CHAPTER 7

Summary, Findings, Conclusions, and Recommendations

7.1 SUMMARY

After 30 years of testing and evaluation, successful implementation of interlayer systems in typical pavement design has not yet been achieved. This could be due to the fact that the benefits of these systems are not quantified. Prior to determining the cost effectiveness of interlayer systems, a quantification of their benefits is essential. It is imperative to realize that some side effects are to be expected; they must be identified and dealt with accordingly.

This study quantifies the benefits of two interlayer systems to different pavement applications: steel reinforcement and a newly-designed geocomposite membrane. The use of the geocomposite membrane was evaluated as a moisture barrier using the results of time domain reflectometry and ground penetrating radar surveys. Results validated that, when placed on top of the granular layers, a geocomposite membrane can reduce or prevent the infiltration of rainwater. The effectiveness of the geocomposite membrane a strain energy absorber was investigated using a 2D finite element approach and deflection measurements using falling weight deflectometer (FWD). In this case, the geocomposite membrane will create a protective, compressive field around the crack tip, separating the criticality of the stress field in the cracked area from the bottom area. However, if the crack passes through the interlayer, a faster propagation rate than in regular pavements is expected. This, therefore, emphasizes the importance of proper interlayer installation.

Steel reinforcement was evaluated as reinforcement in new pavement systems based on experimental results and finite element (FE) modeling. Results of this study indicate that, in general, steel reinforcement would be effective in new pavement systems during both the crack initiation and propagation phases. The effectiveness of steel reinforcement in delaying the reflection of cracks in rehabilitation of existing pavement was validated using a 3D finite element approach. In this case, the crack is already well established in the existing pavement, and the contribution of steel reinforcement starts from the early stage of the overlay service life. In this case, steel reinforcement delays movement of the crack into the overlay and reduces the rate of subsequent crack propagation.

7.2 FINDINGS

This study has determined the following findings:

- Installation of the geocomposite membrane was easy. The bonding between the membrane and the surrounding layers is greatly affected by the applied tack coat rate. An excess of only 0.2 kg/m^2 more than the optimum tack coat was found to significantly reduce bonding.

- Over the entire 20-month monitoring period, when the geocomposite membrane was used, the measured volumetric moisture content was relatively constant, from 8 to 10%. This confirms the long-term effectiveness of the membrane as a moisture barrier.

- The geocomposite membrane proved to prevent water infiltration even if installed in the upper HMA layer; however, the water should be drainable to avoid, stripping of the HMA.

- A geocomposite membrane creates a protective shield around the crack tip, separating the criticality of the stress field in the cracked area from the bottom of the overlay. Moreover, a compressive horizontal field helps close the crack.

- A strain energy absorber would be effective in the crack propagation phase only if the crack does not pass through the interlayer and propagate horizontally at the interlayer-existing pavement interface. In order to prevent the crack from passing through to this interface, the interlayer must be installed correctly. If damage to or tearing of the interlayer occurs, its contribution to absorbing strain energy would be altered.

- Steel reinforcement installation is critical for pavement performance. Its installation was straightforward. Nailing or slurry seal are currently used to install the interlayer.

- Ground penetrating radar can be used as quality control after steel reinforcing netting installation and paving. Although the criticality of the observed distortions could not be quantified, this technique could be used to detect improper steel reinforcing netting installation.

- Given the appropriate boundary conditions and element dimensions, a good agreement was found between the layered theory and the FE method. A recommended element thickness of 6.35mm for modeling the critical regions will help avoid critical jumps at the interfaces and ensure continuity of the straining actions.

- Two- and three-dimensional finite element techniques were successfully used in this study. Use of these techniques is recommended for investigating factors that can not be accurately simulated using the layered theory such as crack propagation, dynamic loading, and friction models.

- Infinite elements were used effectively to model in horizontal directions the far field region of pavement systems. Modeling this region using regular elements would increase tremendously the required computational time and data storage requirements.

- Elastic element foundations were successfully used to simulate the support provided by the subgrade to the pavement structure. These elements, which act as nonlinear springs to the ground, provide a simple way of including the stiffness effects of the subgrade without fixation of nodes at the bottom of the models.

- Finite Element methods are effective in backcalculating the layer moduli of complex pavement systems. In general, up to 20 iterations might be needed to achieve an acceptable level of fit. When regular back calculation programs fail to provide reasonable results, though, this level of complexity is justified.

- The elastic solution could lead to erroneous results that would over-predict pavement service lives against major distresses, such as fatigue cracking. Hence, viscoelastic modeling of the HMA layers must be used to simulate pavement responses to vehicular loading.

- Based on FWD and finite element simulation, it was found that for the considered pavement structures, the contribution of steel reinforcement to surface vertical deflections is minimal. Such testing may be useful to evaluate the contribution of steel reinforcement to weak pavement structures, but is not recommended for strong pavement structures, which was the case in this project.

7.3 CONCLUSIONS

Based on the results of this study, the following conclusions can be drawn:

- Ground-penetrating radar surveys and time domain reflectometer validated the effectiveness of the specially-designed geocomposite membrane in preventing water from infiltrating to the underlying layers and in successfully draining the water to the shoulders. A pavement drainage system, composed of a permeable asphalt-treated drainage layer backed by a geocomposite membrane, appears capable of removing drainable water from the pavement system, as well as provides a dry service condition for the underlying layers even in the event of heavy rain.

- When used in rehabilitation applications, given the appropriate thickness and properties, a soft interlayer is able to dissipate most of the available energy at the crack tip and thus diminish the potential of an existing crack to reflect into the overlay. However, when a strain-energy absorber layer is used, fatigue of the overlay should be adequately controlled through the proper design and selection of the overlay thickness.

- The use of steel reinforcement in new flexible pavement systems was found effective. For the considered pavement structures (sections I and L), steel reinforcement was found to delay the initiation of the cracks by a factor ranging between 6 and 260% depending on the stiffness of the HMA layers, the reinforcing pattern, and the direction of the strain at the bottom of the HMA layers. After crack initiation, the contribution of steel reinforcement to the pavement structure will still be significant because it delays propagation of the crack to the pavement surface. This phase, which was analyzed in pavement rehabilitation applications, will increase the percentage at which the interlayer contributes to pavement performance.

- By contributing positively to the crack initiation and propagation phases, steel reinforcement is effective in delaying the reflection of cracks. The percentage of improvement that occurred during the crack initiation phase ranged between 10-40%, mainly depending on the overlay thickness. The percentage of improvement that occurred during the crack propagation phase ranged between 40-170%, depending on the stiffness and thickness of surrounding layers. The percentage of improvement in the total service life against reflective cracking ranged between 50-80%, depending on the overlay thickness and the pavement structure's existing conditions.

- A simplified overlay design procedure was developed to predict the service live of rehabilitated flexible pavement systems against reflective cracking with and without steel reinforcement. The developed models accurately predict the number of cycles to failure against reflective cracking.

7.4 RECOMMENDATIONS

This study is the first step in effectively quantifying the benefits of interlayer systems to pavement applications. Based on the findings and conclusions of this study, the following guidelines for future research are suggested:

- Although an effort was made to link available experimental observations and well-established engineering theories, field validation is needed.

- A cost-benefit ratio need to be established for the different interlayer systems and compared to typical pavement strategies.

- Although this study exclusively focused on flexible pavement systems, the approach followed in this study should be extended to rigid pavement structures.

- The presented models consider reflective cracking as the failure controlling mechanism. These models may be incorporated into a broader overlay design method that would consist of different modules, each covering a specific failure mechanism of the overlay.

- The developed models consider only reflection of cracks induced by traffic loading. Other parameters that should be considered are the effects of environment.