Effect of Stiffness Ratio on Slippage Cracking Due to Interlayer Bonding Failure in Hot Mix Asphalt Pavement

Yusuf Mehta
Department of Civil and Environmental Engineering
Rowan University
201 Mullica Hill Road
Glassboro, NJ 08028
mehta@rowan.edu

Nusrat Siraj
Department of Civil and Environmental Engineering
Rowan University
201 Mullica Hill Road
Glassboro, NJ 08028
sirajn29@students.rowan.edu

ABSTRACT

Some state agencies, such as the Wisconsin Department of Transportation (WisDOT), have experienced pavement failures that have been attributed to poor bonding at the interlayer. The interlayer nearest the surface of the pavement is where loss of bonding typically occurs. This loss of bonding causes poor load transfer to the lower layers and causes slippage where the surface layer is shoved horizontally. The effect of slippage can be minimized by making the surface layer sufficiently thick or stiff.

In this study, two roads in Wisconsin that experienced varying degrees of slippage distress were analyzed to understand the factors critical to slippage cracking. A total of 17 no-distress and 14 high-distress stations from both roads were studied. This study determined stiffness by backcalculating from falling weight deflectometer (FWD) data and recorded field-observed distresses to identify the factors critical to slippage cracking.

It was observed that the stiffness ratio between the top two layers was higher for no-distress sections than for high-distress sections. Pavements with higher E_1/E_2 values ($E_1/E_2>10$) consistently showed better interlayer bonding performance. Normalized percentage differences in stiffness between full-bond and full-slip pavements appeared to correlate very well with observed distresses. This study provides state agencies with tools to use during pavement design that can help minimize slippage cracking due to interlayer bonding failure.

Key words: asphalt—backcalculation—falling weight deflectometer—interlayer bonding—slippage cracking

Proceedings of the 2007 Mid-Continent Transportation Research Symposium, Ames, Iowa, August 2007.

SUMMARY OF THE RESEARCH

Background

Slippage cracks are caused by insufficient pavement stiffness and thickness or a weak bond between the surface course and the layer below, and the complex interaction between these factors makes it difficult to control slippage cracking. This study utilizes backcalculated stiffness values and field-observed distresses to understand the factors critical to slippage cracking and to develop guidelines that can be used during pavement design to minimize slippage cracking that results from interlayer bonding failure.

Objective

The objective of this study was to provide pavement design guidelines regarding the stiffness ratio between the top two layers of a pavement system that can help minimize slippage cracking due to interlayer bonding failure.

Research Approach

FWD data can be used to estimate the pavement layer stiffness values for both no-distress and high-distress sections. This estimation of layer stiffness can be performed through a method called backcalculation. Using measured surface deflections, backcalculation programs determine the pavement layer stiffness. Figure 2 shows that, for the same FWD load, the deflections of high-distress sections (fully slipped, FS) are higher than those of no-distress sections (fully bonded, FB). The phenomenon of slip is thus manifested in FWD data.

Theoretically, the deflection basin from the FWD data of a fully bonded pavement structure will be much lower than the deflection basin of a fully slipped section. A fully bonded pavement structure will transfer load better through the pavement system and hence will utilize the structural capacity of all layers effectively. On the other hand, a poorly bonded pavement system will be relatively more flexible due to poor load transfer. As explained above, the higher stiffness ratio minimizes the impact of slip. The difference in the deflection basins of fully slipped and fully bonded sections will be greater for pavement structures with low stiffness ratios, as shown in Figure 1. The researchers have used this concept in this study to provide the appropriate stiffness ratio needed to minimize effect of slip.

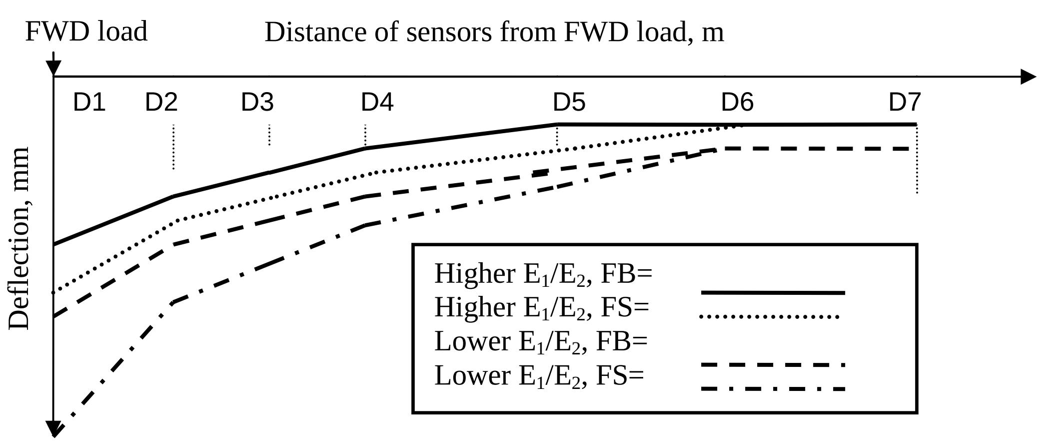

Figure 1. Measured deflection due to FWD load for full-bond and full-slip interface conditions

The following tasks were conducted to achieve the objective stated above:

1. The stiffness values of the different layers were backcalculated for the no-distress pavement sections in full-bond condition, which is the actual condition for no-distress sections. Then, the stiffness values of the HMA layer were calculated by assuming a full-slip condition for no-distress sections, keeping stiffness values in a full-bond condition for all other layers.
2. The stiffness values of the different layers were backcalculated for the high-distress sections in full-slip condition, which is the actual condition for high-distress sections. Then, the stiffness values of the HMA layer were calculated by assuming a full-bond condition for high-distress sections, keeping stiffness values in a full-slip condition for all other layers.
3. The percentage differences of stiffness values between full-bond and full-slip conditions for no-distress sections were correlated to the ratios of stiffness between the top two layers.
4. The percentage differences of stiffness values between full-bond and full-slip conditions were verified with the strain differences between full-bond and full-slip for a specific stiffness ratio.
5. The normalized percentage differences of stiffness values between full-bond and full-slip conditions (for both no-distress and high-distress sections) were correlated to the ratios of stiffness between the top two layers.

Summary of Findings

A summary of findings based on the analysis is presented below:

1. The stiffness ratios between the top two layers for no-distress sections were between 5 and 65, which were higher values than those of high-distress sections (between 1 and 7); this was observed for all sections where the second layer's stiffness was greater than 0.138 GPa.
2. The percentage differences of stiffness between full-bond and full-slip conditions may not be an accurate indicator of the effect of slippage.
3. The normalized percentage differences of stiffness (P.D./E_1) between full-bond and full-slip conditions appeared to correlate very well with observed distresses.
4. A very strong inverse correlation was observed between P.D./E_1 vs. E_1/E_2, with a root mean square value of the curve (P.D./E_1 vs. E_1/E_2) of 0.94.
5. The stiffness ratio appeared to correlate inversely with observed distresses. Higher E_1/E_2 ($E_1/E_2>10$) consistently showed better interlayer bonding performance.
6. When the stiffness ratio was greater than 10, the differences in the slopes of the curves (P.D./E_1 vs. E_1/E_2) were almost zero. Since P.D./E_1 is directly related to the effect of slip, when E_1/E_2 were greater than 10, the pavement was not as adversely impacted from poor interlayer bonding.

Conclusion

If the stiffness ratio between the top HMA layer and the second layer is greater than 10 during design, and if the second layer stiffness value is greater than 0.138 GPa, the pavement will be less affected by slippage than when the stiffness ratio is less than 10.