Infrastructure Management Policies and Practices

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ABSTRACT

This paper describes the influence of non-destructive pavement evaluation techniques on the project management policies and strategies of the New Jersey Department of Transportation (NJDOT). It is demonstrated that utilizing such techniques especially during the early phases of a project can provide an enormous insight into the pavement issues and equip the project managers with a better understanding of the financial obligations for the capital project. Creation of a performance-based capital programming mechanism and certain modifications to the existing project management strategies have created an atmosphere for such timely use of non-destructive pavement evaluation at NJDOT.

State officials and project managers, especially those in charge of funding, have long been aware of the competitive environment for transportation dollars. Limited budgets, an excessive number of deficient pavements, and the growing demand from the traveling public for a smoother pavement have further intensified the need for achieving long-term solutions for pavements. Recognizing this need, NJDOT devised a performance-based capital programming mechanism, called the Capital Investment Strategy (CIS), to make specific investment choices that conform to the broad goals and policies of the DOT. Faced with an aging, complex infrastructure of roadways and bridges, NJDOT has had the foresight to set clear, long-term goals. The decision to use performance measurements for managing this infrastructure was a forward-thinking decision that should help to achieve these goals.

The authors have played an instrumental role in compiling the performance measurements for the existing roadways through the use of Falling Weight Deflectometer testing and in-depth geotechnical investigations. Such non-destructive pavement evaluation techniques, coupled with life cycle cost analyses, have allowed cost-effective alternative investment scenarios (a key element of the CIS) to be developed. This approach has also exposed areas for improvement in the existing project management strategies, which have since been modified. Realizing that the pavement-related items consume more than half of the overall project cost on average, NJDOT has begun to evaluate its most important assets (roadways and bridges) during the early, scoping phase rather than the later, design phase of projects.

INTRODUCTION

State officials and project managers, especially those in charge of funding, have long been aware of the competitive environment for transportation dollars. Limited budgets, an excessive number of deficient pavements, and the growing demand from the traveling public for a smoother pavement have further intensified the need for achieving long-term solutions for pavements.

The tragedies on September 11, 2001 and their devastating effects have further eroded the budgetary health, resulting in serious shortfalls of tax revenues and budget deficits for state agencies. For example, the State of New Jersey faces an overwhelming deficit of more than $5 billion for fiscal year 2003. At the same time, more monies are now being appropriated for ensuring homeland security and strengthening military resources. The effects of such deficits on pavement programs are becoming visible. As a result, a reduction in highway funding for 2003 is possible. Virginia Department of Transportation (VDOT) plans to slash its 6-year road program by $2.9 billion (29%) in an effort to address its budget constraints. California is considering gas tax to remedy the budgetary situations.

It is therefore realized that the need for strong and smart pavement programs to provide healthy, efficient pipelines for managing projects within the DOT network is greater than at any time in the past.

CAPITAL PROGRAMMING FOR PAVEMENT PROJECTS: THE NEW JERSEY APPROACH

DOT authorities in charge of finances and capital programming have long been aware of the necessity for a functional pavement program. The need for such a program is particularly great in New Jersey, as the Garden State has one of the most complex and congested infrastructure systems in the world. Recognizing this need, the New Jersey Department of Transportation (NJDOT) devised a performance-based capital programming mechanism, called the Capital Investment Strategy (CIS). This mechanism provides specific investment recommendations that conform to the broad goals and policies of NJDOT. In a nutshell, CIS is a 10-year plan for strategically investing New Jersey's capital transportation dollars. NJDOT also utilizes other capital programming plans, including *Transportation Choices 2025*, *Annual Transportation Capital Program* and the *Five-Year Capital Plan*, which were instituted as part of the Congestion Relief and Transportation Trust Fund Renewal Act of 2000.

CIS, which provides specific investment recommendations based on the broad goals and policies of NJDOT, promises the following:

- Clear *goals* that tell us where we want to go
- *Performance measurements* that tell us where we are
- Measurable *objectives* that we can work towards
- *Alternative investment scenarios* that we can use to consider "trade-offs" between various investment choices
- *Prioritization techniques* that we can use to evaluate individual projects

The products of CIS that are listed above are commendable. In this paper the authors intend to demonstrate how available techniques in mechanistic pavement engineering can be used to achieve these products. The benefits of achieving and utilizing these products at earlier phases of a project are explained.

Various tools and techniques for measuring pavement performance are and have been available to the transportation community. However, these tools and techniques have not been effectively used by all members of this community. One of the most commonly used tools for measuring pavement performance is the Falling Weight Deflectometer (FWD). In its application to measuring pavement performance, FWD data is used to determine the integrity of the pavement system and the anticipated service life of the pavement. The use of this tool is considered to be essential for the purpose of *performance measurement*. FWD data should also be utilized to prioritize a transportation agency's pavement assets. It is inevitable that the strongest and most efficient programs will take the lion's share of a budget. For example, a comprehensive and efficient bridge management system (such as one that monitors and predicts the performance of the bridge network) will intrinsically indicate that bridges have a strong need for rehabilitation dollars. The actual needs for assets with less comprehensive management systems, therefore, are underestimated, resulting in insufficient funding for such assets. In light of the budgetary constraints, it is therefore vital that the pavement industry advocates and utilizes all available tools and techniques to draw attention to the dire needs of our failing pavement infrastructure.

PERFORMANCE MEASUREMENT AT PROJECT LEVEL

It is beyond the scope of this paper to discuss the effectiveness of a management system (i.e., pavement management system) in achieving the overall strategies of a transportation agency. Instead, the authors intend to show the usefulness of the FWD in optimizing funding for projects that are in a DOT's pipeline. Such optimization of funding can be better achieved if pavement performance measuring techniques are utilized in the early stages of a project (i.e., the feasibility assessment and scope development phases) rather than the latter stages (i.e., the design phase). Such an approach enables better, more informed decisions to be made from both engineering and budgetary standpoints.

Most of New Jersey's roadways are approaching their critical point where pavement rehabilitation should be performed. The officials in charge of the ever-decreasing budgets are confronted with unanticipated pavement-related costs when a pavement actually undergoes construction. Therefore, it is believed that identifying the real budgetary needs of a project at its early stages could allow such authorities to better allocate funds. Hence, performance measurements and the associated pavement condition assessments have become vital complements to the existing programs of state agencies, such as NJDOT.

PAVEMENT EVALUATION APPROACH

NJDOT has determined that a comprehensive pavement evaluation in the early stages of a project can be a useful tool for design managers and financial planners. Currently, such a pavement evaluation is only performed for those projects that are anticipated to have large budget demands or complex construction staging requirements. It is envisioned, however, that more projects will utilize this approach once the evaluation process and life-cycle cost analysis (LCCA) procedure becomes more routine and efficient.

A comprehensive pavement evaluation often includes FWD testing, a detailed visual pavement condition survey, Dynamic Cone Penetrometer (DCP) testing, material testing, and a review of ride quality and surface distress data that are obtained using the ARAN equipment. Investigation of the behavior of the roadway foundation is considered to be a vital component of a proper pavement evaluation. Usually, such an investigation consists of a thorough review of the construction plans (i.e., As-Builts) and reviewing and/or performing a subsurface investigation. Laboratory testing of the underlying soil material is normally a component of a thorough pavement evaluation as well. Depending on the soil extracted from the project site, the proper soil testing is recommended. An analysis of the above-noted information and the use of a mechanistic design approach enable viable, cost-effective design alternatives to be developed. Another product of the pavement evaluation is the computation of the remaining life of the pavement. After the designs have been formulated, constructability issues are considered, the designs are revised (if necessary), and design alternatives are recommended. An LCCA is then performed to enable a cost comparison of the various alternatives.

This paper does not intend to describe in detail the design procedures identified above. Instead, the authors wish to demonstrate the usefulness of such procedures for the capital programming function of a transportation agency. The project examples, summarized below, utilized detailed pavement evaluations performed at the early stages of the design. This approach allowed project and program managers of NJDOT familiarize themselves with the true needs of their projects early on making them better prepared to allocate the construction dollars.

CASE STUDIES

Two recently-completed projects – Route I-295 and Route I-78 – will be used as case studies in this paper. The pavement-related activities for these projects included: the evaluation of the pavement structure for the mainline and shoulder lanes as well as several ramps within the project length; the selection of feasible rehabilitation alternatives for the pavement; development of pavement designs for these rehabilitation alternatives; and, a life-cycle cost analysis of the various rehabilitation alternatives. Sectionalization (i.e., the process of sectioning a project into segments that have a fairly uniform pavement condition and/or cross-section) was performed in these projects. This process helps in achieving the most cost-effective pavement rehabilitation plan for the project. Rather than using one blanket rehabilitation method and design for the entire project area, rehabilitation alternatives and designs that are based on the needs of each segment of the project are analyzed. The above-noted activities were performed for each segment of the projects.

Route I-295 Case Study

A pavement improvements project involving a nine-mile stretch of Route I-295 in New Jersey was studied at the scoping phase of the design. This scoping phase occurs prior to the initial/final design of the project.

The Route I-295 project, located in Camden and Burlington Counties, extended from milepost (MP) 32.0 to 41.0. Within these limits Route I-295 consisted of three 12 ft.-wide mainlines lanes, a 3 ft.-wide inside shoulder lane, and a 12 ft.-wide outside shoulder lane in both the northbound and southbound directions. The existing mainline pavement was constructed of Portland cement concrete (PCC). Transverse joints were spaced at 78 ft. in the Portland cement concrete (PCC) pavement. The existing shoulder lanes consisted of asphalt concrete (AC) pavement. The pavement evaluation and design consisted of extracting sixty (60) cores, compressive strength testing of the PCC cores, soil testing of the base and subgrade materials, DCP testing of the subsurface layers, a comprehensive visual survey (including cataloguing of the pavement distresses), FWD testing at midslab locations as well as joint locations, and a review of the construction history information (i.e., As-Built plans), boring logs, and geotechnical plans.

Based on the above-noted testing/investigative reviews and a review of some constructability issues that were raised by the transportation agency, it was determined that the project area could be sectionalized into two segments – a southern segment (MP 32.0 to 37.0) and a northern segment (MP 37.0 to 41.0). These segments had distinctly different pavement conditions. A detailed explanation of this case study is presented by Frabizzio et.al. (*1*). The causes of the poor performance in the southern segment were determined to be the method used for the stage construction of the project, material variability, a poor subgrade, and traffic-related parameters.

As part of this study, the load transfer efficiency (which is a measure of the ability of a joint to transfer load from one side to the other) of all transverse joints and the modulus values for the pavement layers were determined. The deflection data from FWD testing on the flexible pavement areas was used to backcalculate the AC layer modulus (E_{AC}), the base layer modulus (E_{base}), the subgrade resilient modulus (M_R), and the effective structural number of the pavement ($SN_{eff.}$). FWD testing at midslab locations in the mainline pavement was used to backcalculate the PCC layer modulus (E_{PCC}) and the modulus of subgrade reaction (k).

Based on a comprehensive engineering evaluation, several alternatives were considered for rehabilitating the existing pavement. These included AC reconstruction, PCC reconstruction, an AC overlay; and rubblization with an AC overlay. Backcalculation results from the FWD testing were used as inputs for the pavement designs.

A comprehensive LCCA was also performed for this project. In its application to pavement rehabilitation projects, an LCCA allows the overall costs over a given period of time (i.e., analysis period) for various competing alternative rehabilitation options to be compared. The costs considered include both Agency Costs (i.e., actual costs incurred by the roadway owner, such as those for construction materials) and User Costs (i.e., estimated costs to the users of the roadway for time delay, vehicle operating costs, etc.). The cost comparison provided by the LCCA can help an agency make its decision regarding which pavement restoration alternative should be selected.

The LCCA for this project was based on a 30-year analysis period. The pavement designs, which were based on the FWD test results, were used to determine the life-cycle cost of each rehabilitation alternative considered for each segment. The transverse joint treatments and slab undersealing quantities, which were determined using the FWD joint test results, were used to compute the life-cycle costs for the AC overlay alternative. The total life-cycle cost (including both Agency and User Costs) for each rehabilitation option considered in each segment, including rehabilitation of both the northbound and southbound directions, is provided in Table 1.

Based on the pavement evaluation and design results, the LCCA results, and other considerations, it was decided to utilize the AC overlay alternative for the northern segment. Similarly, it was decided to use the AC reconstruction alternative for the southern segment with the exception of the area from MP 33.7 to 34.6, which was slated for rubblization.

Route I-78 Case Study

At the feasibility assessment (FA) phase (prior to the scoping phase) of the project, NJDOT decided to perform a comprehensive pavement evaluation and project segmentation as well as develop pavement designs for Route I-78. This level of evaluation and design was considered at the FA level of the project because NJDOT felt that a thorough understanding of the pavement issues and construction/rehabilitation costs were critical to the success of the project.

The Route I-78 project, which was located in Essex County, extended from MP 50 to 58. Within these limits Route I-78 generally consisted of two lanes in the local corridor (i.e., local lanes) and three lanes in the express corridor (i.e., express lanes) in each of the eastbound and westbound directions. The mainline lanes were all 12 ft.-wide, while the shoulder lanes had a varying width. The existing mainline pavement was constructed of PCC. Transverse joints were spaced at 78 ft. in the PCC pavement. The existing shoulder lanes consisted of AC pavement. The pavement evaluation consisted of extracting cores, compressive strength testing of the PCC cores, soil testing of the base and subgrade layers, DCP testing of the subsurface layers, a comprehensive visual survey (including cataloguing of the distresses), FWD testing at midslab locations as well as joint locations, a review of the construction history information (i.e., As-Built plans), and a subsurface investigation.

The comprehensive testing and investigative reviews yielded six segments. The number of segments was reduced to three, however, after the pavement design information and constructability issues were considered. The pavement designs for each segment are presented in Table 2. Similar to the Route I-295 project that was previously discussed in this paper, this project also consisted of determining the load transfer efficiency for all transverse joints and backcalculating the pavement layer moduli (i.e., E_{AC}, E_{base}, M_R, SN_{eff}, E_{PCC}, and k) for the AC and PCC pavement areas within the limits of the project.

Based on a comprehensive engineering evaluation, several alternatives were considered for rehabilitating and reconstructing the existing pavement. Due to the scarcity of funds, the project managers and the financial planners were interested in both long-term and short-term solutions. The long-term pavement design alternatives were designed to provide a sufficient amount of structural capacity to enable the pavement to withstand the anticipated traffic volume for the anticipated service life. These alternatives included: (1) placing a structural AC overlay over the existing jointed reinforced concrete pavement (JRCP) after repairing the existing pavement distresses; (2) rubblizing the existing JRCP and placing a structural AC overlay over the resulting rubblized base layer; (3) removing the existing JRCP and performing AC reconstruction; and, (4) removing the existing JRCP and performing JRCP reconstruction. The short-term pavement restoration alternatives included: (1) repairing all of the existing pavement distresses and performing micro-grinding to restore ride quality, and (2) placing a functional (2 in.-thick) AC overlay over the existing JRCP after repairing the existing pavement distresses to restore ride quality and strengthen the pavement system.

A comprehensive LCCA was also performed for this project. This work included determination of the remaining life of the existing pavement structure and development of pavement restoration alternatives and designs. This information was then incorporated into a detailed LCCA to enable construction costs to be optimized. The LCCA considered 162 scenarios for the Route I-78 eastbound and westbound local and express roadways between mileposts 50.4 and 58.5. These scenarios considered the six (6) pavement restoration alternatives, three (3) pavement segments for each of the three (3) I-78 roadways considered in the project, and three (3) discount rates. The results from the LCCA are presented in Table 3.

SUMMARY

It has been demonstrated that the use of non-destructive testing (specifically FWD testing) for pavement evaluation and a thorough investigation of the existing pavement subsurface layers (via coring, DCP testing, material testing, and boring data) can provide useful results for measuring pavement performance. This approach can be especially fruitful if it is done during the conceptual phases of a project. The work performed in the two case studies presented in this paper allowed construction costs and the durations for construction to be determined during the early stages of the projects. Investigation of the remaining life for both short-term and long-term pavement restoration alternatives and the incorporation of the results into the LCCA are especially useful to program managers. The LCCA can be considered in collaboration with the available budget to enable selection of the most cost-effective timing and type of rehabilitation for each pavement segment. By using this approach early in the life of the project, it is possible to program major construction efforts at different times to allocate funding in such a manner as to maximize the return on the investments. This approach also assists in accelerating projects from the design phase to the construction phase, since optimum stage construction can also be evaluated.

It was the intent of the authors to present an approach that provides flexibility to both project managers and financial planners of NJDOT. This approach, which conforms to NJDOT's long-term goals, provides prioritization techniques and flexibility in these difficult times.

REFERENCES

1. Frabizzio, M., V. Ganji, and K. Tabrizi. Case Study: Role of the Falling Weight Deflectometer in Pavement Rehabilitation Projects. Presented at *FWD Users' Group Meeting 2001*, Gulfport, MS, Oct. 14, 15, and 16, 2001.

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TABLE 1 Life-Cycle Costs for Four Rehabilitation Alternatives on Route I-295

Alternative	Southern Segment	Northern Segment
AC Reconstruction	$23,994,000	$19,132,000
PCC Reconstruction	$33,004,000	$26,357,000
AC Overlay	$22,639,000	$16,166,000
Rubblization w/AC Overlay	$21,026,000	$17,029,000

TABLE 2 Pavement Designs for Each Segment of the Route I-78 Roadways

Section No.			**1**	**2**	**3**	**4**	**5**	**6**	**7**
Limits (MP)			**50.6**	**51.9**	**53.1**	**54.8**	**55.4**	**56.7**	**57.1** **58.4**
Segment			**Segment A**			**Segment B**			**Segment C**
Westbound	**Local**	**Repair and Overlay (in.)**	9 in.			8 in.			6 in.
		Rubblize and Overlay (in.)	9 in.			8 in.			8 in.
		Flexible Reconstruction	13 in. AC, 8 in. DGABC, 12 in. Subbase (33 in. Total)			12 in. AC, 8 in. DGABC, 12 in. Subbase (33 in. Total)			12 in. AC, 8 in. DGABC, 12 in. Subbase (33 in. Total)
		Rigid Reconstruction	14 in. PCC, 4 in. BitStab. DGABC, 8 in. Subbase (26 in. Total)			13 in. PCC, 4 in. BitStab. DGABC, 8 in. Subbase (26 in. Total)			13 in. PCC, 4 in. Bit. Stab. DGABC, 8 in. Subbase (26 in. Total)
Eastbound	**Express**	**Repair and Overlay**	9 in.			8 in.			6 in.
		Rubblize and Overlay	9 in.			8 in.			8 in.
		Flexible Reconstruction	13 in. AC, 8 in. DGABC, 12 in. Subbase (33 in. Total)			12 in. AC, 8 in. DGABC, 12 in. Subbase (33 in. Total)			12 in. AC, 8 in. DGABC, 12 in. Subbase (33 in. Total)
		Rigid Reconstruction	14 in. PCC, 4 in. BitStab. DGABC, 8 in. Subbase (26 in. Total)			13 in. PCC, 4 in. BitStab. DGABC, 8 in. Subbase (26 in. Total)			13 in. PCC, 4 in. BitStab. DGABC, 8 in. Subbase (26 in. Total)
	Local	**Repair and Overlay**	9 in.			8 in.			6 in.
		Rubblize and Overlay	9 in.			8 in.			8 in.
		Flexible Reconstruction	13 in. AC, 8 in. DGABC, 12 in. Subbase (33 in. Total)			12 in. AC, 8 in. DGABC, 12 in. Subbase (33 in. Total)			12 in. AC, 8 in. DGABC, 12 in. Subbase (33 in. Total)
		Rigid Reconstruction	14 in. PCC, 4 in. BitStab. DGABC, 8 in. Subbase (26 in. Total)			13 in. PCC, 4 in. BitStab. DGABC, 8 in. Subbase (26 in. Total)			13 in. PCC, 4 in. BitStab. DGABC, 8 in. Subbase (26 in. Total)

TABLE 3 Life-Cycle Costs for Six Rehabilitation Alternatives for Route I-78

	Alternatives	**Segment A MP 50.6 – 54.8**	**Segment B MP 54.8 – 56.7**	**Segment C MP 57.1 – 58.4**	**Total Cost for All Segments**
Long-Term	Structural AC Overlay	$7,358,000	$2,984,000	$1,955,000	$12,297,000
	Rubblization	$6,494,000	$2,784,000	$1,917,000	$11,195,000
	AC Reconstruction	$8,854,000	$3,813,000	$1,755,000	$14,422,000
	JRCP Reconstruction	$10,298,000	$4,369,000	$3,103,000	$17,770,000
Short-Term	JRCP Repairs	$11,092,000	$4,623,000	$3,137,000	$18,852,000
	Functional AC Overlay	$10,718,000	$4,458,000	$3,114,000	$18,290,000