

A Practical Look at Pennsylvania's Bradford Bypass A Perpetual Pavement

State Route 0219, Sections C09 & D09



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ABSTRACT

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A Practical Look at the Bradford Bypass – A Perpetual Pavement, reports the approach to the initiation, thickness design, mix selection, economic impact and post-construction evaluation of the Bradford Bypass, State Route 219, a perpetual pavement, in McKean County, Pennsylvania.

The Bradford Bypass, State Route 219, is a 5.2 mile limited access arterial with an ADT of 16,276 (7-percent truck traffic). Each year Bradford experiences some of Pennsylvania's lowest temperatures and several freeze-thaw cycles. This project will remove the original Portland cement concrete pavement, built between 1969 and 1974 and replace it with a perpetual pavement having a pavement section with 13.5-inches of HMA over 13-inches of aggregate subbase. The truck traffic and harsh environment have contributed to the premature pavement failures of the original construction and, as such, provide an excellent opportunity to evaluate the perpetual pavement concept.

This paper reports the initial decision to build a perpetual pavement, selecting data inputs, designing the pavement section, choosing the HMA mixtures and the PG binder, awarding of the project in December 2005 and the Pennsylvania Department of Transportation's (PENNDOT) post-construction plan to evaluate the pavement's performance. Specifically, the paper includes selecting material moduli, development of the traffic load spectra, environmental considerations, use of PerRoad software for the initial pavement thickness and the improved performance's anticipated benefits to the life cycle analysis.

PENNDOT has developed a post-construction evaluation plan that will prepare annual interim reports noting, pavement defects, remedial actions, International Roughness Index (IRI) and traffic volumes. A final report will be prepared after twelve years or when the first overlay is placed. The final report will include a comparison of the PENNDOT's current HMA performance periods versus the perpetual pavement performance that may ultimately be reflected in the life cycle.

Keywords: perpetual pavement, modulus, strain limits, life cycle

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Introduction

Some agencies have the perception that hot-mix asphalt (HMA) is a relatively short term pavement option (7 to 10 years). That perception may rest in the fact that while the U.S. places in excess of 600,000,000 tons of HMA annually, a very high percentage of that tonnage is overlays of 2-inches or less. When defining the performance of HMA pavements, the thought process of those agencies, quite naturally, is skewed toward overlay performance. Overlays placed on a wide range of existing pavement conditions result in highly variable performance and an average life of 10 plus or minus years. The "Perpetual Pavement Award" program raised an awareness that properly designed and constructed HMA pavements can provide excellent long term performance. The first recipient of that award, the New Jersey Turnpike, served notice that HMA pavements can perform 50-plus years with minimal full-depth repairs (less than 0.1 of a percent) and provide wearing surfaces that averaged 15 to 18 years between overlays. Since that first award in 2001, thirty-five other pavements have received the award. An award that requires 35 years of service, minimal base repair and a minimum average overlay life of 13 years.

The New Jersey Turnpike, fifty-five years old and counting, is a testament to the efforts of those early pavement designers. To recreate that success, today's designers have a number of pavement design options that evaluate the stress/strain relationships that are critical to long term pavement performance. PerRoad, one of those options, developed by Dr. David Timm, Auburn University, was the design software used on the initial design of the Bradford Bypass.

The perpetual pavement concept was introduced to Pennsylvania through a series of presentations at the regional and state level. Those initial presentations were made at

the Northeast Materials Engineers Meeting, the Mid-Atlantic Quality Assurance Workshop and the Associated Pennsylvania Constructors Meeting. All of these meetings were attended by PENNDOT's decision makers. Follow up meetings in each of the PENNDOT's eleven engineering districts afforded the opportunity to provide the details not covered in those earlier presentations. PENNDOT's Engineering District 2-0, located in north-central Pennsylvania, was one of the first districts to step forward and consider building a perpetual pavement. Specifically, State Route 219, originally constructed as a



Figure 1

pcc pavement between 1969 and 1974, had reached the point where the only option was remove and replace the existing pavement. The decision was made to include a perpetual pavement as one of the design options and a PENNDOT/Industry meeting took place in Bradford, PA (Figure 1). The on-site meeting afforded an opportunity for all parties to review the proposed alignment of the 5.2-mile, limited access, Bradford Bypass (SR 219) and to discuss required design inputs and material selection. Those initial discussions covered:

- Will the pavement be a composite (HMA and aggregate base) or Full-Depth (HMA only) pavement,
- Will the sacrificial surface be Superpave or SMA,
- Mix selection for the intermediate layers, and the use of a “rich bottom”
- PG grade binder selection

Thickness Design

The idea of developing a perpetual pavement section seemed straightforward, but it proved to be a bit more complicated. First, there was the decision to meet the perpetual pavement strain criteria with the thickness of the aggregate base and HMA alone or to include additional asphalt cement in the bottom lift, the so called “rich bottom”. In addition, design input values were needed: subgrade, traffic, moduli values for the different materials and environmental conditions of the Bradford area.

Subgrade values were one of the easier tasks since the Bypass is being built on the existing alignment. The soil evaluations from that earlier project along with the investigations of the District 2-0 soil engineers for this project provided a high degree of confidence when selecting subgrade strength values. Both FWD Testing and soil sample test results were used.

Traffic values proved to be a bit more difficult as the required inputs were a departure from the traditional 18,000 pound single axle loads. The concept of “load spectra”, not new to PENNDOT's pavement design engineers, is one which they did not use on a daily basis and consequently it was not readily available in their database. The Department's strategically located weigh stations, the FHWA's Traffic website and PerRoad's typical W-4 Tables were able to provide a representative load spectra.

Moduli values for the aggregate base were chosen based on typical values for aggregate base and the experience and expertise of PENNDOT. Decisions for the moduli of the hot-mix were made after considering values provided with the PerRoad software

and values from MnRoad. In addition, Dr. Mansour Solaimanian, professor at Penn State University, is nearing the end of a 5-year study, a SUPERPAVE In-Situ Stress/Strain Investigation (SISSI), in which he instrumented eight pavements around the state to generate input values for the “New AASHTO Design Guide”. Dr. Solaimanian provided some very preliminary Pennsylvania modulus values for the summer and winter months. Those values were very similar to PerRoad and MnRoad providing confidence that Pennsylvania’s seasonal HMA modulus values could be chosen from PerRoad and MnRoad. (Figure 2)

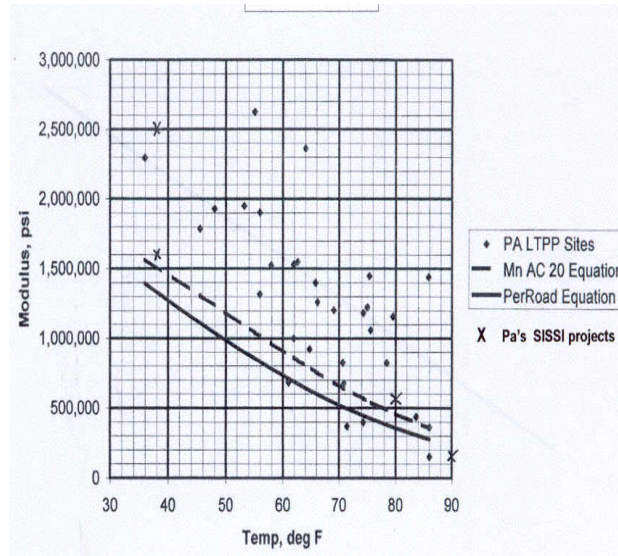


Figure 2

Monthly temperatures and precipitation amounts for Bradford were based on climatic data from the web site “weather.com”.

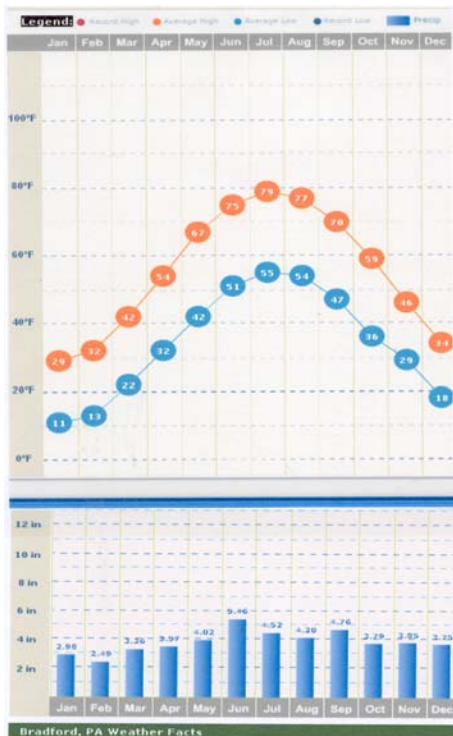


Figure 3

That web site provides average high/low temperatures and precipitation amounts for each month (Figure 3). The PerRoad software allows a maximum of five seasons, requiring some months to be combined, a subjective decision which can be in the eye of the beholder. The preliminary design phase of the Bradford Bypass coincided with the introduction of the Beta version of PerRoad. For that reason several pavement design experts were contacted for assistance and a pavement thickness design was calculated using the Asphalt Institute’s “Advanced Structural Analysis (DAMA) software. However, the PerRoad software was the basis for the initial design.

On the basis of the weather.com climatic data the twelve months were combined into four seasons: Winter (17 weeks), December, January, February, March, Spring (9 weeks), April, May,

Summer (17 weeks), June, July, August, September and Fall (9 weeks), October, November. The seasonal air temperature then became the average of the average of the high and low temperature for each month. Pavement temperatures, used to choose HMA moduli values, were calculated according to the formula: Pavement Temperature = (Air Temperature x 1.05) + 5 deg F. The website's average monthly precipitation graph was also helpful in grouping particular months into a season and estimating seasonal aggregate and subgrade moduli values. Subgrade and aggregate moduli values used in the design are shown below (Figure 4). The modulus value for the HMA material was assumed to be the same for all 13.5-inches and was selected by choosing a value between the PerRoad, MnRoad values and the preliminary findings of the Penn State study.

	Seasonal Pavement Layer Moduli			
	<u>Summer</u>	<u>Fall</u>	<u>Winter</u>	<u>Spring</u>
Hot-Mix	600,000	1,100,000	1,600,000	1,000,000
Aggregate	20,000	26,000	40,000	10,000
Subgrade	15,000	15,000	24,000	7,500

Figure 4 (shown in psi)

Traffic input values presented the most difficult challenge and required using nearby weigh stations, typical load spectra included in the PerRoad software, and the experience of PENNDOT's traffic engineers.

The PENNDOT/Industry effort resulted in a perpetual pavement design that is 13.5-inches of hot-mix over 13-inches of 2A subbase (PENNDOT's dense graded aggregate base). The design was based on an early decision to achieve a minimum of 50 years of service. A PerRoad analysis of the 26.5-inch pavement section indicated the governing failure mode to be the horizontal strain (-70 microstrain) at the bottom of the hot-mix at year 61. The vertical compressive strain (+200 microstrain) at the top of the subgrade provided 66 years of service.

Material Selection

Material selection for the base came down to a choice between using the Department's 2A subbase for all 13-inches of the aggregate base or to use a combination of Asphalt Treated Permeable Base (ATPB) and 2A subbase with the 2A serving as a separation layer between the subgrade and the ATPB. PENNDOT ultimately decided to go with their standard treatment under hot-mix pavements, 2A subbase without the ATPB based on the FHWA's recommendation. The 2A subbase material was modified to minimize the clay and friable particles in an effort to improve the drainage characteristics of the subbase.

Unlike the aggregate base, the mix selection for the hot-mix materials offered numerous possibilities. Some of the possibilities considered were: would the wearing, intermediate and base mixtures be Marshall, SUPERPAVE or Stone Matrix Asphalt (SMA) designs, would the lowest layer in the pavement have higher asphalt binder content, often referred to as a "rich bottom?" The Department's complete transition from Marshall to SUPERPAVE mix designs in 2004 ruled out the use of any Marshall mixes. Tough decisions still remained for mix selection. There was strong consideration to use

an SMA wearing surface, but it was ultimately decided that most of the likely successful

9.5mm @ 1.5-inches
19mm @ 3.0-inches
25mm @ 5.0-inches
25mm @ 4.0-inches "rich bottom"
2A @ 13.0-inches

Figure 5

bidders had no experience with SMA and that this was not the project for the District's first SMA. Current traffic and anticipated growth suggested the Superpave mix should be designed at the 3 to 10 million ESAL level. A 9.5mm SUPERPAVE was chosen for the wearing surface. The 9.5mm offered a relatively fine mix, as compared to a 12.5mm or 19mm, and with its higher asphalt content provided the best opportunity for good durability and impermeability. A 19mm mix was chosen for the intermediate layer and a 25mm mix for the remaining 9-inches of base course. The 25mm mix is to be placed in two lifts. One lift, 5-inches thick, will be designed the same way as the wearing and intermediate mixtures, 3 to less than 10 million ESALS. The bottom 4-inch lift, will be designed at a lower gyration level, 0.3 to 3 million ESALS. The mix for the bottom 4-inches is required to maintain the same gradation as the 5-inch lift directly above it. It is anticipated that the lower gyration level will provide a higher asphalt content, i.e. "the rich bottom." (Figure 5)

Bradford may be the coldest area in Pennsylvania and a PG 58-28 is required to minimize low temperature cracking. When implementing PG binders in Pennsylvania, PENNDOT made an effort to simplify PG storage and selection by using three primary grades; PG 58-28, PG 64-22 and PG 76-22. The decision was made to depart from the norm and specify a PG 64-28 on all HMA lifts. This decision was made because:

- Low temperature cracking is expected to be the critical factor.
- Traffic will be traveling at highway speed, not slow or standing.
- The north end of the Bradford Bypass is also the Pennsylvania / New York state line. New York's workhorse grade is PG 64-28 and is expected to be readily available.

Economics

A perpetual pavement can conjure up visions of unusually thick HMA pavement sections and the resulting economic consequences. A few days after the presentation at the Associated Pennsylvania Constructor's meeting PENNDOT's Bureau of Construction and Materials requested additional discussions. They wanted to revisit the technical aspects of perpetual pavements and to ask, "How much more do they cost?" (This meeting took place prior to any thoughts about the Bradford Bypass possibly being a perpetual pavement.) The primary questions were:

- How does the thickness of a perpetual pavement compare to our current designs?
- What are the economic implications of a "rich bottom" and a modified wearing surface?

Talks regarding the thickness design centered around the idea that this was a new design concept based on stress-strain relationships and it did not automatically result in thicker pavement sections. In some cases they may even result in thinner sections.

The most significant economic concern, thicker HMA sections, was resolved, but it still left the cost increase of modifying the wearing surface and increasing the asphalt content of the base mix. Several typical sections were evaluated and it appeared that initial construction cost would be increased 2 to 3-percent, but the 40-year life cycle cost would decrease. The economic impact of using a modified asphalt wearing surface and a “rich bottom” on the Bradford Bypass proved to be in line with those early estimates.

- Initial construction cost was estimated to increase 2-percent.
- Elimination of the base repairs while maintaining the DOT’s current 10-year performance period will result in a perpetual pavement life cycle that is slightly less than the non-perpetual.
- Extending the performance period from 10 to 12 years will result in a life cycle savings of 3.5 percent.
- Extending the performance period from 10 to 15 years will result in a life cycle savings of 7 percent.

As noted earlier in the “Material Selections” section of this paper, Pennsylvania uses three standard PG grades, and only the PG 76-22 is a modified binder. The PG 64-28 is not expected to be a modified asphalt, resulting in even more favorable economics for the perpetual pavement.

Advertising and Awarding the Project

The Bradford Bypass, State Route 219 has been separated into two projects, Sections C09 and D09. Both projects are expected to be completed and opened to traffic in the Fall of 2009. Section C09 was awarded on December 21, 2005 with construction duration from the Spring of 2006 to Fall 2007. Section D09 is scheduled to be let in 2007 with construction duration from Spring 2008 to Fall 2009.

Construction Follow-Up

The decision to build a perpetual pavement was made with approval of the Federal Highway Administration in anticipation that it would provide improved long-term performance. Performance expected to reduce user delay for the motoring public and overall life cycle costs for the Department. District 2-0 will document the performance of the Bradford Bypass by:

- Maintaining detailed materials and construction records to include: mix design properties, all QC/QA test results and measuring post construction pavement smoothness using the International Ride Index. In addition, at the project’s “Final Close Out”, any remaining issues will be addressed and documented
- Implementing an annual pavement distress monitoring program in accordance with the Department’s Automated Pavement Condition Survey Field Manual (Pub. 336). Any cracking suspected to be fatigue related will be evaluated by

- coring, to define the limits of the crack. Deflection measurements, with a FWD will also be taken in the suspected area.
- Collecting IRI and traffic data on an annual basis
 - Preparing interim reports on a yearly basis, noting any pavement deficiencies and remedial actions taken.
 - Preparing a final report at the end of year 12 or when it is determined that an overlay is required. The final report will include a comparison of the expected performance in PENNDOT's published Pavement Policy Manual performance versus the actual performance of the Bradford Bypass.

Summary

The purpose of the Bradford Bypass is to provide upgraded roadway and infrastructure components that will provide improved serviceability and enhance the overall safety and traveling experience of the motoring public. The Bypass is a moderate volume, limited access arterial with heavy truck traffic and some of the lowest temperatures in Pennsylvania. These factors have influenced the service life of traditional pavement designs and thus provide an excellent opportunity to evaluate the engineering and economic benefits of the perpetual pavement concept.