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EVALUATION OF THE URETEK METHOD® OF PAVEMENT LIFTING

FINAL REPORT

WISCONSIN MATERIALS MANAGEMENT DEPARTMENT OF TRANSPORTATION

APRIL 2007

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16. Abstract

Several methods exist for the correction of differential settlement of concrete pavement, such as slab jacking, HMA overlay, and slab replacement. The Wisconsin Department of Transportation (WisDOT) elected to investigate The URETEK Method® of pavement lifting to adjust the elevation of concrete pavement bridge approach slabs. A five-year project was initiated in coordination with WisDOT's Southwest Region to monitor the functionality of The URETEK Method® and the stability of the slabs after pavement lifting at two test sites. Field surveys were conducted for five and one-half years after construction to monitor slab settlement and crack growth.

The URETEK Method® construction process took longer than anticipated and used two to five times more material than initially estimated by the contractor. Cost of the process was based on the quantity of material used, and therefore The URETEK Method® was less cost effective than initially predicted. Pavement ride quality was improved at both test sites. Hairline cracks developed in the approach slabs after six months, and slight slab settlement was noted during informal ride quality surveys. However, ride quality remained at a comfortable level. Continued monitoring is warranted to determine if the hairline cracks result in a decrease in pavement service life.

17. Key Words concrete bridge approach slabs, concrete pavement restoration (CPR), concrete pavement approach slabs, pavement lifting, polyurethane, slab jacking, The URETEK Method®	**18. Distribution Statement** Approved for public release

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Evaluation of The URETEK Method®
of Pavement Lifting

WisDOT Research Study # WI-01-07

FINAL REPORT
Report # WI-02-07

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1. INTRODUCTION

This study was initiated by the Wisconsin Department of Transportation (WisDOT) in June of 2001 to test The URETEK Method® of pavement lifting. The objective of this study was to evaluate The URETEK Method® and the effectiveness of using the URETEK 486 product to reestablish Portland cement concrete (PCC) pavement elevations. Concrete pavement leading bridge approach slabs were of particular interest.

The URETEK Method® is a process that employs expansive high-density polyurethane foam to lift, realign, and under-seal concrete slabs, and to fill voids between the pavement and the base or subgrade. During the process, a liquid polyurethane component is injected using small holes drilled through the concrete. As the polyurethane expands, voids are filled, and pressure is exerted on a limited (eight- to ten-foot diameter) area of the affected slab. Multiple-pattern drilled injection locations are used to re-support and accurately realign the elevation of the slab. According to the manufacturer, the polyurethane rapidly cures into a strong and stable replacement base material.[1]

2. HISTORY OF THE URETEK METHOD®

In 1975, URETEK Finland began working with special formulations of high-density polyurethane. From a wide cross-section of possible blended characteristics, a limited number of specialized urethane components were selected to create URETEK 486, the brand name chosen for this unique system of lifting and under-sealing concrete pavement. URETEK later acquired a patent for The URETEK Method® in the United States, Canada and Sweden. In 1988, URETEK USA, Inc. was given exclusive license rights to sell this product and method in the United States and Mexico.[1]

2.1 National Perspective

The URETEK Method® of pavement lifting has been employed in numerous locations throughout the country, and this process has been the focus of several state research studies. In several cases, motivation to evaluate The URETEK Method® of pavement lifting was due to previous problems encountered with mud jacking and grout injection. Difficulties included slab weakening due to large access holes, limited spreading of grout into voids, and lack of a standard procedural process.[2,3] The need for a cost-effective slab-raising method was cited as motivation for another test project.[4] The results of the research studies were mixed; some reported noticeable improvement in ride quality after a faulted PCC slab was raised, while other results indicated that The URETEK Method® provided only temporary improvement and may also have been the cause of cracking in the adjusted slabs.

A research effort conducted by the Louisiana Department of Transportation yielded positive results after two bridge approach slabs were lifted and monitored for several years. After the injection procedure was complete, the international roughness index (IRI) was reduced 33% to 57%. The approach slabs were still in good condition after four years, and no additional slab faulting had occurred. In addition, methods investigated to determine in advance the amount of URETEK material that would be necessary for a pavement lifting project proved to be successful.[5]

A URETEK evaluation project that focused primarily on raising bridge approach slabs was conducted in Oklahoma in 1994. Pavement lifting was conducted in six divisions around the state, and in three of these divisions, cracking occurred during or just after the injection process. In one case, a PCC slab broke in half during injection.[2] Data from subsequent monitoring of the Oklahoma test locations was not available.

An evaluation of The URETEK Method® conducted by the Michigan Department of Transportation concluded that the process "did raise the pavement and provided a temporary increase in base stability." There was also an initial improvement in ride quality. However, the ride values reverted back to pre-construction values after just one year.[4]

In June 2000, the state of Oregon carried out a bridge and approach slab lifting and re-aligning project using The URETEK Method®. After construction, the slabs were checked for cracking and settlement every three to six months for two years. Three PCC slabs were raised approximately 3.5 inches using a total of 4,650 pounds of URETEK material. It was noted in the three-month crack and elevation survey that cracking and settlement had occurred in the slabs. In addition, after two years it was noted that several injection holes had not been properly sealed and experienced raveling during that time. Injection holes that had been properly sealed were performing adequately.[3] The Oregon Department of Transportation researchers also investigated the ability of the URETEK material to penetrate small holes when extensive void filling in the sub-base would be necessary to provide pavement lift. The material was able to penetrate holes with diameters as small as 0.125 inches.[3]

2.2 Manufacturer-listed Advantages

According to the manufacturer, the advantages of using URETEK 486 and The URETEK Method® are:[1]

1. URETEK 486 is guaranteed for ten years against any significant shrinkage or deterioration.
2. From set-up through cure, implementation time for The URETEK Method® is short compared to other repair techniques.
3. The material has high compressive and tensile strength and will not erode or consolidate. URETEK 486 expands to up to 20 times its volume after injection, thoroughly filling voids.
4. To employ The URETEK Method®, relatively few small-diameter (5/8-inch) holes are required. Slab-bottom breakout is therefore avoided at the holes, and less slab weakening occurs than with mud-jacking.
5. This slab raising process is more controllable, accurate and efficient than other methods.
6. URETEK 486 expands into cracks, providing a seal to help prevent water infiltration.
7. The material is lightweight, providing little additional overburden weight.
8. Since the material is not affected by subsurface temperatures ranging from 0° to 100ºF, this work can extend into colder seasons. However, the process is limited by the presence of frozen subgrades.
9. All equipment and material can be carried in one URETEK truck and trailer. A crew of three is required to perform the work.

3. CURRENT METHODS AND PRACTICES

Several methods for differential settlement correction of PCC pavement are currently available. Discussion of some familiar methods is presented below.

3.1 Mud-Jacking

Mud-jacking is a grouting process used to lift concrete slabs and structures back to near-original levels. Grouting material is injected into two- to three-inch access holes drilled in the slab, and the grout fills voids in the subgrade. One day of work is usually required, and the pavement can be reopened to traffic immediately after completion of the process. For realignment of two to four leading approach slabs to a bridge, mud-jacking typically costs $3000 for a full day of work, including materials and labor. This cost translates into $40 to $60 per square yard of pavement. The process is environmentally friendly because only cementitious grouts are used. However, several lanes of traffic must be closed at once, and if voids remain, the pavement can settle and break. In addition, the access holes are relatively large and must be filled.

3.2 Hot Mix Asphalt Overlays

Hot mix asphalt (HMA) overlays are placed over existing concrete slabs. After an overlay is compacted, the finished surface matches the adjacent slabs, resulting in a smoother ride. The cost of a 1.5-inch thick HMA overlay, including milling of the existing pavement, is between $45 and $65 per square yard. The pavement may be used on the day of completion. This method requires regular crack sealing, which adds to the cost of the overlay during its total service life. Additionally, there are requirements for minimum lift thickness of an HMA overlay. In the case of concrete pavement bridge approach slabs, the settlement would have to be significant enough so that the final elevations after placement of an overlay would not cause a bump and result in a rough ride.

3.3 Slab Replacement

Slab replacement is the removal of old concrete and placement of new concrete. First, the existing concrete slab is removed. Crushed aggregate base course is then placed in the open excavation to fill the existing voids. The base course is leveled and compacted. Dowel bars and tie bars are inserted, and a replacement concrete slab is cast in place. The entire process, from the time a slab is removed to the time it is opened to traffic, often takes several days. The total cost of slab replacement varies depending on the type of concrete used and thickness of the pavement, but is at minimum $425 per square yard for a 12-inch thick slab.

4. DESCRIPTION OF THE URETEK METHOD®

4.1 Material

URETEK 486 is water blown, high-density polyurethane. According to the manufacturer, the URETEK 486 polyurethane foam system will have a free-rise density of 3.0 to 3.2 lb/ft^3, with a minimum compressive strength of 40 psi. When the foam expands under pressure, the resulting density is higher than the free-rise density. Compressive strength is a function of the density of the foam material, so the material produced during the lifting process normally has a higher compressive strength than foam produced without restriction (free rise).[1]

According to the manufacturer's literature, polyurethane has good resistance to chemicals, solvents, greases, and oils. Rigid polyurethane foams swell in the presence of oxygen but after drying regain their original properties. They are stable in water solutions of common detergents, salts, acids, and bases. Strong acids and bases will cause chemical degradation. Solvents that contain oxygen can damage the foam, but the foam has limited solubility in these chemicals.[1]

Rigid polyurethane foam will not mold or decay. Insects and rodents find no nutritional value in the foam. If exposed to sunlight, the foam will turn yellow, and its surface will become brittle.[1]

4.2 Cost

The installation cost of The URETEK Method® is determined according to the actual amount of polyurethane material used. In 2001, the price that was typically charged for labor, equipment use, and material was $7 per pound of foam used. (It is estimated that seven pounds of foam is required per cubic foot of filling.) For sites in this study, however, the contractor charged WisDOT a discounted demonstration rate. At the time that this report was published, a company representative indicated that the cost of the URETEK injection process had become more economical and would be approximately $6 per pound of foam used.[6]

4.3 Equipment

The minimum required equipment consists of:

1. A pneumatic drill and an electric drill capable of drilling 5/8-inch diameter holes.
2. A truck-mounted pumping unit capable of injecting the high-density polyurethane foam between the concrete pavement and the aggregate base course. The pumping unit must also have sufficient precision to raise the pavement at a controlled rate.
3. A laser leveling unit to ensure that the concrete is raised to an even plane and to the required elevations.

4.4 Construction Process

Prior to foam injection, the site is evaluated to determine where the pavement needs to be raised. A horizontal string line is set to assist with elevation measurements. Several station locations are established, and elevation is monitored at these stations throughout the process. The contractor determines locations for a series of injection holes. The 5/8-inch holes are then drilled through the concrete.

After drilling of the 5/8-inch holes, the high-density polyurethane foam is injected under the slab through the holes. The foam expands and hardens, creating the necessary lifting forces. The pumping unit provides a regular rate of injection, and the amount of pavement rise can be controlled. After the nozzle is removed from the hole, excess polyurethane material is cleared from the area, and the hole is sealed with a non-expansive cementitious grout. The foam material reaches 90% of its maximum compressive strength after 15 minutes.[1]

Final elevations are measured when injection is complete. The contractor states that final elevations shall be within 1/4-inch of the elevations initially proposed. See Figures B-1 through B-4 in Appendix B for construction photos.

5. PROJECT WORK

The URETEK Method® of pavement lifting was performed at two WisDOT test sites. These sites and the work performed at each are described below.

5.1 Test Site #1: I-39, Columbia County

Test Site #1 was located in the WisDOT Southwest Region on I-39 southbound, at the interchange of I-39 and USH 78. The test slabs were located in the leading approach to the bridge over USH 78 (see Appendix A, Figures A-1 and A-2). The slab lifting work was performed in both the passing and driving lanes. The URETEK treatment was applied to a total of four concrete slabs in the bridge approach (two in each lane). The slabs had varying lengths, but were each twelve feet wide and twelve inches thick. A noticeable dip had developed in these slabs approximately 15 feet ahead of the bridge joint, and pavement lifting in this area was necessary to improve ride and safety in both lanes. Elevation measurements were taken prior to and immediately after the pavement lifting process. At each station, measurements were taken at the left and right edges of the slabs.

Work on the driving lane was performed while the passing lane was open to traffic, and vice versa. Columbia County forces were in charge of traffic control. The contractor started work at 7:00 a.m., Thursday, June 21, 2001 and expected to finish slab lifting in both lanes by 2:00 p.m. that afternoon. It was estimated that 600 pounds of foam material would be used to complete lifting in both the driving and passing lanes.

5.1.1 Work in the Passing Lane

The URETEK Method® was first applied to the two slabs in the passing lane. The slabs were to be lifted by varying amounts, depending on the location. The maximum required elevation change was 1-1/2 inches between Stations 30 and 40 at the right edge of the passing lane slabs. Locations for Stations 0 to 60 were indicated by paint dots placed at ten-foot increments on the pavement. Initial elevation readings were taken at these locations. These were not drill locations, but were used for elevation reference only. The locations to be drilled were subsequently set and marked (Figure 1). String lines were set up on both the left and right sides of the lanes and were used to monitor the slab rise as material was injected. One end of the line was secured before Station 0, and the other end was secured after Joint 3 (Figure 1).

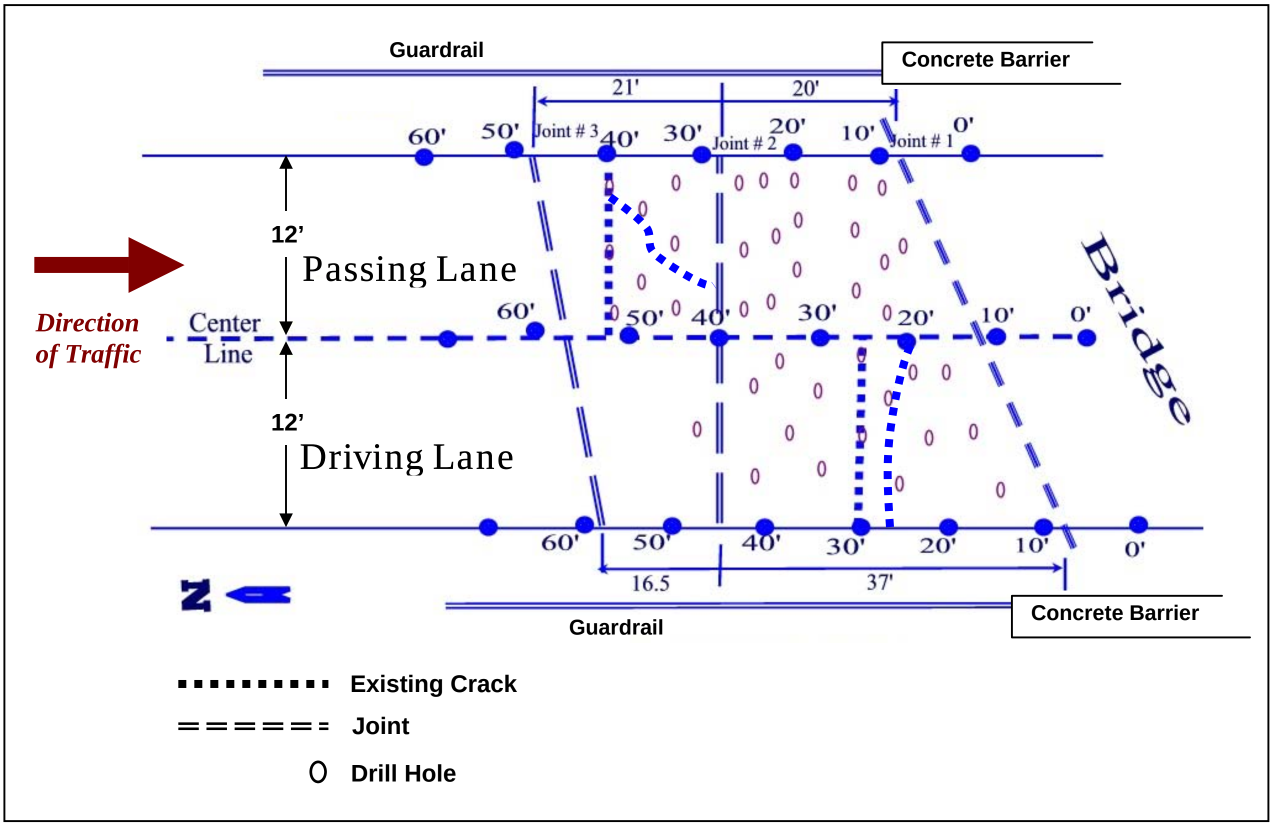

Figure 1 Station and Drill Hole Layout, I-39 Southbound
(Figure not to scale)

Holes of 5/8-inch diameter were drilled through the twelve-inch thick concrete slabs. This was a time-consuming process. Occasionally, the drill would hit steel rebar, causing the drill head to become dull. The drill bit would then have to be replaced. A total of 20 holes were initially marked to be drilled, and after the drill operator had completed drilling of six holes, the URETEK injection operator began to fill the holes with the foam material.

The first filled hole was located on the left side of the passing lane, at Station 20. Immediately following injection, material began to seep out of the joint between the slab and the shoulder. Shortly thereafter, water began to seep out. Based upon the large amount of water that was subsequently displaced through the joints between the slabs, the contractor concluded that numerous voids were present under the slab.

By 8:20 a.m., the slab had been raised by one-quarter of an inch. The slab continued to rise at a slow rate. The voids in the area between Joints 1 and 2 were filled, followed by the area between Joints 2 and 3. There was no predetermined limit on elapsed time of placement or quantity of material injected in the initial holes. However, if no progress was made within a certain radius of an initial injection site, additional injection holes were drilled. After two and one half hours the slab had been raised by only one-half of an inch; therefore, four additional holes were drilled in this area.

At 11:30 a.m., it was observed that the corner of the slab at Joint 1 (near the left edge of the passing lane) was 1/2-inch higher than the corner of the bridge deck. This eventually leveled off after injecting material under the shoulder. After filling of all holes and raising of the shoulder, the slab was lifted by 1-1/4 inches (1/4-inch short of the intended 1-1/2 inches).

The amount of material used for lifting in the passing lane was 1,900 pounds. This amount already exceeded the initial contractor estimate of 600 pounds of material for the both the passing and driving lanes. After both lanes had been lifted and the entire project was complete, the contractor mentioned that it is possible to use ground penetrating radar (GPR) to more accurately estimate the quantity of URETEK material needed – a service that would normally be performed at no additional charge. However, the contractor did not have access to the GPR equipment at the time the estimate was made for this project.

At 1:00 p.m., the contractor decided to begin work in the driving lane. The contractor expected that, while injecting material under the driving lane, material would continue to flow under the passing lane and raise the slab the additional 1/4-inch that was needed to achieve the intended final elevation. As the contractor expected, the final elevation change in the middle of the passing lane slabs (i.e. at station 30) was very close to the intended 1-1/2 inch change. Table 1 shows the final changes in elevation in the passing lane. These changes were within 1/4- to 1/2-inch of the target elevation changes.

Station	Left Edge of Slab	Right Edge of Slab
0	0.00	0.00
10	0.72	0.00
20	0.48	0.84
30	0.48	1.44
40	0.24	1.20
50	0.12	0.60
60	0.00	0.24

Table 1. Final Elevation Changes in the Passing Lane, I-39 Southbound, inches

5.1.2 Work in the Driving Lane

At 2:00 p.m., the lane change to direct traffic into the passing lane was complete, and work began on the driving lane. The maximum required elevation change of the driving lane slabs was 1-1/2 inches at Station 30 at the left edge of slab. The same set-up and application procedures were used as for the passing lane. The string lines were set and measurements were made for the positioning of the stations. After two hours of injecting material, the right edge of the slab was raised by 1/4-inch, and the left edge of the slab had risen 1/2-inch.

After losing an hour due to rain, the project was complete at 6:30 p.m., four and one-half hours later than the estimated time for completion. When complete, the left edge of the driving lane slab (i.e. at the centerline between the driving and passing lanes) was raised by approximately 1 inch between stations 20 and 40. The right edge of the lane was raised by approximately 1/2-inch. Table 2 shows the final changes in elevation in the driving lane. These changes were within 1/2-inch of the target elevation changes.

Station	Left Edge of Slab	Right Edge of Slab
0	0.00	--
10	0.00	0.00
20	0.96	0.00
30	1.20	0.60
40	0.84	0.36
50	0.48	0.36
60	0.00	0.24

Table 2. Final Elevation Changes in the Driving Lane, I-39 Southbound, inches

The actual time to completion and the amount of materials used both exceeded the initial estimate given by the contractor. The time was exceeded by more than three hours, not including the time lost due to rain. The total amount of material used in both lanes was 3,240 pounds. This amount was more than five times the initial estimate of 600 pounds.

It was intended that three sites receive the slab lifting treatment in this research study: one in Columbia County, and two in Dane County. After completion of work at the first site, however, state officials eliminated one of the Dane County sites because of the excessive cost of the first project.

5.2 Test Site #2: USH 12, Dane County

Test Site #2 was located in the WisDOT Southwest Region on USH 12 westbound, in the City of Middleton, in Dane County (see Appendix A, Figures A-1 and A-3). The work was performed on the leading approach slabs to the bridge over University Ave, in the left and center lanes of the three-lane highway. The URETEK treatment was applied to four slabs in the bridge approach.

The contractor started work at 9:50 a.m., Friday, June 22, 2001 and expected to finish by 2:00 p.m. on the same day. The slabs were twelve feet wide, twelve inches thick, and had varying lengths (Figure 2). The URETEK, Inc. contractors estimated that 550 pounds of material would be required to adjust the slabs. As at Test Site #1, GPR was not employed to determine a more accurate estimate. Dane County forces were in charge of traffic control for the lane closures.

5.2.1 Work in Both Lanes

Because the roadway consisted of three lanes, work could be performed simultaneously on all four slabs in the left and center lanes, leaving the right driving lane open to traffic. Measurements were taken for the positioning of Station 0, and subsequent stations were marked every 10 feet. String lines were set at the left edge of the left lane, at the centerline between the left and center lanes, and at the right edge of the center lane. The north ends of all string lines were secured before Station 10, and the south ends were secured after Joint 3 (Figure 2). Setting string lines in three locations provided a good visual idea of the lifting that needed to be performed, because vertical gaps between the pavement and string lines were visible at several locations. The largest vertical gaps were located at Station 30 at the far left string line location, at Station 20 at the center string line location, and at Station 10 at the right string line location. These vertical gaps indicated that the highest level of pavement lifting was required at these locations.

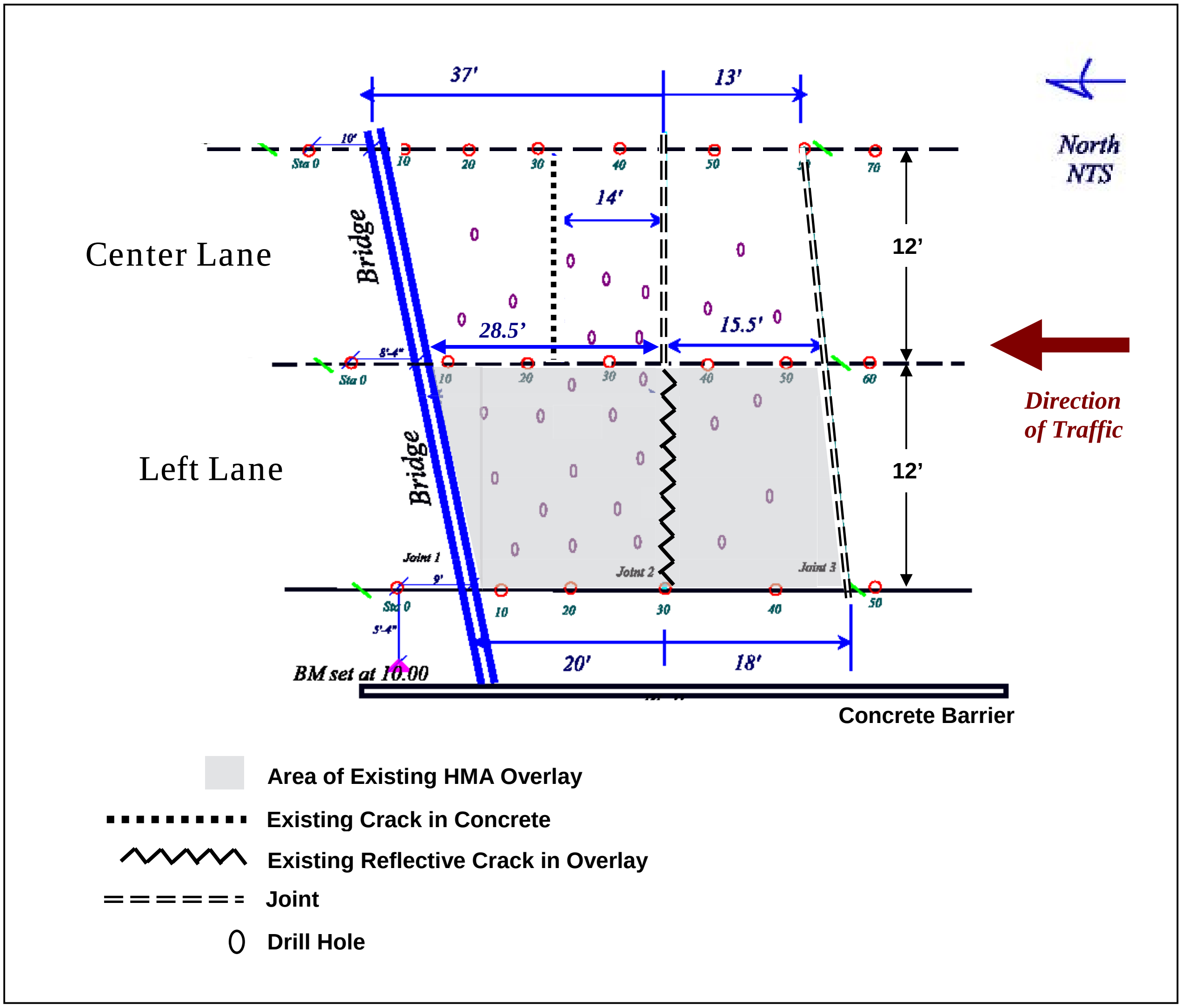

Figure 2 Station and Drill Hole Layout, USH 12 Westbound
(Figure not to scale)

An advantage at this test site was that Dane County forces were available to help with the drilling. The contractor and Dane County forces each had their own drills, speeding the drilling and thus the injection processes. In an initial effort to improve ride in the left lane, the two left lane approach slabs had been overlayed with HMA pavement less than one year earlier. The county opted to leave the overlay in place during the slab lifting process so that grooves in the original PCC pavement due to the grinding operation prior to the HMA overlay would not be exposed. To ensure that the URETEK material did not flow between the overlay and the concrete, a 1/2-inch diameter extension attachment was used to inject the material. The drill hole was 5/8-inch in diameter, so the attachment was wrapped in paper to ensure that no material leaked out.

The project ran smoothly with no delays. By 1:00 p.m., the slabs were raised to satisfactory elevations. Very little material was lost at the joints. By 1:30 p.m., the drill holes were being filled with caulk, the clean up process was underway, and the new elevations were being recorded. The project was finished on time by 2:00 p.m. The left edge elevations improved by just over 1/2-inch, the center elevations by approximately 1 inch, and the right edge elevations by 1/4-inch (Table 3). These changes were within acceptable limits of the target elevation changes. These changes took place at the stations where the aforementioned large vertical gaps existed between the string lines and the pavement. However, 1,043 pounds of material had been used in the lifting process, almost double the initial estimate of 550 pounds. This underestimation reiterates the need for a GPR analysis prior to pavement lifting with URETEK material.

Station	Left Edge of Left Lane Slab	Centerline Between Left and Center Lanes	Right Edge of Center Lane Slab
0	0.00	0.00	0.00
10	0.36	0.48	0.24
20	0.60	0.96	0.12
30	0.60	0.96	0.00
40	0.00	0.60	0.00
50	0.00	0.12	0.24
60	--	0.00	0.00
70	--	--	0.00

Table 3. Final Elevation Changes in Left and Center Lanes, USH 12 Westbound, inches

6. COST COMPARISON

A cost comparison between The URETEK Method® and other slab faulting repair methods is shown in Table 4 for the two test sites. Costs for The URETEK Method® are based on the current quoted rate of $6 per pound of material. While other important factors, such as expected service life, must be considered in the selection of a repair method, this table provides a rough comparison of initial cost. Times to completion are based on total time that the pavement would be closed to traffic.

For the tests sites in this study, full slab replacement would have been the most costly repair method, and mud-jacking the least expensive. Cost of The URETEK Method® fell in the middle, with a cost per square yard higher than an HMA overlay but lower than slab replacement. For the I-39 project, the relatively high cost of The URETEK Method® was due to the large volume of voids beneath the slab that required filling. On USH 12, the cost per square yard for The URETEK Method® was less than half of that for the I-39 work. At both test sites, the time to completion for the foam injection was the lowest of all repair methods.

Location	Method	Total Cost	Cost per yd^2	Days to Complete
I-39 ($80\ yd^2$)	URETEK	$19,440	$243	0.75
	Slab Replacement	$34,000	$425	3
	HMA Overlay	$3,630	$45	1
	Mud-jacking	$3,000	$38	1
USH 14 ($53.3\ yd^2$)	URETEK	$6,260	$117	0.5
	Slab Replacement	$22,670	$425	3
	HMA Overlay	$3,375	$63	1
	Mud-jacking	$3,000	$56	1

Table 4. Cost Comparison for Four Slab Faulting Repair Methods

7. POST-CONSTRUCTION EVALUATION

Semi-regular post-construction surveys of the two projects were conducted at six months, one year, two years, three years, and five and one half years after the pavement lifting process. These surveys were conducted to evaluate the serviceability of the approach slabs. The survey consisted of a visual inspection and a qualitative evaluation of the pavement's ride quality. Official International Ride Index (IRI) measurements were not taken.

7.1 Test Site #1: I-39 Southbound

After six months, four fine transverse cracks had developed in the test slabs. Two of the cracks were in the driving lane (one in each slab), and two were in the passing lane (both in the first slab). At five and one half years after lifting, an additional crack had formed in the first slab of the driving lane (Figure 3).

It is likely that the new cracks induced in the test slabs were a result of the pavement lifting process. The cracks tended to occur between injection hole locations, and cracks occasionally spread through drill holes as well. (See Figures B-5 through B-7 in Appendix B) It is hypothesized that injection and expansion of the foam material exerted additional stresses in the slab, which resulted in the transverse cracking noted during the visual inspections.

Approach slabs to an overpass approximately 750 feet north of the test slabs were checked for cracking at five and one half years. These approach slabs had not been adjusted with The URETEK Method®. One large crack was present in one of the non-test slabs; this was assumed to be a construction crack similar to the initial cracks that were present in the test slabs. Fine cracks were not present in the non-test slabs. This supports the theory that the fine cracking that occurred in the test slabs was a result of the pavement lifting process.

With the exception of the cracks that developed, the pavement continued to perform well after utilization of The URETEK Method®. In terms of ride quality, a slight dip developed in the right lane just prior to the bridge joint. This indicates resettlement of the test slab. However, after five and one half years, the ride quality was still better than it was prior to slab lifting.

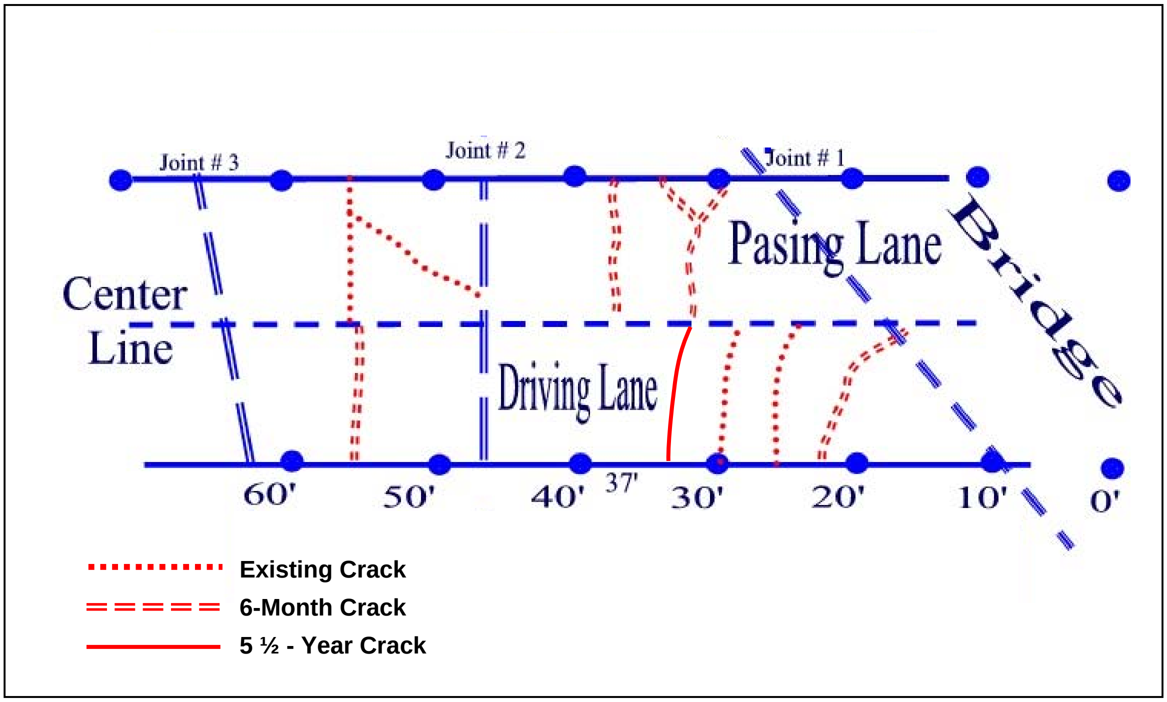

Figure 3. Location of Existing and New Cracks, I-39 Southbound

7.2 Test Site #2: USH 12 Westbound

Crack surveys at 6 months and one and two years found that no new cracks had developed in the approach slabs. However, the HMA overlay which was present at the time of pavement lifting concealed any fine cracks that may have developed in the left lane. The ride quality remained adequate. During the 2004 and 2005 construction seasons, USH 12 was reconstructed in this area, and the pavement test slabs were removed and replaced. Surveys for cracks and ride quality were not continued.

8. CONCLUSIONS

1. Overall, the slab lifting process was successful at both test sites. The slabs were raised to the desired elevation, to within 1/4 to1/2-inch of the intended final elevation. Safety and ride quality were improved on the approach slabs.
2. There were substantial shortcomings in the estimation of material required for the lifting process. The actual amount of material used at Test Site #1 was five times greater than estimated. Twice the estimated amount of material was required at Test Site #2. These underestimations resulted in higher than anticipated costs.
3. A method such as ground penetrating radar (GPR) should be used to better estimate the nature and size of the voids underneath the pavement. This will result in a more accurate estimation of the material quantities needed to lift the slab and fill the voids. An acceptable material estimation should be within 10-25% of what is required.
4. The URETEK Method® may not be cost effective for pavement lifting projects that involve filling of large voids, as evidenced at Test Site #1. Additional time is also required when void-filling is necessary.
5. The slabs at Test Site #1 developed fine cracks within six months of pavement lifting. These cracks, which are likely due to stresses induced by pavement lifting, may reduce the service life of the slabs. Fine cracks were also noted in pavement tested in other states' research studies.[2,3]
6. Minor settlement of the approach slabs occurred at Test Site #1 after one year in service, as indicated by a small dip noted during informal ride quality surveys.

9. RECOMMENDATIONS

1. It is recommended that The URETEK Method® be used only for the lifting of an approach slab and not for void filling. Void filling should be performed using other methods such as concrete slurry. A large amount of fill material is potentially required when voids are present, and use of the URETEK material is not cost effective in that case.
2. The URETEK Method® is practical for use on high traffic volume highways where lane closure time is critical.
3. It is not recommended that this method be used to lift a slab that is sagging in the middle. This could lead to cracking of the slab, and consequently reduction of the slab service life. In this situation, slab replacement or and HMA overlay may be better solutions.
4. Use of ground penetrating radar (GPR) is recommended for an accurate estimate of material required for lifting.

10. REFERENCES

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3. Soltesz, S., "Injected Polyurethane Slab Jacking," *Final Report*, Report Number FHWA-OR-RD-02-19, Oregon Department of Transportation Research Group, Jun. 2002.
4. Opland, W. H., and V. T. Barnhart, "Evaluation of The URETEK Method for Pavement Undersealing," Research Report Number R-1340, Michigan Department of Transportation in Cooperation with the U.S. Department of Transportation, Aug. 1995.
5. Gaspard, K., and M. Morvant, "Assessment of the Uretek Process on Continuously Reinforced Concrete Pavement, Jointed Concrete Pavement, and Bridge Approach Slabs," *Technical Assistance Report*, Report Number 03-2TA, Louisiana Department of Transportation and Development, Louisiana Transportation Research Center, Dec. 2004.
6. Sickels, D. Regional URETEK USA Representative. URETEK USA. Electronic Mail. Jan. 12, 2007.

APPENDIX A Test Site Locations

Figure A-1. Location of Test Sites #1 and #2

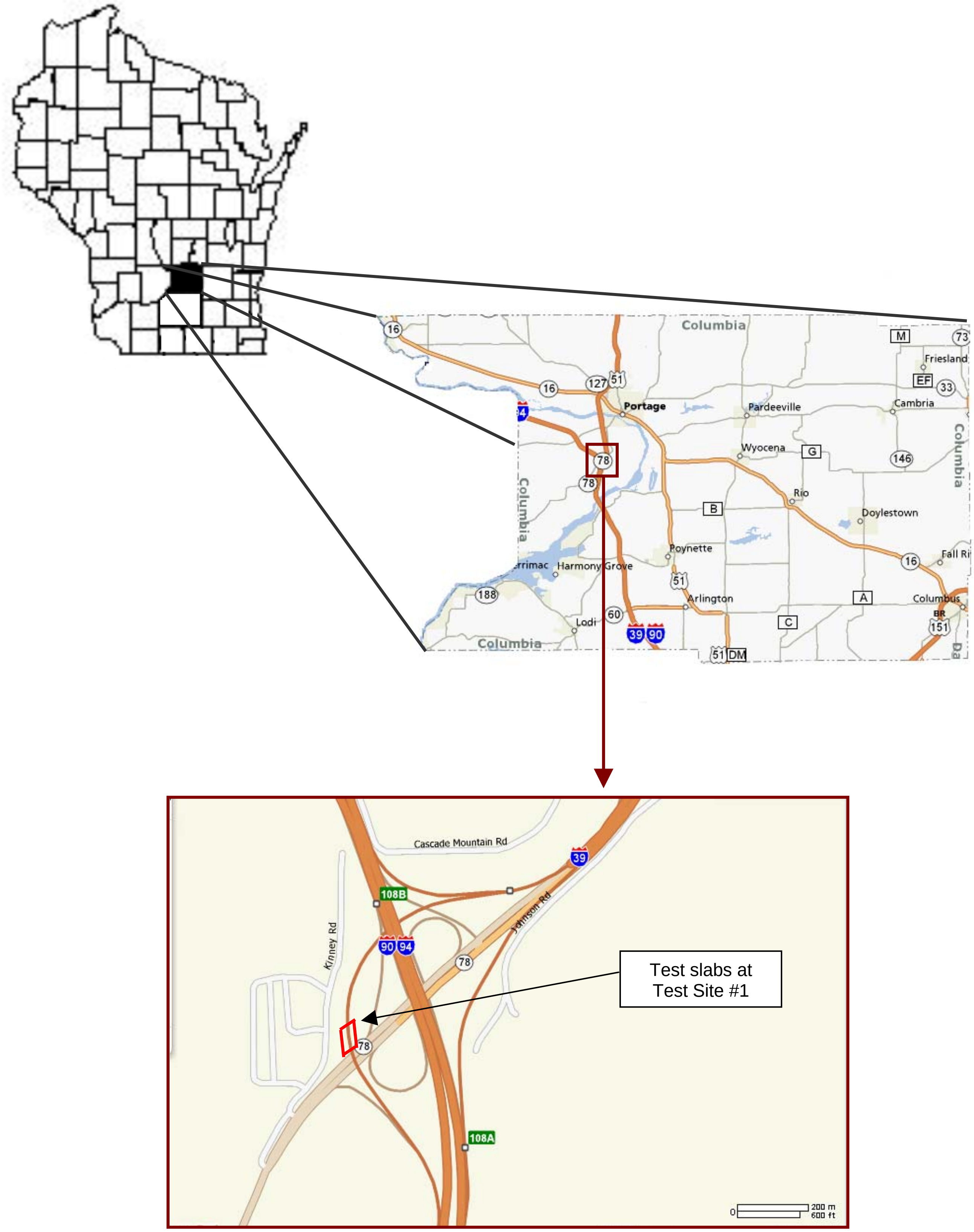

Figure A-2. Location of Test Slabs at Test Site #1, Columbia County

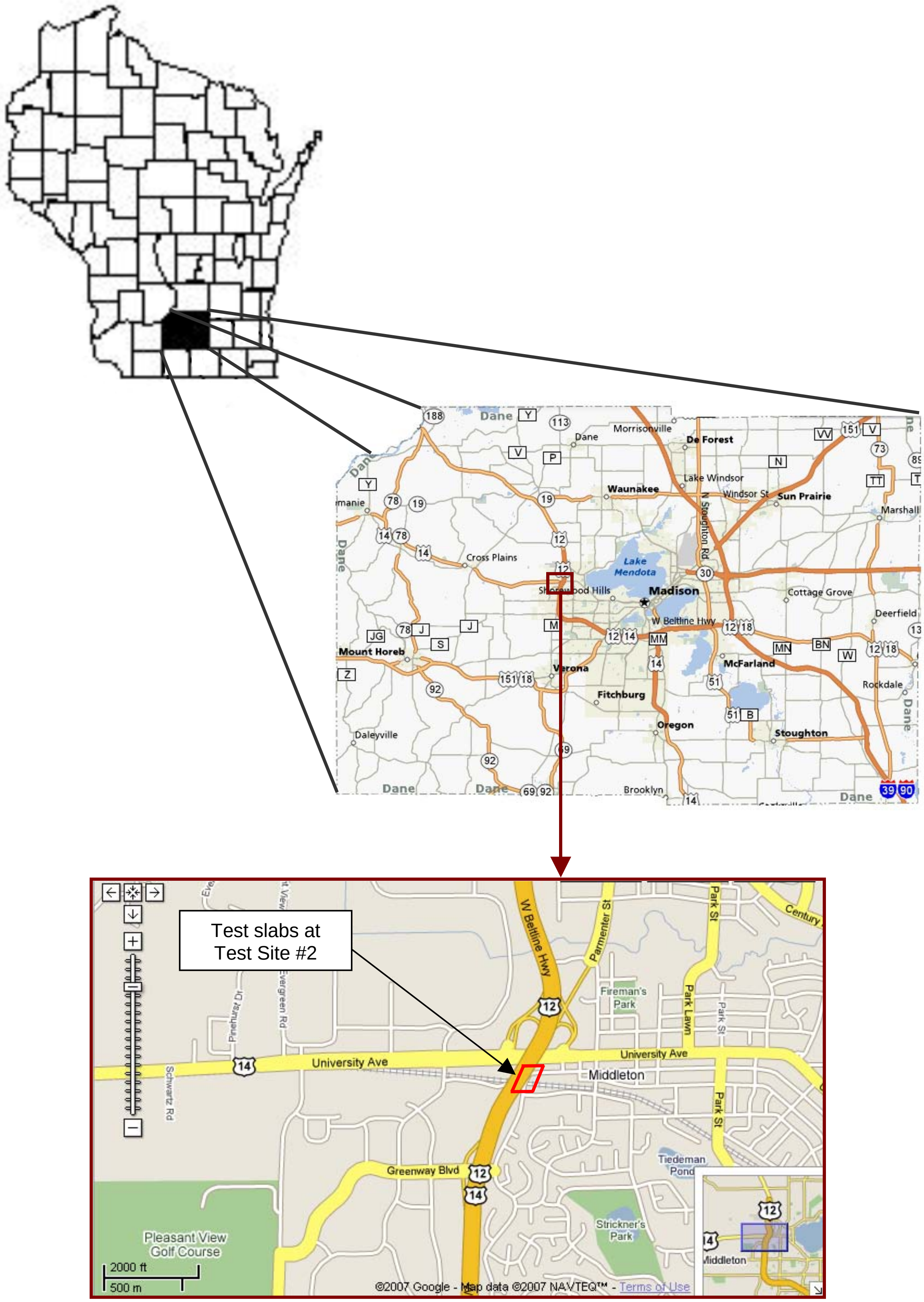

Figure A-3. Location of Test Slabs at Test Site #2

APPENDIX B Photos

Figure B-1. Worker setting up the string line at Test Site #2

Figure B-2. Paint markers showing the location of the holes and station points at Test Site #2

Figure B-3. Drilling of holes at Test Site #2, with URETEK equipment truck in background

Figure B-4. Elevation measurement as holes are drilled and injected at Test Site #2

Figure B-5. Crack that developed at Test Site #1
(Photo taken at 6-month crack survey)

Figure B-6. Crack that developed through a drilled hole at Test Site #1
(Photo taken at 6-month crack survey)

Figure B-7. Crack that developed between drilled holes at Test Site #1
(Photo taken at 6-month crack survey)