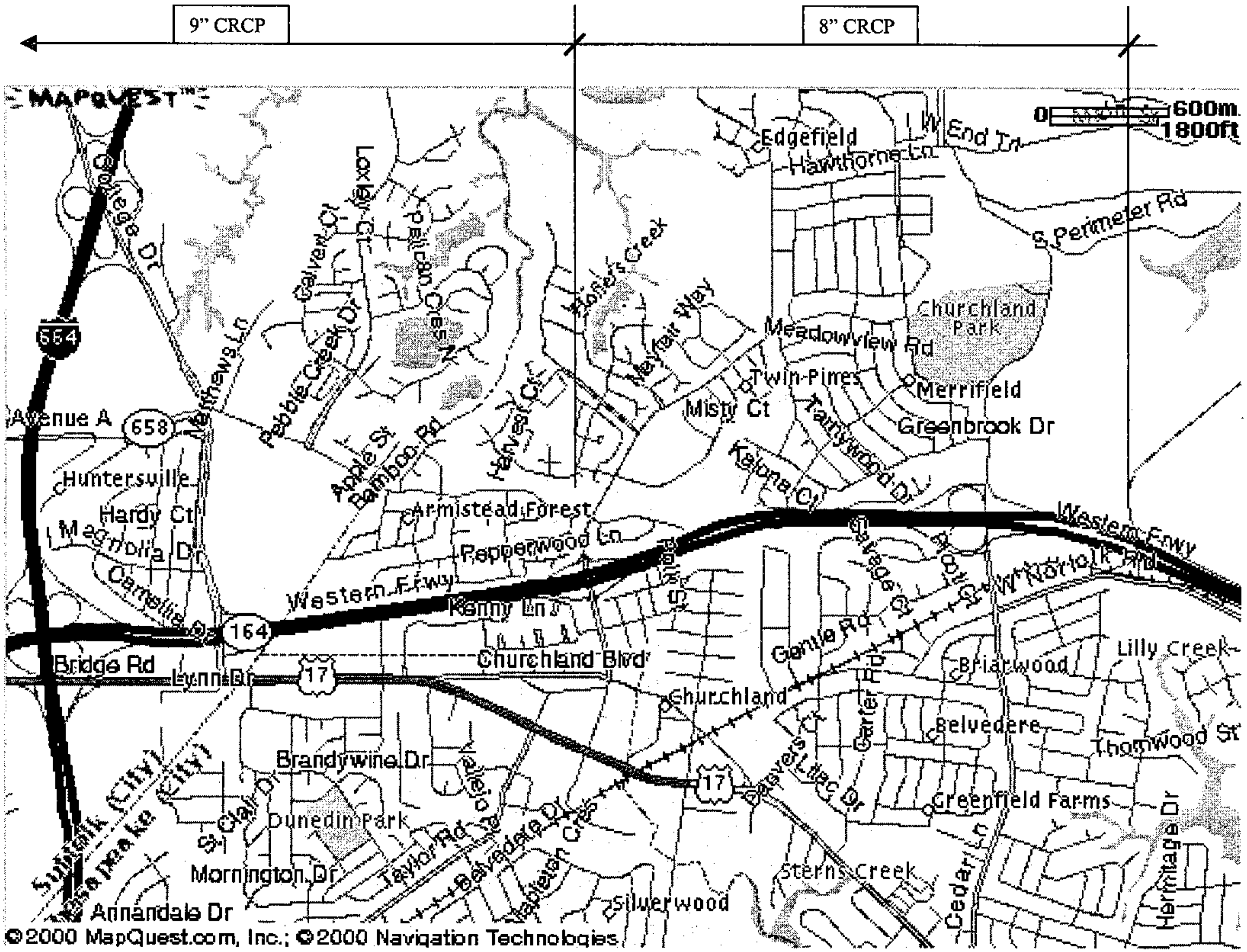
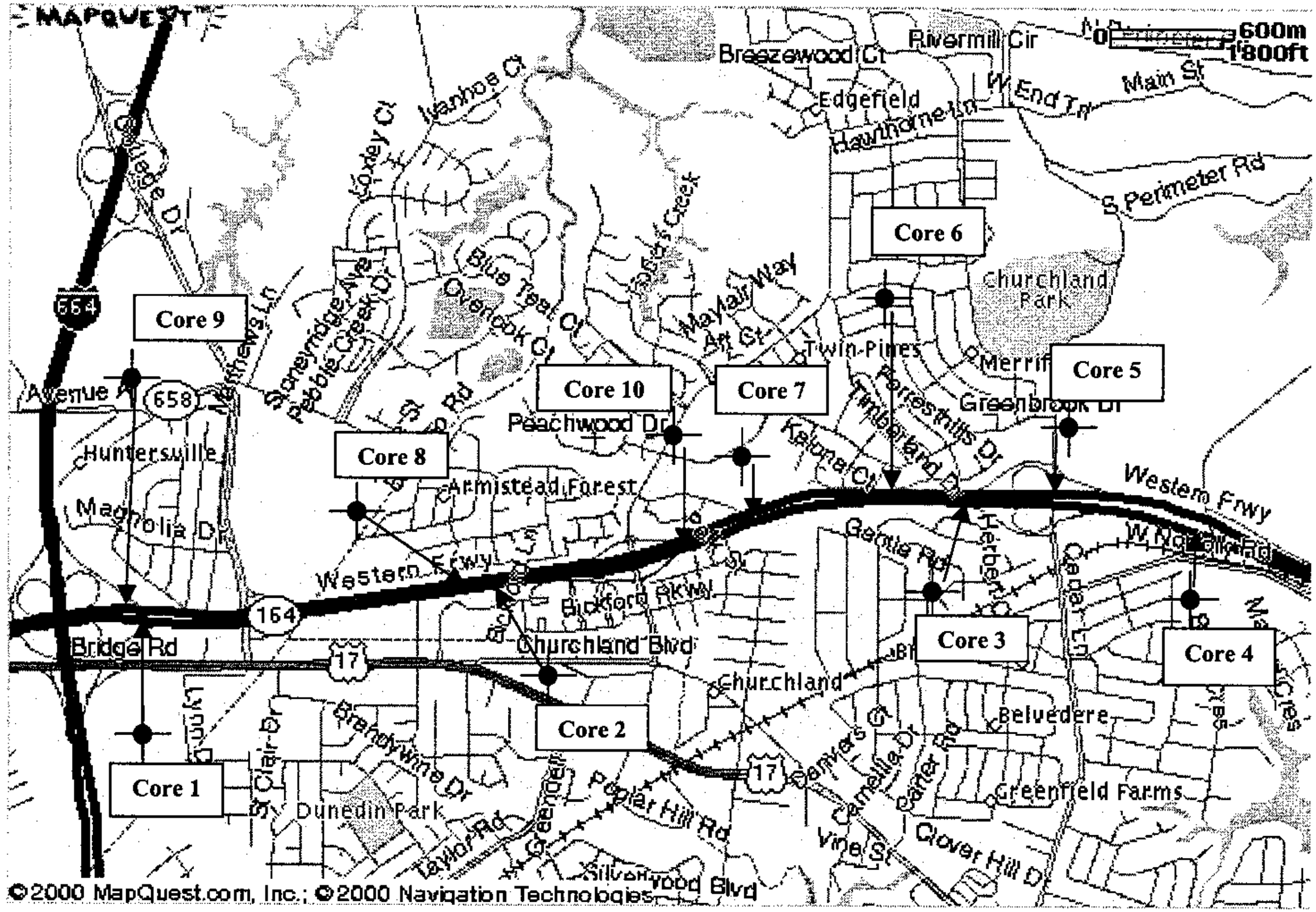


Figure 1 Project Location	Drawn: T.R. Tate Date: 7/31/2001	Pavement Design & Evaluation Materials Division Virginia Department of Transportation	Pavement Evaluation SR 164 – Western Freeway Suffolk & Portsmouth, Virginia



LEGEND

C-1 Approximate Core/Boring Location

Figure 2 Core/Soil Test Boring Location Plan	Drawn: T.R. Tate Date: 7/22/2001	Pavement Design & Evaluation Materials Division Virginia Department of Transportation	Pavement Evaluation SR 164 – Western Freeway Suffolk & Portsmouth, Virginia

TABLES

TABLE 1
Summary of Concrete and Soil Cement Core Information
State Route 164 EBL & WBL, MP 1.07 to 2.86
Portsmouth & Suffolk, Virginia
July 30, 2004

Core No.	Location			Concrete			Soil Cement	
	Co.	Dir.	MP	Thickness, inches	Specified Thickness, inches	Compressive Strength, psi	Thickness, inches	Compressive Strength, psi
1	61	EB	0.92	9.5	9	5,750	4.0	-
2	64	EB	0.63	9.5	9	-	4.5	-
3	64	EB	2.06	8.5	8	8,380	9.0	1,230
4	64	EB	2.69	7.6	8	-	5.0	-
5	64	WB	2.17	8.9	8	6,500	4.5	-
6	64	WB	1.61	8.6	8	5,750	4.0	-
7	64	WB	1.31	7.8	8	-	4.0	-
8	64	WB	0.40	9.3	9	6,200	7.5	1,490
9	64	WB	0.87	8.6	9	-	5.5	-
10	64	WB	1.29	8.0	8	-	6.5	1,300
Average				8.2	8	6,516	5.5	1,340
				9.2	9			

Notes: Specified thickness of soil cement, 6 inches.
Typically no corrosion noted on reinforcing encountered.
Counties: 61 – Suffolk, 64 - Portsmouth