Department of Civil Engineering and Construction

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Illinois Asphalt Pavement Association (IAPA)

Scholarship Research Report

Mechanics Behind Tack Coat Failure

Prepared for the IAPA Scholarship Committee

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Introduction

Tack coat is used in the pavement to allow the pavement layers to bond together and act as one system, and be able to handle stress from the traffic [1]. The use of a tack coat ensures that the layers act as a monolithic system, preventing any slippage on the layer interface. The boding of tack coat determines how a road can function and for how long, without needing to be repaired. “Improper bonding between layers can cause a deficient transfer of radial tensile and shear stresses into the entire pavement structure. It can also cause a stress concentration at the bottom of the wearing course” [2]. “The lack of tack coat can lead to de-bonding of the overlay, slippage between layers, and premature fatigue cracking (WSDOT, 2002)” [3].

The application of the tack coat is significant to accomplish a full boding between two pavement layers. Slippage problems arise when an excessive amount of tack coat material is sprayed during construction [4]. On the other hand, an inadequate amount of tack coat can result in deboning problems over the design life (especially in the wheel paths) of the pavement structure [5]. Before the application of tack coat, the optimum residual application rates should be determined by putting the following conditions into consideration: the surface’s texture and age, environment, temperature, humidity, and wind.

Objective and Scope of Work

The objective of this paper is to understand the mechanics of tack coat bounding and the mechanics behind its failure. This paper will mention a problem statement created to understand the different situations where the tack coat is applied within different interface conditions for each layer of pavement. KENPAVE software was used to solve the problem statement using different situational interface conditions for bonded and unbonded layers.

Problem Statement

Figure 1 shows a pavement structure composed of the following five layers: the top three layers each are 2 in asphalt concrete with the elastic modulus of 400,000 psi, 10 in base with elastic modulus 20,000 psi, and a subgrade with elastic modulus 10,000 psi. All layers are assumed to have a Poisson's ratio of 0.5. The goal is to find the maximum horizontal tensile strain at the bottom of each asphalt concrete and the maximum vertical compressive strain on the top of the subgrade under a 40,000 lb. wheel and 150 psi contact pressure, assuming that the wheel contact area is a circle.

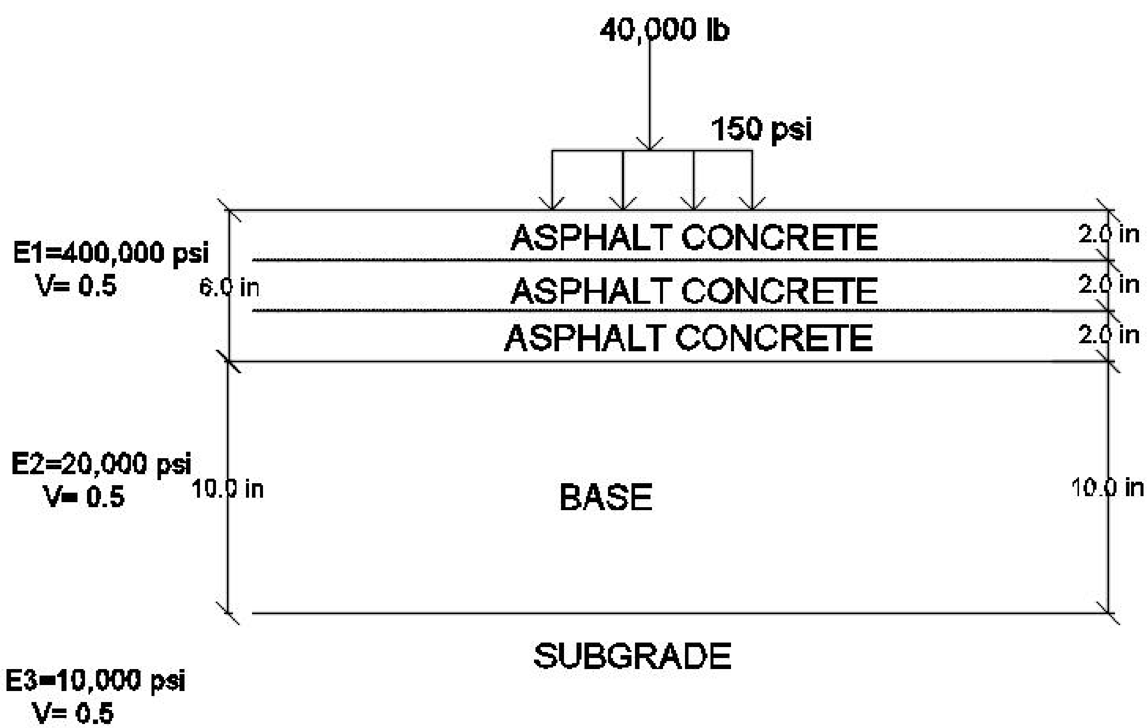

Figure 1. Asphalt concrete pavement layers under a wheel load.

The KENPAVE software allows for a selection of pavement layers to have a bond between layers or not bonded. In the software, a menu option of Interface condition allows for a selection for the number 1 being a bonded layer or number 0 being an unbonded layer. The software enables that selection for each layer and the results will be different because some layers are bonded while the others are unbonded. Figure 2 shows a 3D perspective of the structure that is analyzed using KENPAVE software.

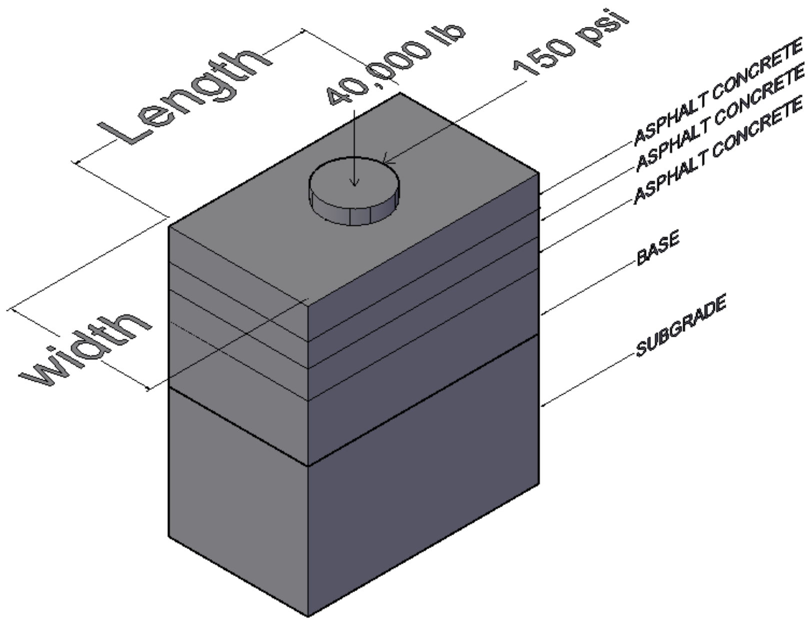

Figure 2. 3D geometry of the asphalt concrete pavement layer.

Results

Table 1 shows the different interface conditions in relation to radial strain, vertical stress, and vertical displacement. Situation #1 represents all three asphalt concrete layers being bonded; the Situation #2 represents only the first layer being bonded with the second layer and the second layer is not bonded with the third layer; the Situation #3 represents only the second layer is bonded with the third layer while the first layer is not bonded with the second layer; Situation #4 represents only the last layer being bonded while the first two layers are not bonded with each other. The positive value indicates compression while the negative value indicates tension.

Table1. Different interface conditions in relation to Radial strain, vertical stress, and vertical displacement.

	Interface Condition, 1 = Bonded 0 = Unbonded	Location below Surface (in)	Radial Strain (in/in)	Vertical Stress (psi)	Vertical Displacement (in)
Situation #1	1	2	0.000158	125.778	0.08619
	1	4	-0.000273	78.326	0.08595
	1	6	-0.000753	48.811	0.08394
	1	-	-	-	-
Situation #2	1	2	-0.000112	118.602	0.11544
	0	4	-0.001112	87.228	0.11304
	0	6	-0.000610	79.929	0.11273
	1	-	-	-	-
Situation #3	0	2	-0.000671	142.740	0.11364
	1	4	-0.000105	111.410	0.11518
	0	6	-0.001102	80.076	0.11281
	1		-	-	-
Situation #4	0	2	-0.000912	139.534	0.12906
	0	4	-0.000901	129.132	0.12856
	1	6	-0.000748	113.744	0.12861
	1	-	-	-	-

Figure 3 shows the results for the radial strain against each situation of the different interface conditions for the layers given. As it is shown, Situation #1 seems to have the best radial strain with an almost linear line which means compressive strain at the top of the pavement is the same as the bottom of the pavement as expected.

Situation #1 is the ideal condition. Situation #1 represents when each of the three layers of asphalt concrete is bonded. Situation #2 has compressive strain increases, but tensile strain decreases at the bottom of the asphalt concrete layer. Situation #2 does not have tack coat bonding between the second and third layers. Situation #3 has the lowest compressive strain but the highest tensile strain. Situation #3 is the most vulnerable to double up a crack at the bottom of the pavement. Situation #4 has a moderately low compressive strain compared to Situation #2 but higher tensile strain at the bottom compared to Situation #2.

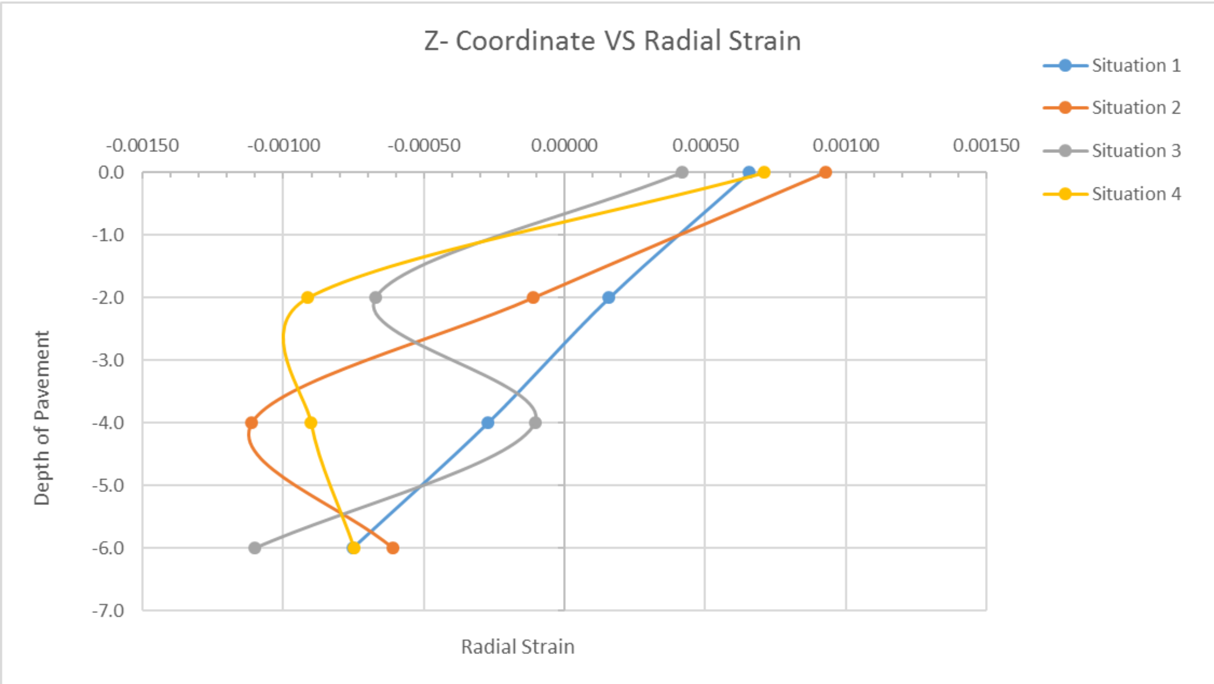

Figure 3. The relationship between the layers and the radial strains for the four different interface conditions.

Figure 4 shows the results for the vertical stress against each situation of the different interface conditions for the layers given. It is expected that the vertical stress will reduce with the depth of the pavement. Situation #1 has the lowest vertical stress at the bottom of the pavement layer. Situation #2 and Situation #3 each are 1.6 times higher in compressive stress at the bottom layer than Situation #1. Situation #4 is 2.3 times higher in compressive stress at the bottom layer than Situation #1.

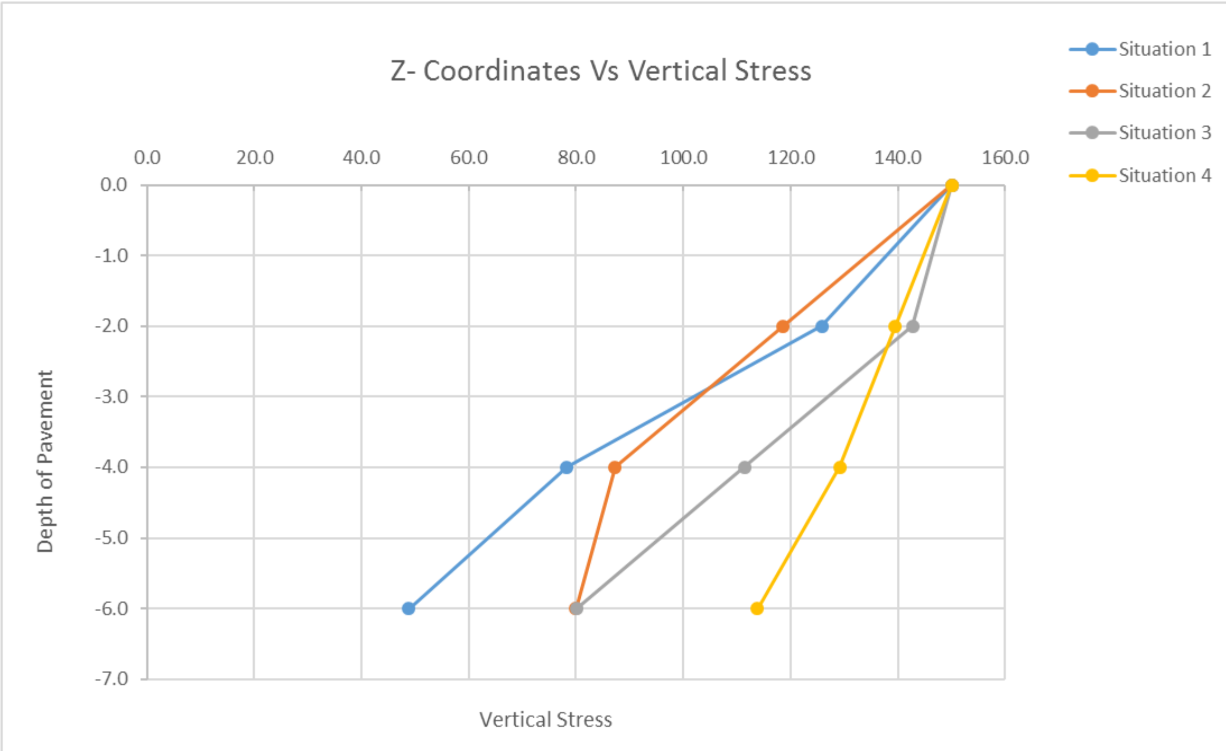

Figure 4. The relationship between the layers and the vertical stress for the four different interface conditions.

Figure 5 shows the results for the vertical displacement against each situation of the different interface condition for the layers given. The vertical deformation at the top of the pavement for Situation #1 is ideal. Situation #2 and Situation #3 each are 1.3 times higher in deformation at the top of the pavement layer than Situation #1. Situation #4 is 1.5 times higher in deformation at the top of the pavement layer than Situation #1.

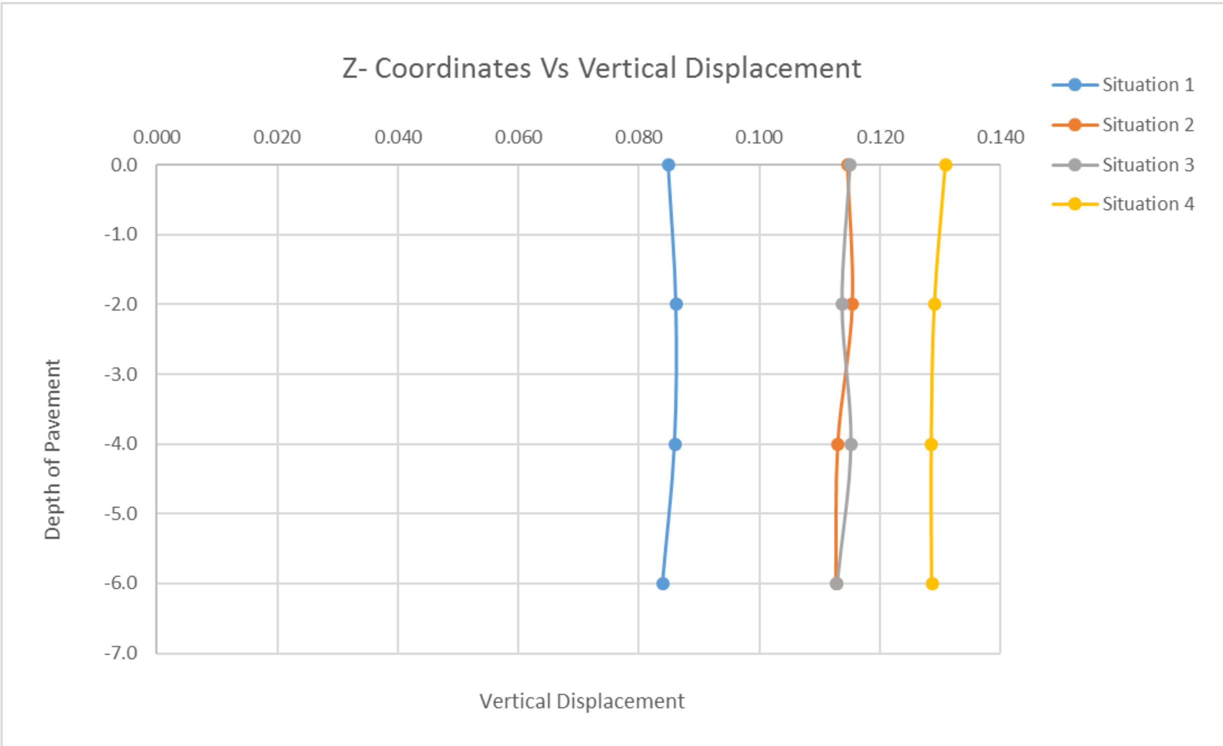

Figure 5. The relationship between the layers and the Vertical displacement for the four different interface conditions.

Summary

Situation #1, with all the layers bonded, is the ideal condition for a great result in radian strain, vertical stress and vertical displacement. Situation #2 is 1.6 times higher in vertical compressive stress (bottom layer) and 1.3 times higher in vertical deformation (top of the pavement) compared to Situation #1. Situation #3 is 1.6 times higher in vertical compressive stress (bottom layer) and 1.3 times higher in vertical deformation (top of the pavement) compared to Situation #1. Situation #4 is 2.3 times higher in vertical compressive stress (bottom layer) and 1.5 times higher in vertical deformation (top of the pavement) compared to Situation #1. The pavement is less likely to go through any stress when all layers are bonded. The first and third layers being bonded on any situation is essential.

References

[1] National Cooperative Highway Research Program. (2012). *Optimization of Tack Coat for HMA Placement.* Washington, D.C.: Transportation Research Board.

[2] Louay, M.N., Abdur Raqib, M., and Huang, B. (2002). “Influence of Asphalt Tack Coat Materials on Interface shear Strength,” *Transportation Research Record 1789*, Transportation Research Board.

[3] Chehab, G., Medeiros, M., Solaimanian, M., (2008). “Evaluation of bond performance of fast tack emulsion for tack coat applications.” Commonwealth of Pennsylvania department of transportation, contract #510602, project #021.

[4] Mahmoud, Aiman Mustafa H. (2016) “Development of Technologies to Evaluate Hot MixAsphalt Adhesion through Tack Coat.” ScholarsArchive@OSU, Oregon State University, 25 Aug.2016.

[5] Tashman, L., Nam, K., & Papagiannakis, T. (2006). Evaluation of the Influence of Tack Coat Construction Factors on the Bond Strength Between Pavement Layers. Report prepared for Washington State Department of Transportation #WCAT 06-002.