COMPARATIVE EVALUATION OF DEFLECTION AND WAVE PROPAGATION NONDESTRUCTIVE TESTING METHODS FOR PAVEMENTS: IMPLICATIONS FOR IMPLEMENTATION AT STATE AND LOCAL LEVELS

FINAL REPORT - PHASE I

Submitted to

REGION II TRANSPORTATION RESEARCH CENTER

and

NEW YORK CITY DEPARTMENT OF TRANSPORTATION

NEW YORK STATE DEPARTMENT OF TRANSPORTATION

NEW JERSEY STATE DEPARTMENT OF TRANSPORTATION

by

CUNY INSTITUTE FOR TRANSPORTATION SYSTEMS
THE CITY COLLEGE
NEW YORK, NEW YORK
Neville A. Parker   Hesham A. Ali

CORNELL UNIVERSITY
ITHACA, NEW YORK
Lynne H. Irwin   Peter Messmer

RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY
PISCATAWAY, NEW JERSEY
M.H. Maher   Nenad Gucunski

July, 1994

ACKNOWLEDGEMENT

The authors of this report wish to acknowledge the encouragement and the support of New York City Department of Transportation (NYCDOT), the New Jersey Department of Transportation (NJDOT), the New York State Department of Transportation (NYSDOT) and the Consolidated Edison Company of New York (Con Ed). Individuals in these organizations who were particularly helpful, are also acknowledged as follows:

NYCDOT:	Dr. Lucius Riccio (formerly commissioner), Tom Jelliffe, Richard Ocken, Barney LaGreca, Anthony Fasulo, Dan Mando, Frank Mark.
NJDOT:	Richard Hollinger, Nicholas Vittolo
NYSDOT:	Dr. Wei-Shih Yang
Con Ed.:	Richard Scholz, Theodore Bavuso, Frank Ayers, George Greenwood

NYCDOT and NJDOT provided both cash and direct services as matching funds to the USDOT grant, while NYCDOT and Con Ed provided the laboratory of NYCDOT streets during the day and at night as needed, including traffic control. Both NYSDOT and NJDOT provided access and traffic control on their state highways for open condition field verification testing of FWD and SASW equipment. To all agencies and personnel, listed and unlisted who have supported the project we extend our deepest appreciation, and look forward to continued collaboration in the next phase of study.

Finally, the authors acknowledge the contributions of the following graduate students to the project:

City University of New York:	Courtney Nation, Joseph Valcin, William Adzimahe
Rutgers, The State University:	Vahid Ganji

EXECUTIVE SUMMARY

In New York City, as in other highly urbanized areas, several factors exist that make it too difficult to apply pavement management systems methodology in the traditional way. One factor is the existence of underground utilities (pipes, conduits, sewers, electrical cables, etc) whose condition and life expectancy would greatly affect the rehabilitation decisions. Another factor is the existence of utility cuts which is the most significant life-limiting factor for NYC pavements. A third factor is the potential of future patching which affects pavement performance. A fourth factor is the fact that more than 70 percent of NYC pavements are made of a special type of pavements, i.e. "composite pavements", which is not the type of pavement idealized for some of Non-Destructive Testing (NDT) analysis techniques such as Falling Weight Deflectometer (FWD).

This complexity has long discouraged planners and pavement engineers from employing NDT-based pavement management systems. Instead, they employ distress- based pavement management systems. Although the latter system is easier to implement, the Street Assessment Rating (SAR), a distress- based system used by NYCDOT to evaluate pavement condition (excellent, good, fair, poor, etc.), has limited utility as a determinant for rehabilitation strategies. SAR indicates only the "current" condition of the pavement, which may not by itself be a reliable indicator of remaining economic life.

Each street block in NYC is unique depending on the type and the condition of the underground utilities, the type of pavement, the future patching rate and the expected traffic volume. Therefore, the use of a probabilistic approach, in isolation from the circumstances of each individual street block, is questionable. The following scenarios[1] can best illustrate this concept:

> Scenario One: A street of very low SAR needs pavement rehabilitation or reconstruction. The street's age is likely between 50 and 70 years. Utilities need replacement, but this utility work can wait 10 to 15 years, for example. However, repair of the pavement can not wait because it is in such poor condition. According to current practice, this scenario could likely be addressed by a mill and overlay of only 1/2 inches, for example , due to budget constraints. According to experience, this may not be an appropriate decision to last the 10 to 15 years. Often, on high traffic streets in poor condition, the mill and overlay might last only 5 to 8 years.
>
> In this scenario, the engineered resurfacing approach could apply technology and analysis to generate several potential rehabilitation alternatives that should last the remaining 15 years until total reconstruction of the street, in combination with major repairs to water and sewer mains, is undertaken. Although the engineered resurfacing alternative chosen would have a first cost that is more expensive than mill and overlay of 1/2 inches, it should be selected because it has a lower life-cycle cost over the 15 years period. In

[1] These scenarios are declared to be of great interest to NYCDOT, because they are frequently encountered.

contrast, the mill and overlay alternative may result in the need for a second rehabilitation, before the reconstruction work is done. Or, if a second rehabilitation is not undertaken after the first one fails, the result will be higher vehicle operating costs and discomfort to the traveling public, due to poorer road surface.

The key to cost effective decision making, would be to compare the potential rehabilitation alternatives generated through the engineered resurfacing approach, using life-cycle cost. The alternative with the lowest life-cycle cost or highest benefit to cost ratio, for the 15 year period, should be chosen.

Scenario Two: A street needs major geometric improvement. The utilities below are in a good condition and do not require major work. However, the street will be opened up for the geometric improvement and there is an opportunity to reconstruct the whole pavement structure if necessary, At issue is whether the PCC layer actually needs to be replaced or can a more cost effective rehabilitation alternative be designed to last for some desired life: In this case the engineered resurfacing approach would be needed.

Scenario Three: A limited utility work must be done. Because the street will be opened up for the utility work, the issue arises of how extensive the pavement replacement should be, since it will have to be rebuilt to some extent anyway. The answer to this is a function of how intact the existing PCC and AC layers are. Whether it would be prudent to replace the entire pavement or rehabilitate it is a question that must be considered. If it is possible to rehabilitate, then an engineered resurfacing alternative can be developed to last a desired life time.

The objective of this project is to develop a Non Destructive Testing (NDT)- based framework to effectively manage urban pavements at the project level. This framework incorporates the conditions of the underground utilities, the type of pavement, the existing patches and the future patching in the decision making process. The proposed framework is deemed to be cost effective, simply because it is based on selecting the alternative associated with the lowest life-cycle cost, among all other potential alternatives.

In order to accomplish this objective, a three-stage plan was designed. The first two stages have been executed in this Phase I, while the third one will be performed in the next Phase. The components of the plan are:

Stage One: Examining a Variety of NDT Techniques in the Urban Environment. The objective of this stage is to develop a better understanding of the capabilities of some NDT techniques, namely, Falling Weight Deflectometer (FWD) and Spectral Analysis of Surface Waves (SASW), and to identify the areas of strength and weakness of each technique. A series of tests were conducted to achieve the objective of this stage:

First, the performance of SASW test setup was examined in two locations :

1) On May 27, 1992, both SASW and FWD techniques were examined in the

"open highway" conditions. The testing took place at SHRP LTPP test section on I-481, north of Syracuse, New York

2) On July 7, 1992, SASW testing was conducted at I-195 east of Princeton, New Jersey. Besides collecting data, the test was also used to demonstrate SASW technique to members of NJDOT and NYCDOT.

Second, SASW testing was conducted in two locations in New York City for the purpose of examining and assessing the capabilities of this technique in urban conditions:

1) On May 13, 1993, at the corner of Broadway and 32nd Street, NYC

2) On May 14, 1993, at the corner of 10th Avenue and 49th Street.

Finally, both SASW and FWD were conducted simultaneously, in New York City, to examine each technique against the other in the urban environment. Testing took place on June 14, 1993, at East 16th Street between 5th Avenue and Union Square West. Parallel to the above testing, was pavement sampling and coring to provide a basis for comparison.

Stage Two: Develop an NDT- Based Framework to Effectively Manage Urban Pavements at the Project Level. This framework is represented in Figures 5.1 and 5.2.

Stage Three: Evaluate/ Validate the Proposed Framework By Applying it in a NYC Street. A trial project is required to implement the process. The trial project should be a city street where total reconstruction is planned. This stage is to be performed in Phase II of this project.

The following are the project findings up to the present point

OUTPUTS OF STAGE ONE:

* FWD Deflection Profiles can be used to identify the likely location of full depth AC patches, in a PCC slab, that have been covered by AC overlays.

* Back-calculation of layer moduli might well not be necessary because the mechanistic-empirical overlay design methods currently in use, might not be precisely relevant to composite pavements.

* In the case where deflection data indicates extensive areas of utility cuts and cracking in the PCC slab, there may be a benefit in performing back-calculation, provided that enough test points do not violate the assumption of layered-elastic theory and yield valid solutions for layer moduli.

* Detailed utility information is required. A 12" water main close to the surface (for example, at a 2 feet depth) may have a significant impact on the measured deflections and back calculated moduli.

* SASW determined moduli are based on the speed at which a wave moves through a material. The result is a modulus which is an actual material property. For composite pavements, FWD back-calculation techniques have difficulty in determining the modulus of the AC and PCC layers, that are representative of the actual material properties, because the deflections are dominated by only the PCC layer. In this case the SASW moduli can be used to determine the AC and the PCC moduli.

* SASW data determines layer thickness. This is an important feature of SASW. SASW could eliminate the need for cores taken exclusively to determine layer thickness. Also SASW could be used to verify potential patches detected by FWD deflection profiles.

* Ground Penetrating Radar (GPR) is a third technique that could be added to enhance the performance of NDT family of techniques. It is capable of providing layer thicknesses, locating the underground utilities, and confirming the location of full depth AC patches.

OUTPUTS OF STAGE TWO:
The output of stage two is a framework to use FWD/SASW/GPR together with the utility information and patching data to select a cost-effective remedial solution for urban pavements. Figures 5.1 and 5.2 demonstrate this framework and are reproduced here for demonstration purposes. Again, this methodology needs to be tested in a trial project.

ORGANIZATION OF THE REPORT

This report consists of five sections. Section I "Introduction", in which the objectives of the project, the participating universities, the supporting agencies, the generated reports, and the evolution of the project to its present fashion are presented. Section II "Failure Mechanizms" discusses the failure modes associated with each pavement type (flexible, rigid and composite). A discussion as to how pavements deteriorate due to patching, and how to incorporate the effect of patching when designing a rehabilitation scheme is also presented in this section. The importance of section II is that it allows the reader to understand how pavements fail, what factors contribute to its failure and how to prevent or "control" that failure.

Section III "Nondestructive Testing Techniques" provides an overview of three pavement testing techniques: FWD, SASW and GPR. In this section a brief explanation of the theoretical background, the data collection process, the equipment used and the data analysis methods of each technique is presented. If the reader is familiar with these techniques, then he can skip this section without loss of continuity.

Section IV "Field Investigation and Results" presents the testing plan that the research team has developed and executed in several locations, the collected data, the analysis of these data and the lessons learnt from these field investigations. Section V "Conclusions and Recommendations" concludes our findings for Phase I and presents our recommendations for Phase II.

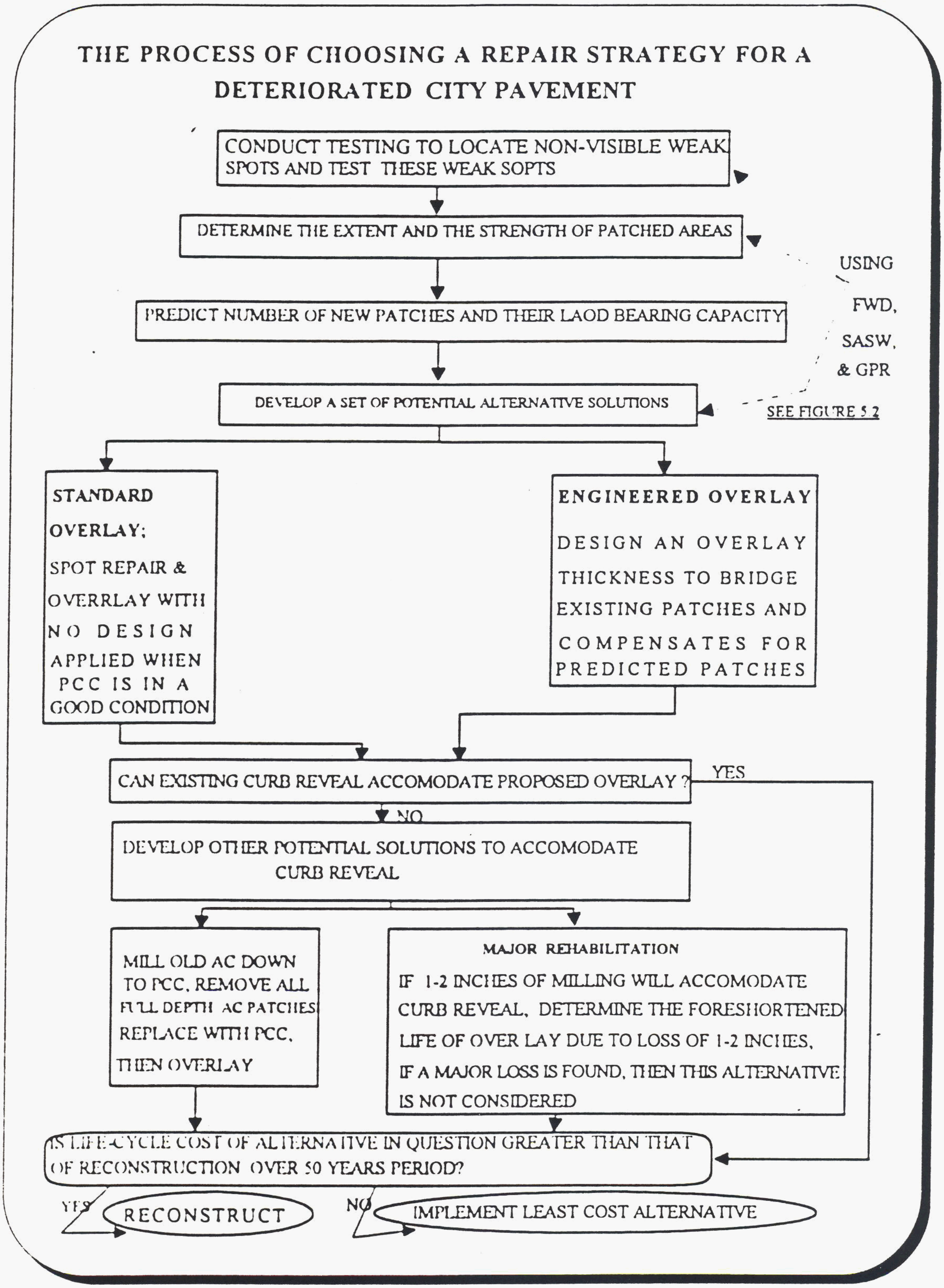

FIGURE I (SAME AS FIGURE 5.1)

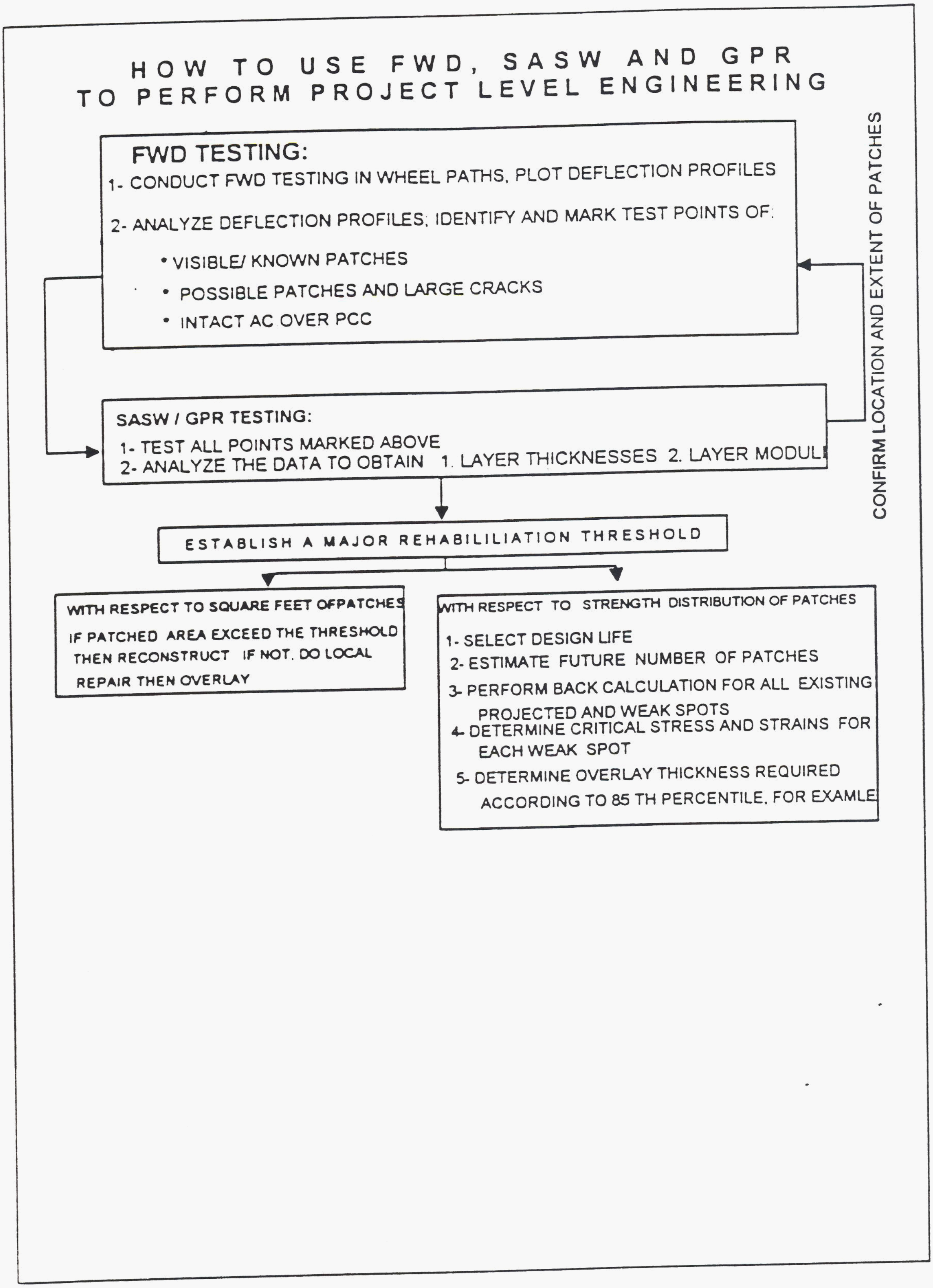

FIGURE II (SAME AS FIGURE 5.2)