CHAPTER 1

Introduction

1.1 INTRODUCTION

For the viability of national, state, and local economies, efficient operation of the United States highway network is critical. The U.S. is served by the world's largest highway system, including 6.3 million kilometers of streets, roads, and highways, as well as more than 570,000 bridges. Annually, this transportation system carries—at a level of $775 billion—over four trillion passenger miles of travel and 3.8 trillion ton miles of domestic freight, close to 11 percent of the Gross Domestic Product (GDP) (U.S. Department of Transportation 1995).

The majority of the US highway system was constructed during the 1950s and 1960s according to population, travel, and freight estimates relevant to those periods. Now, however, as traffic and freight loads have increased exponentially, and as aging, environmental action, use, and misuse have taken their toll, these older systems have begun to deteriorate rapidly, a situation that demands more effective pavement rehabilitation methodologies. In 1993, 52% of the Interstate Highway System was found to be in fair to poor condition (FHWA 1995). From 1973 to 1993, road and street mileage increased only 2.6%, while the number of vehicles using those roads increased 54%, and vehicle miles of travel by 75% (FHWA 1995). Since the weakened infrastructure of the highway system cannot simply be replaced, rehabilitating it presents a serious challenge. The monetary cost and the disruption to daily life would be astronomical: according to the 2001 ASCE report, over the next five years, $1.3 trillion will be needed to fix the nation's highway infrastructure.

In recent years, interlayer systems have received considerable attention as viable solutions to the problem of enhancing flexible pavement performance. Introduction of such systems to the transportation field was prompted primarily by the unsatisfactory performance of traditional materials to the dramatic increase and change in traffic patterns. The use of interlayer systems is not new, however. As early as the 1930's, Beckham and Mills (1935) suggested the use of cotton fibers, similar to onion bag material, as an interlayer system in South and North Carolina highways. Nowadays, such degradable materials as cotton fibers are not the best alternative for reinforcement, but the concept remains the same.

Although it is generally recognized that each interlayer product should be used for a specific goal and that not all interfaces have a strengthening function, it is not well understood that, if used inappropriately, interlayers actually can contribute negatively to pavement performance. Surveys have shown that field engineers tend to believe any interlayer products can be applied to improve pavement performance regardless of their contributing mechanisms (Francken 1993). This oversimplified view of the situation has led to a certain amount of mistrust among highway agencies regarding the benefits of interlayer systems. Contradictory opinions and experiences also have been reported in the literature. While some studies emphasized the surplus advantages, such as substantial savings in hot-mix asphalt (HMA) thickness (Kennepohl et al. 1985), others found the use of interface systems "useless" (Donna 1993).

Pavement systems are already among the most difficult civil engineering structures to analyze using analytical methods, and adding to them an interlayer system increases the complexity level of the analysis. To optimize the use of interlayer systems in flexible pavement, several concerns must be addressed:

- Understanding the contributing mechanisms for each distinct function.
- Determining the type of interlayer systems to be used for each application.
- Installation procedures for each interlayer system.
- Quantification of the benefits provided by each interlayer.
- Possible reverse effects of interlayer systems.

1.2 PROBLEM STATEMENT

Utilizing interlayer systems to improve the performance of existing and new pavement appears promising. However, after 30 years of evaluation and testing, reports on their performance are still mixed and anything but conclusive. This is due mainly to the gap between in-situ performance and the lack of a well-conceived mechanism to quantify system effectiveness. In addition, new interlayer products are regularly introduced to transportation agencies that lack the fundamental supportive information necessary to an accurate determination of their benefits. The current situation is best described by Steen's observations (2000):

> *"Over the years, I have noted many attempts to enter this huge road maintenance market. Every manufacturer within the geosynthetic field seems to have tried to use some of their standard geotextile products as a solution to retard reflective cracking. More or less successfully, however. Each time, expensive, complicated, and overestimated solutions are used in road maintenance, it simply destroys the whole idea of geosynthetic interlayers, and this also reflects on suitable solution."*

1.3 OBJECTIVES

To address the aforementioned problem statement, the main objective of this study is to quantitatively validate the effectiveness of interlayer systems in flexible pavement. To achieve this general objective, three different interlayer systems—a newly developed geocomposite membrane and two types of steel reinforcement nettings— have been installed in four sections of the Virginia Smart Road. Using field measurements and theoretical investigation, these interlayer systems were evaluated in the following applications:

1. Quantify and validate the geocomposite membrane effectiveness as a moisture barrier using ground penetrating radar (GPR) and time domain reflectometer probes.

2. Quantify and validate the geocomposite membrane effectiveness as a strain energy absorber.
3. Quantify and validate steel reinforcing nettings effectiveness when used as reinforcement for HMA.
4. Quantify and validate steel reinforcing nettings effectiveness to prevent reflective cracking in rehabilitation applications.
5. Develop a design scheme for flexible pavements incorporating steel reinforcement used in rehabilitation applications.

1.4 RESEARCH APPROACH

To accomplish the objectives of this study, the following tasks were proposed (see Figure 1-1):

- Task 1. Quantify the ability of geocomposite membrane as a moisture barrier: This task was achieved by monitoring the water movement within the pavement structure using GPR, and instrument response (time domain reflectometer) due to water variation in the granular layers. The effect of the geocomposite membrane on the measured moisture content in the granular layers was evaluated.

- Task 2. Verify the capability of geocomposite membrane as a strain energy absorber: This task made use of a 2-Dimensional (2D) finite element model. A crack was induced underneath the interlayer system and propagation of the crack was studied based on a fracture mechanics approach.

- Task 3. Verify and quantify the capability of steel nettings as reinforcement for HMA: This task was divided into two subtasks:

    - Evaluate steel reinforcement effectiveness in reducing vertical deflections. Steel reinforcement was installed in sections I and L at the Virginia Smart Road in the instrumented lane, while the passing lane consisted of the same pavement design without steel reinforcement. Comparison was therefore established between the deflection measurements with and without steel reinforcement.

To validate field measurements, a 3-dimensional (3D) finite element model was then developed to accurately simulate steel reinforcing nettings (non-homogeneous layer with openings). This model was then used to investigate steel reinforcing netting effectiveness based on FWD measurements. The first step consisted of backcalculating the layer moduli using finite element for the passing lane without steel reinforcement. Then, once steel netting was incorporated into the model, its effect on the calculated deflections was evaluated.

- Develop a second 3D finite element model to evaluate the performance of the steel reinforcing netting when subjected to dynamic vehicular loading. After calibration of the model based on instrument responses and backcalculated moduli from task (3-a), the effects of steel reinforcement on pavement responses were evaluated. The viscoelastic behavior of HMA was considered in the analysis.

- Task 4. Verify and quantify steel nettings effectiveness in rehabilitation applications: A set of 3D finite element models was developed to study the ability of steel reinforcement to abate reflective cracking, which results from the movement (due to thermal and traffic loadings) of existing cracks in an old pavement into a new placed HMA overlay. The stress intensity factor was calculated for the crack at different locations, and a regression model was used to describe the resulting stress intensity factor as a function of the crack location. While the crack initiation phase was described using a classical fatigue law developed by the Belgium Road Research Center (BRCC), the crack propagation phenomenon was described using the empirical power law developed by Paris and Erdogan (Paris and Erdogan 1965):

$$\frac{dc}{dN} = A(\Delta K)^n \qquad (1.1)$$

where

c = crack length;

N = number of loading cycles;

A and n = fracture parameters of the material; and

ΔK = stress intensity factor amplitude.

- Task 5. Design scheme: This task involves reflecting upon and quantifying the results of Task 4 by incorporating steel reinforcement in a design procedure that easily predicts the service life of a rehabilitated flexible pavement against reflective cracking. The strategy followed to achieve this task is shown in Figure 1-1.

1.5 SCOPE

In this dissertation, each chapter is considered a stand alone work with minimal references to other parts of the study. This format hypothesizes that a technical paper will result from each chapter; therefore, each chapter possesses its own conclusions and references. An effort was, therefore, made to include in each chapter the necessary background, with special care to avoid redundancy. Background related to this study is presented in Appendix A.

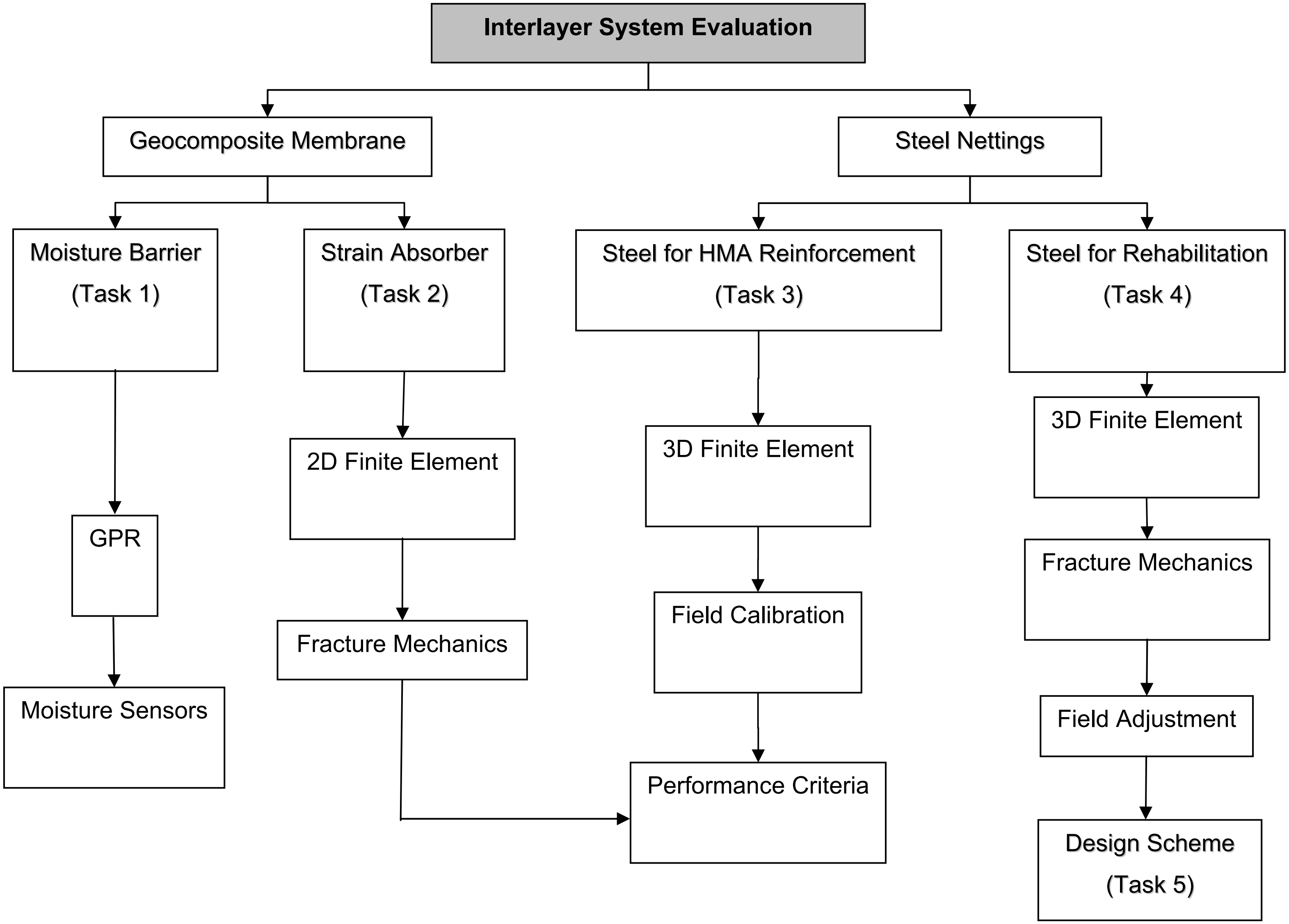

Figure 1-1 Research Approach

The specific objective of each chapter is as follows:

- Chapter 2 investigates the effectiveness of the geocomposite membrane as a moisture barrier.
- Chapter 3 validates the effectiveness of the geocomposite membrane as a strain energy absorber.
- Chapter 4 presents the effectiveness of steel reinforcing netting as reinforcement for HMA.
- Chapter 5 validates the effectiveness of steel reinforcing netting to delay the reflection of cracks in rehabilitation applications.
- Based on the results of Chapter 5, Chapter 6 introduces the development of a new overlay design model that considers reflective cracking as the failure controlling mechanism.
- Chapter 7 presents a summary of this study, along with findings, conclusions, and recommendations for future research.

1.6 REFERENCES

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