REPORT 2013 - 04

VERMONT AGENCY OF TRANSPORTATION

Materials & Research Section
Research Report

ALTERNATIVE PAVEMENT DESIGNS

RANDOLPH PARK AND RIDE

Report 2013 – 04

May 2, 2013

Alternative Pavement Designs – Randolph Park and Ride

Final Report

Report 2013 – 04

April, 2013

Reporting on Work Plan 2007-7

STATE OF VERMONT
AGENCY OF TRANSPORTATION

MATERIAL & RESEARCH SECTION

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16. Abstract

Previous research on alternative pavement type bidding has proven that various treatments are unique in terms of constructability, material characteristics, and associated performance. While some treatments may have higher initial costs, it is important to consider future maintenance needs as well as life cycle. Other considerations may include construction sequencing, user delays, or potential benefits to the environment. Evaluation of these variables should occur during the bid selection process to ensure the construction of the most cost effective treatment for a given location. For this investigation, three alternative pavement treatments were proposed for the construction of a park and ride located in Randolph at the intersection of VT Route 66 and Town Highway 46. The options included a conventional bituminous pavement, a porous bituminous pavement, and a porous concrete pavement. The purpose of this study is to perform a cost analysis of the bids and compare the annualized costs of each alternative over their expected service life. The study will also examine constructability performance in association with some preliminary monitoring, and will summarize operations practices during an initial service period.

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ABSTRACT

Previous research on alternative pavement type bidding has proven that various treatments are unique in terms of constructability, material characteristics, and associated performance. While some treatments may have higher initial costs, it is important to consider future maintenance needs as well as life cycle. Other considerations may include construction sequencing, user delays, or potential benefits to the environment. Evaluation of these variables should occur during the bid selection process to ensure the construction of the most cost effective treatment for a given location. For this investigation, three alternative pavement treatments were proposed for the construction of a park and ride located in Randolph at the intersection of VT Route 66 and Town Highway 46. The options included a conventional bituminous pavement, a porous bituminous pavement, and a porous concrete pavement. The purpose of this study is to perform a cost analysis of the bids and compare the annualized costs of each alternative over their expected service life. The study will also examine constructability performance in association with some preliminary monitoring, and will summarize operations practices during an initial service period.

INTRODUCTION

Alternative pavement type bidding is a process in which state agencies request multiple cost estimates for the construction of various pavement treatments, including, but not limited to, bituminous and concrete compositions. Previous research has proven that various treatments are unique in terms of constructability, material characteristics, and associated performance. While some treatments may have higher initial costs, it is important to consider future maintenance needs as well as life cycle. For instance, asphalt pavements tend to have lower initial costs but require more maintenance as compared to pavements composed of concrete. Other considerations may include construction sequencing, user delays, or potential benefits to the environment. Evaluation of these variables should occur during the bid selection process to ensure the construction of the most cost effective treatment for a given location.

According to the Wisconsin Department of Transportation, the Federal Highway Administration (FHWA) encouraged the use of alternative bidding in its innovative contracting initiative of the mid 1990s. However, FHWA has since discouraged its use due to the problems associated with bid comparisons and selection. For this investigation, three alternative pavement treatments were proposed for the construction of a park and ride located in Randolph at the intersection of VT Route 66 and Town Highway 46. The options included a conventional bituminous pavement, a porous bituminous pavement, and a porous concrete pavement. The purpose of this study is to perform a cost analysis of the bids, an examination of constructability in association with some preliminary monitoring, and summary of operations practices during an initial service period. For this analysis, a life cycle of 20 years is assumed for bituminous concrete pavement and 40 years for concrete pavement.

PROJECT LOCATION AND SUMMARY

The proposed improvement, project number CMG PARK (21) S, for the town of the Randolph is a park and ride located at the intersection of Vermont Route 66 and Town Highway 46, approximately 60 feet easterly of the northbound interchange of I-89 at Exit 4. See Figure 1.

Work performed under this project included the decommissioning of the pre-existing park and ride lot and the construction of a new park and ride lot including accommodation for mass transit at the facility. Work included subbase, pavement, pavement markings, stormwater treatment, lighting, landscaping, reconstruction of VT Route 66 for a left turn lane, and miscellaneous appurtenances.

Figure 1. Project Location in Randolph, VT.

MATERIAL DESCRIPTION

Three varying treatments were to be bid as follows:

Alternative A – 1.5” of bituminous concrete pavement (1 lift of type III which has a nominal aggregate size of ½”), 2” of bituminous concrete pavement (1 lift of type II with a nominal aggregate size of ¾”), 15” of subbase with dense graded crushed stone, 20” of sand borrow and geotextile for roadbed separator and stormwater treatment systems to accommodate an impervious surface.

Alternative B – 4” of porous bituminous concrete pavement. 2” of porous pavement choker course, a minimum of 36” of porous subbase, and geotextile for roadbed separator. A choker course layer comprises of single size, crushed stone (AASHTO #57 stone). It is used to stabilize the open-graded asphalt surface for paving. The subbase shall consist of AASHTO #2 stone.

Alternative C – 6” of porous Portland cement concrete pavement, 2” of porous pavement choker course, a minimum of 34” of porous subbase and geotextile for roadbed separator. The choker course shall consist of an AASHTO #57 stone. The subbase shall consist of AASHTO #2 stone.

Alternative C, porous Portland cement concrete, was chosen for the park and ride due to cost (see Cost Analysis section) as well as its reported longevity and environmentally friendly features. Porous pavements are paved areas that produce less stormwater runoff as compared to conventional pavements through infiltration, storage and evaporation.

In highway application, the other known benefits include (1):

1. Reduced spray from vehicle tires.
2. Better visibility.
3. Better traction.
4. Reduced hydroplaning.
5. Tire to pavement noise reduction.

These benefits were not considered in the Park and Ride application.

A porous asphalt or concrete wearing course is placed over a bed of uniformly graded course aggregate, woven geotextile and uncompacted soil. Uniform gradation allows for maximum porosity and therefore, maximum storage capacity. The high rate of infiltration through the porous wearing course is achieved through the exclusion of fine aggregates that are generally utilized in conventional paving mixtures (2). The porosity of the mix is substantially increased as a result. Runoff is then stored in the underlying basin and allowed to infiltrate into the soils that reside below the basin over time as a function of soil permeability.

In addition to reducing or eliminating runoff and increasing storage capacity, porous pavements have been shown to remove or reduce runoff pollutants. Removal mechanisms include absorption, staining, and microbiological decomposition in the soil.

The entire parking area was constructed with a cross section from top to bottom consisting of:

1. 6” previous concrete wearing course
2. 2” “choker” course consisting of an AASHTO No. 57 stone (aggregate sizes from 0.1 to 1.5 inches)
3. A minimum of 34” of an AASHTO No. 2 stone (aggregate sizes from 0.75 to 3 inches)
4. A non-woven geotextile over subgrade

The typical cross section is provided in Figure 2.

COST ANALYSIS

All costs for the construction of the park and ride and associated improvements were paid for through the project. Table 1 shows the bids of the three alternatives listed above from the eleven contractors that submitted bids, listed in order from lowest total project bid to highest.

Contractor 1, E.E. Packard Enterprises, won the bid due to their overall lowest total project cost. The letting date of the contract was September 14, 2007.

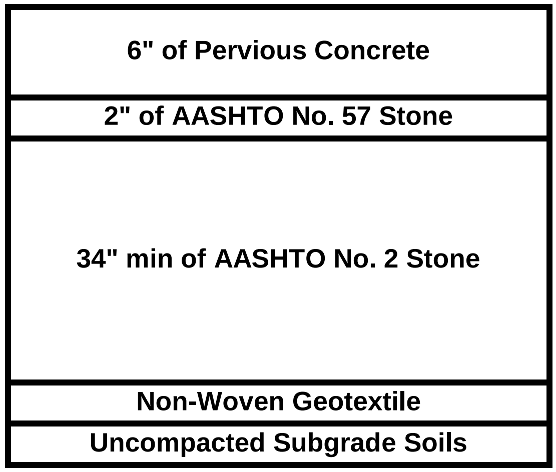

Figure 2. Porous Portland cement concrete cross section.

Alternative A, the standard bituminous concrete pavement, had the lowest initial cost for construction. The two porous alternatives were roughly 50% more expensive. Alternatives B and C, porous bituminous concrete and porous Portland cement concrete, had similar initial construction costs. As stated earlier, a life cycle of 20 years was chosen for bituminous pavements and 40 years for PCC pavements. With these periods, and an assumed inflation rate of 3.34% (3), the equivalent annual costs for each alternative were determine as shown in Table 1B. Alternative C provided the lowest annualized costs of the alternatives; therefore, providing the basis for the selection of this alternative as the construction method.

Table 1A. Results of all bids for the three alternatives.

Contractor	Alternative A	Alternative B	Alternative C	Common Costs
1	582,584	1,101,851	1,021,348	405,052
2	791,260	1,240,626	1,050,021	395,875
3	839,985	1,156,925	1,050,575	396,286
4	815,540	1,125,719	1,026,439	435,589
5	811,287	1,175,189	1,058,489	460,564
6	566,174	1,177,355	990,982	589,386
7	756,022	1,294,261	1,197,586	413,410
8	995,833	1,406,698	1,293,563	419,306
9	917,594	1,338,082	1,286,959	442,662
10	849,975	1,249,478	1,441,878	412,085
11	1,053,075	1,428,575	1,442,525	500,844

The alternate pavement type bid process worked well for this project and led to a desirable candidate being chosen amongst them. The bids that were received along with assumed factors such as lifespan and environmental advantages led to the choice of porous Portland cement concrete being placed at the Randolph Park and Ride.

Table 1B. Annualized value of the bids for the three alternatives.

Alternative	A	B	C
Period	20 Years	20 Years	40 Years
Contractor 1	$68,488.89	$104,498.14	$65,146.34
Contractor 2	$82,323.41	$113,485.28	$66,036.76
Contractor 3	$85,730.81	$107,709.42	$66,080.83
Contractor 4	$86,761.16	$108,270.92	$66,773.54
Contractor 5	$88,198.15	$113,433.41	$69,377.98
Contractor 6	$80,133.80	$122,516.94	$72,178.35
Contractor 7	$81,095.77	$118,420.65	$73,577.18
Contractor 8	$98,134.64	$126,626.61	$78,229.91
Contractor 9	$94,328.71	$123,487.99	$78,995.01
Contractor 10	$87,519.18	$115,223.23	$84,673.94
Contractor 11	$107,758.52	$133,798.05	$88,757.28
Averages	$87,315.73	$117,042.79	$73,620.65

Does not take into account any replacement or reconstruction costs after the life of the project.

CONSTRUCTION

Preliminary construction began in October of 2007 on the project by the prime contractor E.E. Packard Enterprises Inc, and continued through completion in October of 2008. Concrete was produced and placed by Carroll Concrete, as a subcontractor. Concrete pours were performed over a month period, beginning on August 13, 2008 and finishing on September 17. Concrete was poured in nine strips, as shown in Figure 4. Placements were made in an alternating pattern from an east to west direction, which allows extra days for curing before adjacent sections were placed. Two of the first sections of the parking lot were placed on August 13 and 19 and in a few days started to exhibit unexpected early-age raveling. It was decided that with 80 gallons of water per truck, the concrete mix on these days was too dry; therefore, it was requested that the slabs placed on these days be removed and replaced. By the August 21 placement, the amount of water was increased to 180 gallons per truck, yielding a much more workable mix that seemed to finish better and eliminated segregation and cement aggregate binding issues.

Prior to the end of placing the concrete, it was noted that an area in the northeast corner of the lot was showing signs of raveling. The raveled section was removed and placed once again on September 10. A typical installation at the park and ride is shown in Figure 3, with the roller in the middle, the as-poured material on the right and the rolled material on the left. The plastic sheeting, used for curing, is also beginning to be placed over the slab on the far left.

Figure 3. Placement and rolling of porous concrete.

PERFORMANCE

The performance and condition of the porous concrete park and ride has been monitored extensively from the time it was placed to the present through a separate research project by the Vermont Agency of Transportation, SPR-705 "Porous Pavement Performance Evaluation in a Cold Weather Climate, Randolph Park and Ride." All detailed findings of these items will be discussed in the future report. As part of that project it has been fully documented that the porous concrete structure has not fared well, as parts have completely raveled and coring has shown a breakdown of cement paste through the depth of the structure in some areas. The deteriorated parts of the lot are mostly to the west side of the median in the parking lot as shown in Figure 11.

Since construction, the parking lot has been subjected to segregated plowing and salting maintenance activities during the winter. It was decided that no sand would be placed on the structure, as this is known to easily clog the pours in the concrete thus limiting its drainage capabilities; therefore only salt has been used. Maintenance personnel have maintained only the west side of the parking lot, with plowing and salting. During the winter, the lot is closed east of the median; however, some people will park their cars when the snow accumulations are low. It has been determined through freeze-thaw testing of cores removed from the parking lot during construction that there is a high probability that the addition of de-icing salt onto the front part of the lot is the primary cause of the breakdown of the porous concrete structure.

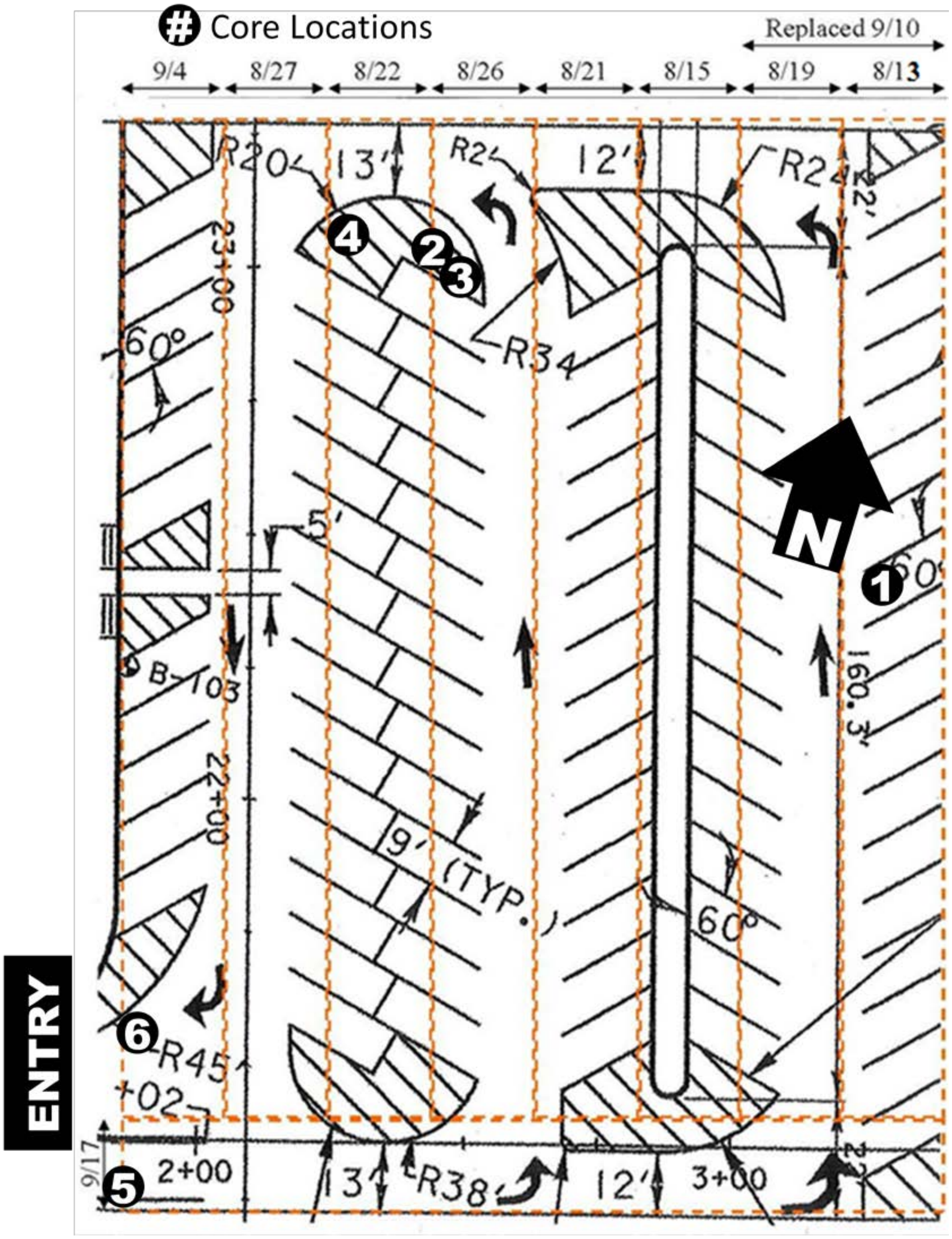

Figure 4. Concrete placement pattern and dates during construction.

Six pavement cores were taken through the concrete structure during the summer of 2010 once distresses in the concrete were first noticed. Cores were taken both in areas that appeared to be in good and poor condition. The locations of the cores are shown in Figure 4. Pictures and brief descriptions of these cores are as follows.

Core 1

Core 1, was taken from a location east of the median, where winter maintenance activities are not performed. The location was selected in the eleventh parking space from the southern edge of the last row of spaces because the visual and audibly testing suggested the area was sound. As seen in Figure 5, the 6 in. core was extracted fully intact and represented the specified design depth.

Figure 5. Core 1, taken from a visually and audibly sound portion of the lot.

Core 2

Core 2, as seen in Figure 6, was taken from a location that visibly looked good (virtually no raveling) but sounded delaminated during sounding tests. It was taken from the pavement marking gore area located at the northern end of the parking lot encompassing parking rows two and three. The core was extracted in three material regimes. The top of the core was a few solid pieces of concrete roughly 0.75 in. thick (top of picture). The bottom of the core was one solid piece roughly 1.5 in. thick (middle of picture). The middle approximately 3.75 in. came out as un-adhered concrete, or rather, gravel (on the ground in the picture), with very little cement present on the aggregates.

Core 3

Core 3, as seen in Figure 7, was taken from a location 2 ft. away from Core 2, where sounding tests indicated a spot of good concrete, in addition to a good visual spot. The core was also located in the gore area. When extracted the core was indeed in sound condition as it came out as a complete 6 in. core.

Figure 6. Core 2, taken from a visually sound but audibly unsound location.

Figure 7. Core 3, taken from a visually and audibly sound location, two feet from Core 2.

Core 4

Core 4, as seen in Figure 8, was extracted from one of the most severely raveled areas, also in the same gore area, in which an approximately 1 in. deep hole had already raveled away. When extracted, the bottom roughly 2.5 in. of the core were intact (shown in the picture) while all concrete above this was gravel-like with little cement visible.

Figure 8. Core 4, taken from a visually and audibly unsound location.

Core 5

Core 5, as seen in Figure 9, was taken from the entrance lane onto the porous concrete, in the southern most concrete slab. Sounding tests on this area indicated good concrete. When extracted the core came out whole and measured 7 in., one inch thicker than the specified 6 in. thickness.

Figure 9. Core 5, taken from a visually and audibly sound but clogged location at the entrance.

Core 6

Core 6, as seen in Figure 10, was taken from the exit lane from the porous concrete, in the second slab from the south. As with Core 5, sounding tests in this area indicated good concrete. When extracted the core came out whole and measured 7 in., one inch thicker than the specified 6 in. thickness.

Figure 10. Core 6, taken from a visually and audibly sound but clogged location at the exit.

After seeing the condition of these cores, it was evident that at least portions of the porous concrete slab were in danger of significant failures, which has continued to present itself over the course of the following two and a half years.

During the summers of 2010 through 2012, chain drag sounding tests were performed to document the extent of potential delaminations and structural breakdowns within the porous concrete structure. The survey taken in 2012 is shown in Figure 11. Deteriorated areas identified by the chain drag test are drawn and shaded. As can be seen, the greatest extent of deficiencies is present in the front (left of the median) portion of the lot. The shaded areas represent approximately 15% of the entire lot and about 30% of the front portion. In addition to these findings, more of the surface of the concrete has shown signs of raveling and deterioration beyond these areas.

Other ongoing monitoring activities at the lot include periodic water quality sampling and infiltration testing. Water quality sampling has been performed at monitoring wells at elevations above and below that of the lot in an effort to determine the filtering capabilities of the system. Water has been sampled for total petroleum hydrocarbons, phosphorous, various metals, de-icing salt compounds and other miscellaneous chemicals. To date, the downstream (western) testing has shown very similar levels of all items as the upstream (eastern) samples, all at low or non-existent levels. In some cases, the upstream sampling has shown a higher concentration of sodium chloride than the downstream samples. Infiltration testing has been performed to determine the change in the rate at which water can pass through the porous concrete over time. Nine random spots were chosen over the pavement. Seven locations were tested in the front of the lot and two in the back. Overall, four of the locations have ended testing, as they no longer allow water passage, utilizing our testing method; they however still allow water passage at a greater, immeasurable amount, than conventional concrete. All four locations that no longer readily infiltrate water are in the front of the lot, due to excessive clogging of pours and the breakdown of the overall structure. The two locations in the eastern section of the lot have not lost any of their infiltration capabilities.

A site visit was conducted in March of 2013 to photograph the condition of the lot following the majority of its fifth winter season. The lot displayed readily noticeable deterioration since the previous fall. Two pictures of its state during this visit are shown in Figures 12 and 13.

SUMMARY AND RECOMMENDATIONS

The porous concrete Randolph Park and Ride lot has been operational for four and a half years, encompassing five winter seasons. To date, from the testing results that have been obtained through hydraulic and environmental properties, the parking lot seems to be functioning as designed and desired. However, from a structural perspective, the lot has not held up as planned. The lot is in dire need of remedial action to halt any more damage.

With the current state of the porous concrete taken into account, the previously described cost analysis should be updated. In the initial analysis, a life cycle of 20 years was chosen for bituminous pavements and 40 years for PCC pavements. With this taken into account, Alternative C (the constructed porous pavement) provided the least overall cost of the alternatives on a per year basis. With the lot presently being five years old, it can be estimated that its actual life span may be no longer than 10 years; placing this into Table 2 shows a significant downgrade for its cost per year. Assuming a 40-year life resulted in 84% of the cost of a conventional bituminous pavement lot; with an updated 10-year life increased this figure to 220% of the cost per year for a conventional hot mix asphalt pavement. This experiment did not verify the 20 year hot mix asphalt pavement service life.

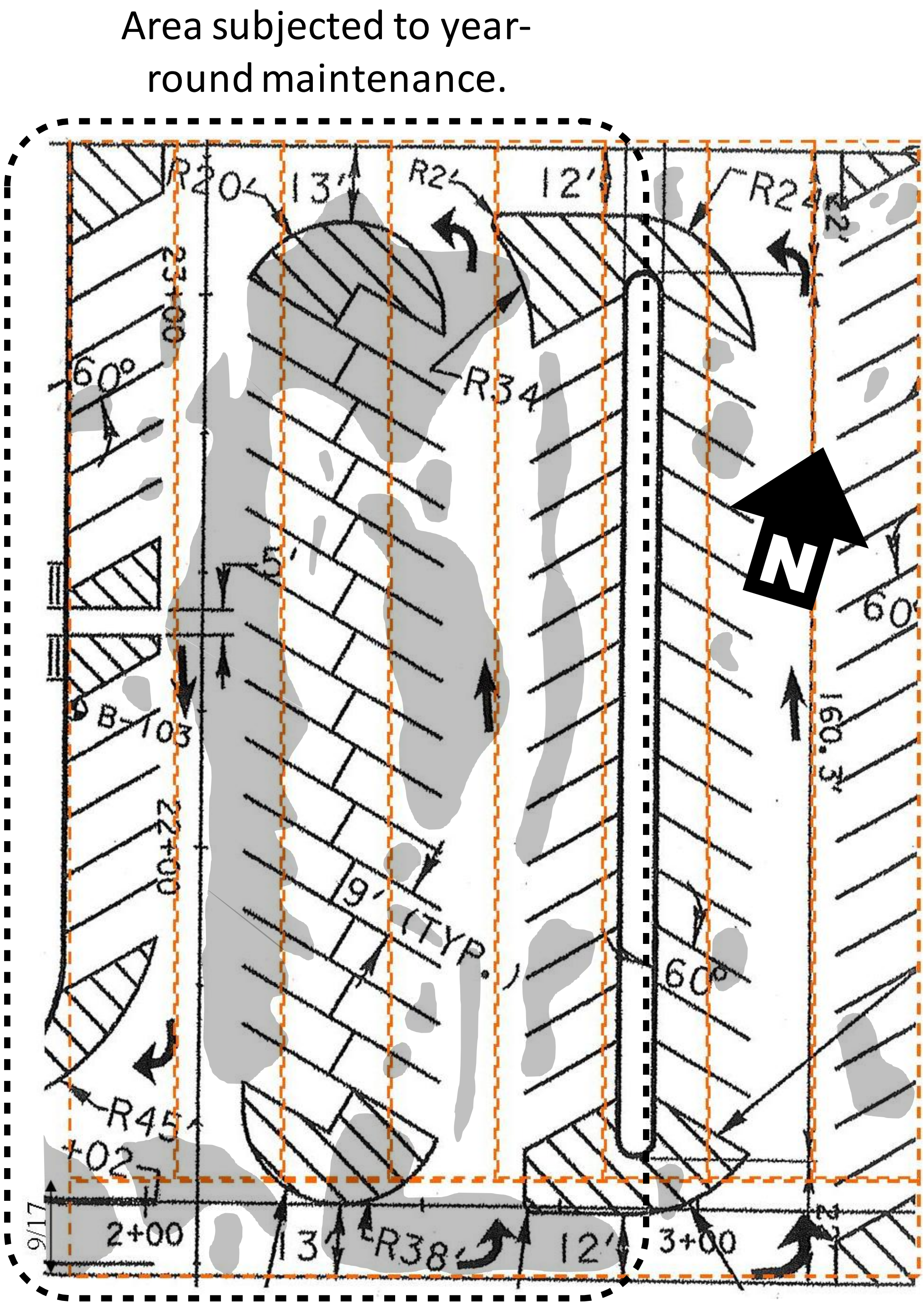

Figure 11. Deteriorated areas, as determined by chain drag sound testing, after four winter seasons.

Figure 12. Deterioration in the gore area of the front portion of the lot after five winter seasons.

Figure 13. Deterioration at the transition between the bituminous drive (left) and porous concrete lot (right) after five winter seasons.

Table 2. Updated life cycle cost comparison between material alternatives.

	Alternative A	Alternative B	Alternative C
Average Bid Cost	$816,303	$1,244,978	$1,169,124
Original Life Cycle Estimate	20	20	40
Per Year Cost	$87,316	$117,043	$73,621
Cost Factor	1	1.34	0.84
Updated Life Cycle Estimate	20	20	10
Updated Per Year Cost	$87,316	$117,043	$192,263
Updated Cost Factor	1	1.34	2.20

Does not take into account any replacement or reconstruction costs after the life of the project.

At the current rate of deterioration, a considerable amount of the west portion of the porous concrete is rapidly deteriorating. Within a few more years could most likely be thought of as a gravel lot. Assuming this outcome is not desirable, remedial action would be required in the near future. The lot was originally designed and constructed so that if the concrete failed the lot could be paved over with bituminous asphalt; conventional drainage is already in place to deal with an impermeable lot. There are concerns that the partial deterioration of the concrete slab may lead to differential settlement of the asphalt and premature failure. It is generally believed that the science of porous concrete for northern climates is continually improving; therefore, it may be possible to replace existing concrete with a new porous concrete structure, one of improved mix design. The Agency is currently working with Norwich University and the University of Vermont to refine the porous concrete mix used on this project for strength and durability while maintaining porosity.

Another possible alternative would be to replace some (or all) of the deteriorated areas with removable/replaceable porous concrete panels that are available on the market. These are designed to have the same environmental properties of a monolithic porous concrete slab, but are able to be removed and replaced easily and cost effectively by Agency personnel if they become damaged of clogged with fines. The removed panels can be cleaned for reuse in future maintenance projects. Either of these two options would be viable and would represent opportunities for further research of the technologies for not only Vermont Agency of Transportation use and knowledge, but also other local communities that have a history of soliciting advice from the Agency for these types of products' use.

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Prepared By: Jennifer Fitch
Date: July 31, 2007

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH SECTION

WORK PLAN FOR RESEARCH INVESTIGATION
Alternative Pavement Designs – Randolph Park and Ride
Work Plan No. WP-2007-7

OBJECTIVE OF STUDY:

Alternative pavement type bidding is a process in which state agencies request multiple cost estimates for the construction of various pavement treatments, including, but not limited to, bituminous and concrete compositions. Previous research has proven that various treatments are unique in terms of constructability, material characteristics, and associated performance. And while some treatments may have higher initial costs, it is also important to consider future maintenance needs as well as life cycle. For instance, asphalt pavements tend to have lower initial costs but require more maintenance as compared to pavements composed of concrete. Other considerations may include construction sequencing, user delays, or potential benefits to the environment. These variables should be evaluated during the bid selection process to ensure the construction of the most cost effective treatment for a given location.

According to the Wisconsin Department of Transportation, the Federal Highway Administration (FHWA) encouraged the use of alternative bidding in its innovative contracting initiative of mid 1990s. However, FHWA has since discouraged its use somewhat due to the problems associated bid comparisons and selection. For this investigation, three alternative pavement treatments will be proposed for the construction of a park and ride located in Randolph at the intersection of VT Route 66 and Town Highway 46. The options are to include a conventional bituminous pavement, a porous bituminous pavement and a porous concrete pavement. The purpose of this study will be to perform a cost analysis of the bids, an examination of constructability in association with some preliminary monitoring and summary of operations practices during an initial service period . For this analysis, a life cycle of 20 years will be assumed for bituminous concrete pavement and 40 years for concrete pavement.

LOCATION:

The proposed improvement, project number CMG PARK (21) S, for the town of the Randolph is a park and ride located at the intersection of Vermont Route 66 and Town Highway 46, approximately 60 feet easterly of the northbound interchange of I-89 at Exit 4.

Work to be performed under this project includes the decommissioning of the existing park-and-ride lot and the construction of a new park-and-ride lot including accommodation for transit interoperation at the facility. Work will include subbase, pavement, pavement markings, stormwater treatment, lighting, landscaping, reconstruction of VT Route 66 for a left turn lane, and miscellaneous appurtenances.

MATERIAL:

As stated previously, three varying treatments are to be bid as follows:

Alternative A – 1.5" of bituminous concrete pavement (1 lift of type III which has a nominal aggregate size of ½"), 2" of bituminous concrete pavement (1 lift of type II with a nominal aggregate size of ¾"), 15" of subbase with dense graded crushed stone, 20" of sand borrow and geotextile for roadbed separator and stormwater treatment systems to accommodate an impervious surface.

Alternative B – 4" of porous bituminous concrete pavement. 2" of porous pavement choker course, a minimum of 36" of porous subbase, and geotextile for roadbed separator. The choker course shall consist of a AASHTO #57 stone. The subbase shall consist of AASHTO #2 stone.

Alterative C – 6" of porous portland cement concrete pavement, 2" of porous pavement choker course, a minimum of 34" of porous subbase and geotextile for roadbed separator. The choker course shall consist of a AASHTO #57 stone. The subbase shall consist of AASHTO #2 stone.

COST:

All costs for the construction of the park and ride and associated improvements will be paid for through the project. In addition to collecting the overall cost of the selected alternative, the total cost for each treatment, as displayed in the bids, will be acquired.

SURVEILLANCE AND TESTING:

1. During construction, the selected pavement treatment is to be monitored during production and placement. The contractor and plant location will be recorded along with any other pertinent information. On the project site, all application procedures are to be noted including adherence to specifications, construction sequence, compaction efforts and any other applicable construction considerations. Specific investigation of alternate

practices in placement of the wearing surface for any selected porous pavement will be included.
2. Following construction, a windshield survey is to be performed on an annual basis for a period of 24 months. During the inspection, any observed pavement distresses will be noted with special attention to raveling and pop-out. Other distresses to note include severe rutting, and thermal and fatigue cracking. A visual examination of the condition of the stormwater treatment system and its operating components will be recorded in the resulting reports.
3. In addition, an analysis of received bids will be performed. Analysis of unit costs among all bids, in addition to the selected bidder will enable a full assessment of factors in the pricing.

STUDY DURATION:

The duration of this study will be no more than two years or until final conclusions can be drawn from the observations and retroreflectivity readings.

REPORTS:

An initial report will be prepared once installation is complete. A final report will be published once the evaluation is complete.

Reviewed by: ______________________________

William E. Ahearn, P.E.
Materials and Research Engineer
Date:

Approved by Material and Research on Date (WEA-08/03/2007)
Approved by Federal Highway Administration on Date (CPJ-08/08/2007)