AN ALTERNATIVE METHOD FOR PREDICTING THE RESPONSE OF FLEXIBLE PAVEMENTS TO TRAFFIC LOADS

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ABSTRACT

This paper discusses and provides example results for a simple yet effective approach to predicting the stress and deflection response of flexible pavements to surface loads. This alternative was originally derived for predicting stress transmission through granular materials, so it is referred to as the "particulate media approach." This approach is effective for multi-layer asphalt-surfaced and unsurfaced pavement structures. Two experimental pavement test sections, with measured internal response to several types of tire loads, are used to demonstrate the usefulness and accuracy of this alternative. An advantage of the particulate media approach is that stress state predictions are dependant only on a coefficient of lateral stress for each pavement layer; coefficient of lateral stress is conceptually similar to coefficient of lateral earth pressure. Once stress state is established, strains and deflections are dependent only on the elastic moduli of pavement layers. This division of the influence of two material properties simplifies calculations and permits simultaneous, accurate predictions of stress and deflection.

INTRODUCTION

The US Army Corps of Engineers (USACE) conducts on-going research to improve engineering predictions of the response of pavements to vehicular and environmental loading. The USACE methods for analyzing pavements, as well as the resulting criteria, have included the use of homogeneous, isotropic, linear elastic, half-space models since the 1950's [*1*]. Layered linear elastic analyses have been included in the USACE options for pavement design criteria since the 1970's [*2*]. Recent efforts have included the use of advanced models that account for non-linear response and plasticity [*3*] and also better quantification of the effects of partial saturation in soil [*4*]. The "alternative method" of analyzing pavement response to load that is implemented in this paper was produced under a parallel research effort where emphasis has been placed on simplicity and computational efficiency.

The "alternative method" of analyzing pavements represents an extension of response predictions in particulate media, as developed by Harr in 1977 [*5*]. In his original text, Harr derived predictions for both full stress state under vertical surface point loads and vertical stress state under uniform vertical surface pressures, applied over rectangular areas. These predictions can be considered as probabilistic in origin because their derivations stem from applying a random walk approach to the transmission of unknown forces between particles. The predictions of expected stress rely on the central limit theorem of probability. Recently, under contract with the USACE, Harr [*6*] extended the probabilistic predictions for stress to include full stress state under uniform vertical surface pressures and he used the derived stress predictions and the assumption of Hooke's Law to advance a method for predicting vertical deflections within layered pavement structures. Harr's predictions for vertical deflection include those caused by infinitely long strip loads (at any transverse offset distance), deflections under point loads (at any transverse offset distance), and deflections directly under uniform vertical surface pressures applied over circular areas. The predictions for both stress and deflection can be accomplished at any depth within multi-layer structures.

PARTICULATE MEDIA APPROACH

Due to its origin in Harr's text [*5*], the alternative method for analyzing pavements will be referred to herein as the "particulate media approach." All solutions are closed-form. However, despite its simplicity, space limitations for this paper preclude a detailed listing of equations, sign conventions, and nomenclature. The primary purpose of this paper is to demonstrate the usefulness of the particulate media approach. Readers who are interested in obtaining a list of equations are encouraged to either contact the authors or look for two forthcoming publications [*6*, *7*]. Following is a description of the particulate media approach, as well as its conveniences.

For each pavement layer, a single material property controls the distribution of stresses. This property, which Harr [*5*] named the coefficient of lateral stress (ν), reflects the tendency for stress to be transmitted horizontally versus vertically. This property is calculated as σ_h/σ_v, where σ_h is horizontal stress and σ_v is vertical stress. This property is similar to the coefficient of lateral earth pressure (*K*), which is a well-known property for characterizing the state of materials in geotechnical engineering. For each pavement layer, a second material property, elastic modulus (*E*), controls the amount of compression that is experienced by the layer for a given state of stress. Unlike linear elastic theory, however, *E* in the particulate media approach does not affect stress state. Layer compression is calculated after stress state is established by loading, layer thicknesses, and layer ν-values. This separation of material properties, in terms of their effects on stress state and strain (or deflection), offers simplifying advantages, as will be shown in this paper.

Some capabilities and conveniences of the particulate media approach, to include stress and deflection predictions, can be summarized as follows.

- The pavement has finite thickness. The assumption of infinite depth is not required.

- The approach is applicable to multi-layered structures and the solutions do not impose discontinuities at pavement layer interfaces. In other words, stress just above an interface is approximately equal to the stress just below an interface. The multi-layer approach relies on *derived* layer equivalencies, not *contrived* layer equivalencies that happen to provide reasonable solutions (as in Odemark's [*8*] simplified approach to layered linear elastic analysis).

- The separation of influence of material properties (i.e. ν affects stress state and *E* affects the conversion of stress to vertical strain), provides for accurate predictions of *both* stress and strain. Addressing stress and then strain in series, rather than in parallel, simplifies predictions of pavement response and simplifies back-calculation of material properties (ν and *E*) when pavement response and loading are known.

- Predictions of stress state at any particular depth within a pavement structure are affected only by materials residing at shallower depths. Deflection predictions are affected by the ν-values of all pavement layers, but are affected by the *E*-values only of materials below the depth in question. The absence of the need to consider all pavement layers for every calculation of response, as is necessary in layered elastic solutions, provides for convenient simplifications when automating analysis routines (i.e. software programming).

- The particulate media approach does not require assumptions related to slip (or no slip) at pavement layer interfaces, thus eliminating another complicating factor in traditional analyses.

DESCRIPTION OF PAVEMENT TEST SECTIONS

Response data to be used in this paper were obtained from two recent test sections, which were constructed and trafficked at the US Army Waterways Experiment Station in Vicksburg, MS. Both test sections were surfaced with asphalt concrete. One test section was considered "heavy-duty" and served to represent typical airfield construction. The second test section was considered "light-duty" and served to represent a secondary road pavement. The heavy-duty pavement included two test items named "North" and "South," as shown in Figure 1. The two items were similar in that they were comprised of airfield-grade asphalt concrete, a crushed limestone base course (California bearing ratio, CBR = 100+%), and a fat clay subgrade (CBR = 5 to 6%). The Unified Soil Classification (USC), ASTM D 2487, for base and subgrade were SP-SM, and CH, respectively. The only difference between the items was that the South Item had a thicker base course (see Table 1). For both heavy-duty pavement items, the unprepared subgrade (beneath the fat clay test subgrade) was lean clay with CBR = 15 to 25, as estimated by a dynamic cone penetrometer (DCP).

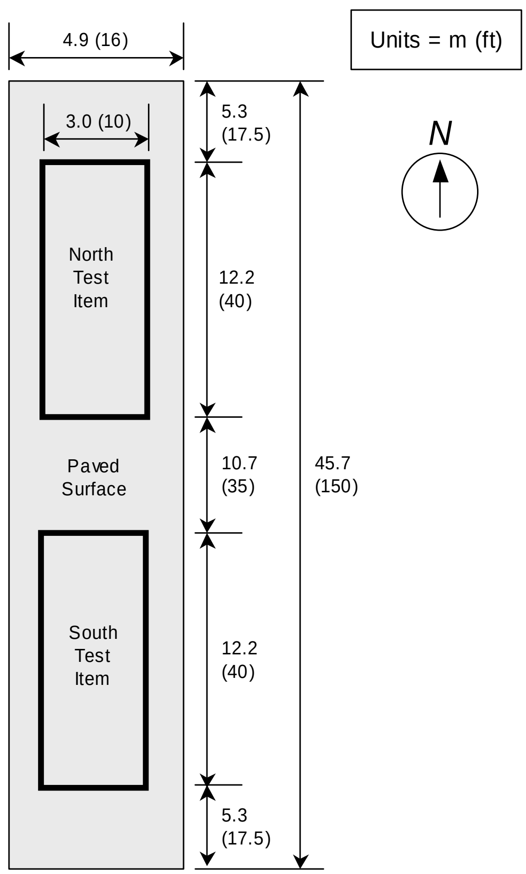

Figure 1. Layout of the Heavy-Duty Pavement Test Section

Table 1.
Thicknesses for the Heavy-Duty Pavement

Pavement Layer	North Item				South Item			
	Mean, mm (in.)		Standard Deviation, mm (in.)		Mean, mm (in.)		Standard Deviation, mm (in.)	
Asphalt Concrete	114	(4.5)	7.6	(0.3)	114	(4.5)	7.6	(0.3)
Crushed Limestone Base Course	584	(23)	15	(0.6)	838	(33)	20	(0.8)
Fat Clay Subgrade	1220	(48)	No data		1220	(48)	No data	

The light-duty pavement included eight lanes, 15.2 m in length and oriented north to south (see Figure 2). The entire pavement area was constructed with roadway-grade asphalt concrete, a gravelly clayey sand base course (CBR = 40 to 70%), and a fat clay subgrade (CBR = 7 to 9%). The base aggregate was rounded river gravel. The USC for base and subgrade were SC and CH, respectively. Target thicknesses for the pavement layers were the same for all lanes, but they differed slightly due to construction variability. Thicknesses for Lanes 4 and 6, which are those of interest to this paper, are summarized in Table 2. For both light-duty pavement items, the unprepared subgrade (beneath the fat clay test subgrade) was sandy lean clay with CBR = 10 to 20, as estimated by a DCP.

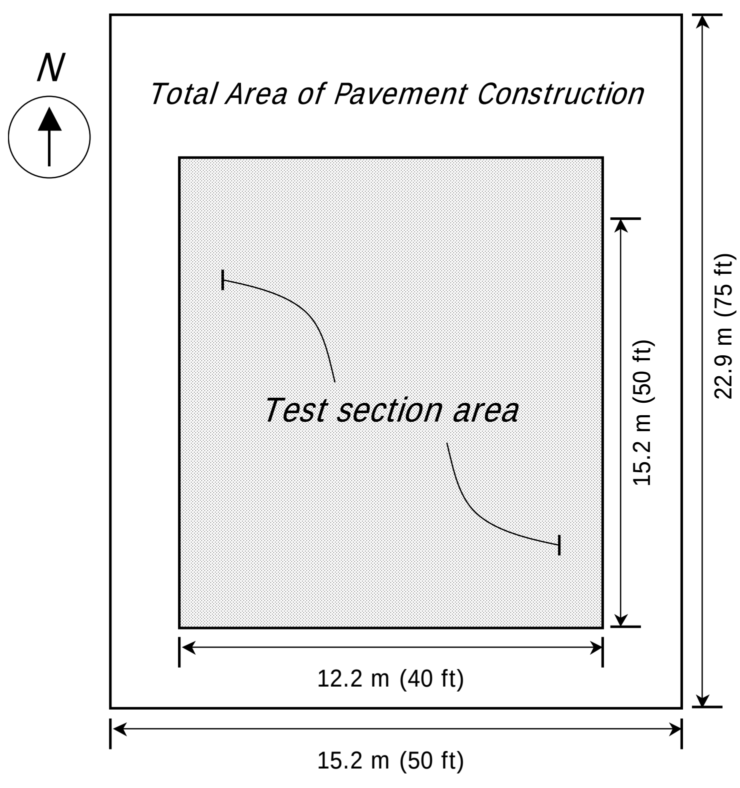

Figure 2. Layout of the Light-Duty Pavement Test Section

Table 2.
Thicknesses for the Light-Duty Pavement

Pavement Layer	Lane 4				Lane 6			
	Mean, mm (in.)		Standard Deviation, mm (in.)		Mean, mm (in.)		Standard Deviation, mm (in.)	
Asphalt Concrete	57	(2.25)	6.9	(0.27)	45	(1.76)	8.4	(0.33)
Gravelly Clayey Sand Base Course	160	(6.3)	13	(0.51)	150	(5.9)	18	(0.71)
Fat Clay Subgrade	1000	(39.5)	6.4	(0.25)	1030	(40.4)	16	(0.64)

For brevity, this paper considers only pavement responses under single tire loads. Although each test item mentioned previously was loaded with a variety of wheel assemblies including single tires and multiple wheel assemblies, representing both roadway vehicles and aircraft, this paper will be limited to the loads summarized in Table 3. The C-17 aircraft load was applied to the heavy-duty pavement and the F-15 and super-single truck tire loads were applied to the light-duty pavement. Dates for measuring pavement response and the corresponding mat surface temperatures are summarized in Table 4. Although the application of F-15 loads to a light-duty pavement may seem fortuitous, it serves a definite purpose. The ongoing USACE research in predicting pavement performance includes both permanent and contingency airfields, so a pavement life of only 5000 passes is of interest and can be productive. Also, the development of prediction tools for pavement response to loading would preferably not be limited to particular combinations of load type and pavement structure.

Table 3.
Types of Traffic Loads

Tire Type	Load, kN (kips)		Print Area, m^2 ($in.^2$)		Print Width, m (in.)		Print Length / Width	Contact Pressure, kPa (psi)	
C-17 Aircraft	160	(35.9)	0.199	(308)	0.44	(17.5)	1.2	800	(116)
F-15 Aircraft	40.0	(9.0)	0.032	(50)	0.14	(5.6)	1.6	1240	(180)
Super-Single Truck Tire	40.0	(9.0)	0.068	(105)	0.32	(12.5)	0.67	590	(86)
	66.7	(15.0)	0.094	(146)	0.32	(12.5)	0.93	710	(103)

The pavement response measurements presented in this paper include only vertical stress and vertical deflection. Vertical stress measurements were obtained by fluid-filled, 230-mm-diameter soil pressure cells manufactured by Geokon, Inc. Vertical deflection measurements were obtained either by multi-depth deflectometers (MDDs) manufactured by Construction Technology Laboratories, Inc. or by single-depth deflection gages (SDDs) manufactured and assembled in-house by the US Army Engineer Research and Development Center. The SDDs were comprised of linear variable displacement transducers secured within steel housings. Both the MDDs and the SDDs relied on referencing pavement movement to “fixed” rods that extended to a depth where deflection under load was considered to be non-existent. These depths were approximately 5.5 m for the heavy-duty pavement and 3.0 m for the light-duty pavement. The reference depth for the light-duty pavement was permitted to be shallower because that pavement was subjected to lighter loads. The depths of all gages are summarized in Table 5.

Table 4.
Measured Response Under Loading

Date	Mat Surface Temperature, °C (°F)	Test Items	Types of Traffic Loads[a]
12 Mar.1999	10 (50)	North and South, Heavy-Duty	C-17
25 Apr. 2000	19 (67)	North, Heavy-Duty	C-17
06 Nov. 2001	21 (69)	Lane 4, Light-Duty	SS
18 Dec. 2002	16 (61)	Lane 4, Light-Duty	F-15
07 Jan. 2003	8.3 (47)	Lane 6, Light-Duty	SS and F-15

[a] SS = super-single at both 40.0 and 66.7 kN

Table 5.
Gage Depths

Pavement Items	Type of Gage	Relative Position Among Similar Gages	Description of Depth
Heavy-Duty	Stress	Top Middle Bottom	305 mm below top of base 305 mm below top of subgrade[a] 150 mm above bottom of subgrade
Heavy-Duty	Deflection	Top Middle Bottom	Pavement surface Base/subgrade interface Mid-depth of subgrade
Light-Duty	Stress	Top Middle Bottom	Bottom of base Mid-depth of subgrade Bottom of subgrade
Light-Duty	Deflection	Top Middle Bottom	Pavement surface Base/subgrade interface Bottom of subgrade

[a] subgrade = prepared subgrade

The response measurements included in this paper were obtained under slow rolling loads (2 to 8 km/hr). Responses for the heavy-duty test items were measured at relative transverse positions (gage-to-tire) of 0, 760, and 1520 mm. Responses for the light-duty test items were measured at relative transverse positions (gage-to-tire) of 0, 250, and 510 mm. Only a fraction of reduced responses will be presented in figures, but all average responses will be summarized in tabular form. Each reported response represents the average response under four or eight rolling loads.

RESPONSE PREDICTIONS

Material properties were back-calculated from pavement response measurements. This process eliminated complications that could be introduced by mismatches either between nondestructive testing loads and trafficking loads (i.e. impact versus rolling) or between laboratory tests and field tests (commonly mismatched in terms of stress state and/or rate of loading). The term "back-calculation," as used in this paper, implies a process that seeks to find an optimum combination of material parameters for a layered structure. The optimum combination of material parameters is that combination that produces pavement response predictions that minimize squared differences with measured values for pavement response at corresponding locations.

Each back-calculation procedure compared either predicted stresses or deflections at three different depths, corresponding to the measured stresses or deflections. While predictions of pavement response were later accomplished at each rolling load transverse offset (i.e. offset relative to gage locations), the back-calculation process used only the measured pavement responses at zero offset. While looping through combinations of ν or E, the test for best fit involved calculating the sum of squared percent deviations (SPD) between the three pairs (measured and predicted) of stress or deflection. Because stress and deflection measurements deep within the pavement become small and approach the reasonable precision of reduced measurements, the SPD were assigned relative weights. The SPD for the middle gage was weighted 10 times the SPD for the lowest gage. The SPD for the top gage was weighted 100 times the SPD for the lowest gage.

The particulate media approach is convenient for back-calculating material properties from stress and deflection measurements. The transfer of stress depends only on the coefficients of lateral stress (ν-values) for the various pavement layers. Therefore, stress measurements were first used to determine the "best-fit" ν-values. Strain and deflection depend on both the ν-values and the elastic moduli of the various pavement layers. Therefore, while the established ν-values are held constant, "best-fit" moduli are obtained from the deflection measurements.

The multi-layer linear elastic approach is slightly less convenient for the purpose of using response measurements to back-calculate material properties. Both stress and deflection are affected by both the Poisson ratio (μ) and the elastic modulus (E) for each pavement layer. Because μ is less influential than E in terms of pavement response predictions, μ was assumed to be known and constant for the purposes of this paper. The μ-values for asphalt concrete, unbound base, and clay subgrade were assumed to be equal to 0.3, 0.3, and 0.4, respectively. These values conform to those that are commonly used by DOD pavement design procedures [*9*] and are within the ranges of values that are commonly assumed by other agencies [*10*, *11*]. The back-calculation process for multi-layer linear elastic structures was accomplished separately for measured stress and deflection. While response predictions were eventually accomplished with the multi-layer linear elastic analysis software, WINJULEA [*12*], the back-calculation process required the use of Odemark's assumptions, as described by Ullidtz [*13*].

The response of Lane 6, a light-duty pavement test item, to the F-15 load will be used as the example pavement while describing the sequence of results. Results from the other test items will then be included in tabular data summaries, which will provide for more general conclusions. Starting with the particulate media approach, back-calculation with measured stresses in Lane 6 provided best-fit ν-values of 3.7, 0.35, and 0.25 for the asphalt, base, and subgrade, respectively. Using these ν-values, the predicted stresses match the measured stresses well, even stresses at transverse tire offsets greater than zero (see Figure 3). All predicted stresses are within 15 kPa (2 psi) of the measured stresses. With the established ν-values, layer modui could be back-calculated using measured deflections at various depths. For simplification in this study, all layer moduli were assumed to be equal (i.e. the structure assumed a “composite” modulus). The composite modulus for the structure was back-calculated to be 105 MPa (15 ksi). Composite moduli, when used in combination with layered ν-values, have been found by the authors to be useful for pavement assessments. Using the back-calculated ν values and the back-calculated composite modulus value, the predicted deflections matched the measured deflections well, as shown in Figure 4. Deflections at transverse tire offset did not match quite as well as the stresses, but all deviations between predictions and measurements were within 230 um (9 mils).

For the layered linear elastic approach, two back-calculations were conducted, one to match measured stresses and one to match measured deflections. Both processes considered the pavement as a three-layer structure (no preconceived use of “composite” modulus). The measured stresses in Lane 6 provided best-fit moduli of 11700 MPa (1700 ksi) for the asphalt concrete and 340 MPa (49 ksi) for both the base and subgrade. Using these moduli, predicted stresses were within 40 kPa (6 psi) of the measured stresses (see Figure 5). The measured deflections in Lane 6 provided a best-fit modulus of 140 MPa (20 ksi) for all three pavement layers. The only criterion imposed on the back-calculation process was that moduli had to decrease with depth. With this requirement, a single modulus of 140 MPa (20 ksi) for all layers provided the set of three moduli that minimized the sum of SPD. The predicted deflections matched the measured deflections well, with all deviations residing at values less than 140 um (5.5 mils), as shown in Figure 6. A comparison between the moduli back-calculated from stresses and those back-calculated from deflections reveals an interesting problem for the layered linear elastic approach: the layer moduli that provide the best predictions of stress are not the same as the layer moduli that provide the best predictions for deflection. This problem occurred with all test items included in this study. The significance of this discrepancy can be seen in the predictions of stress and deflection that are shown in Figures 7 and 8, respectively. In Figure 7, stress predictions are accomplished with moduli back-calculated using deflections. The predicted stress under the tire load and at a depth of 195 mm is approximately twice that measured. In Figure 8, deflection predictions are accomplished with moduli back-calculated using stresses. The predicted pavement surface deflection under the tire load is less than one-third of the measured deflection.

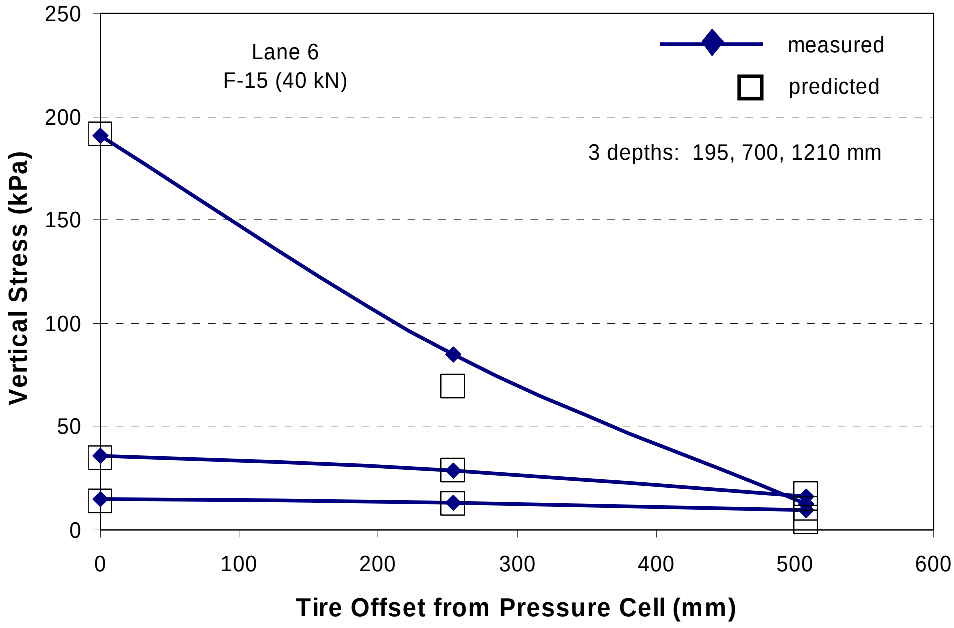

Figure 3. Measured Stresses and Stresses Predicted by the Particulate Media Approach

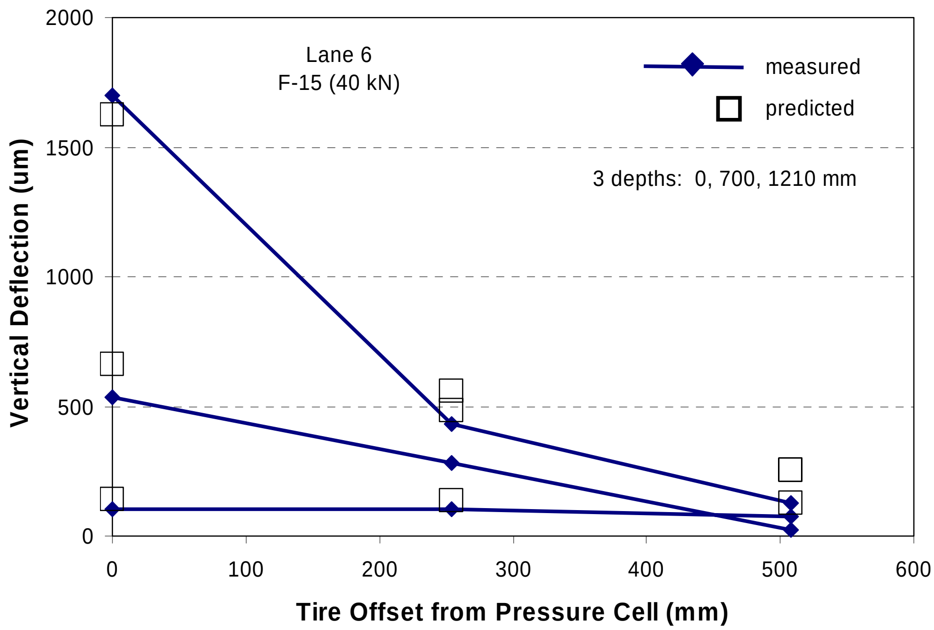

Figure 4. Measured Deflections and Deflections Predicted by the Particulate Media Approach

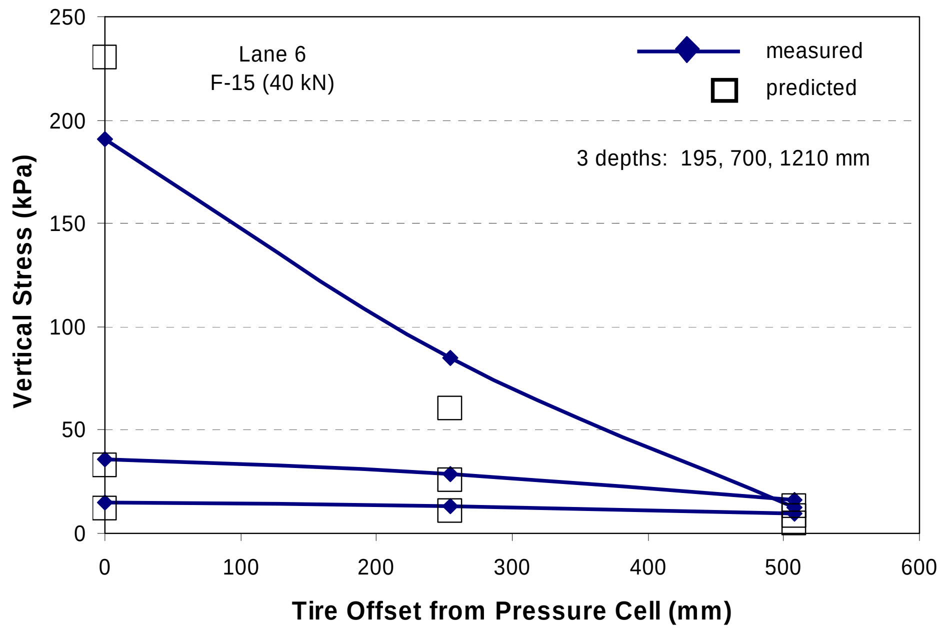

Figure 5. Measured Stresses and Stresses Predicted by the Layered Linear Elastic Approach

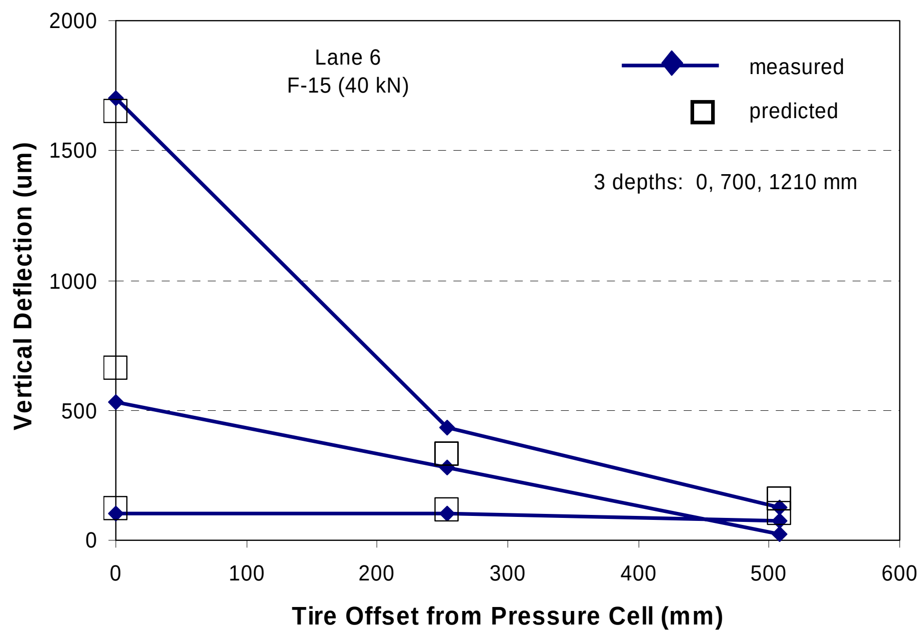

Figure 6. Measured Deflections and Deflections Predicted by the Layered Linear Elastic Approach

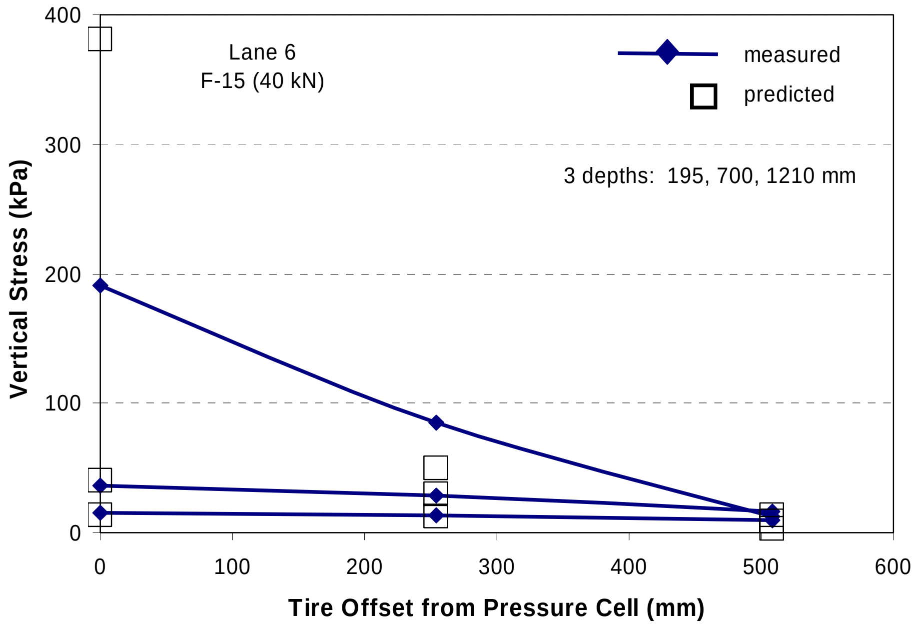

Figure 7. Stresses Predicted by the Layered Linear Elastic Approach, Using Moduli Back-Calculated from Deflections

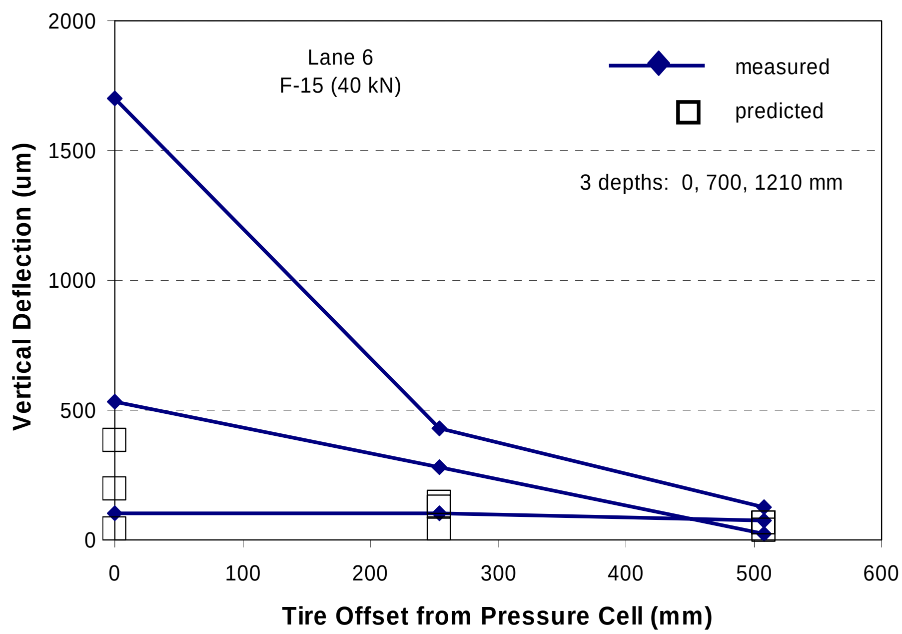

Figure 8. Deflections Predicted by the Layered Linear Elastic Approach, Using Moduli Back-Calculated from Stresses

Back-calculated values for ν and *E*, as obtained from all test items, are summarized in Tables 6 and 7. The summaries for ν and moduli that were back-calculated from stresses, include both heavy-duty and light-duty pavements (nine pavement loading scenarios). The summaries for the moduli that were back-calculated from deflections include results only from the light-duty pavement test items (six pavement loading scenarios). The deflections obtained from the heavy-duty test item were not used because the gages did not work properly. Of particular note in Table 6 are the findings for ν-values. Asphalt concrete was characterized with a ν-value ten times that of the base and subgrade materials. This is a reflection of the improved ability for asphalt to distribute load laterally, as provided by its cohesive nature. The ν-values for subgrade materials and for the light-duty base (gravelly clayey sand) are approximately one-third in magnitude, which is the ν-value that Harr [*5*] proved to be the particular case for his approach that emulates "elastic" (i.e. Boussinesq) type of responses. In other words, Harr's solution for a single-layer system with a ν-value equal to one-third predicts stress levels very similar to those predicted by the Boussinesq solution for an isotropic, homogeneous, linear elastic half-space. The ν-value for the well-graded crushed limestone base in the heavy-duty pavement is lower than those ν-values found for the other unbound materials. The relatively low ν-value for crushed limestone is a reflection of its tendency to transmit stresses vertically (i.e. poor lateral distribution of stress). This is a well-known phenomenon for uncemented crushed aggregate bases where particle-to-particle contacts can impose columnar-type transmissions of stress. The back-calculated ν-values for unbound materials were commensurate with the coefficients of lateral earth pressure (*K*) that one would expect for these materials.

Table 6.
Back-Calculated Material Properties Using the Particulate Media Approach

Pavement Layer	Coefficients of Lateral Stress Back-Calculated from Stresses		Elastic Moduli Back-Calculated from Deflections	
	Mean (ν-values)	Coefficient of Variation (%)	Mean, MPa (ksi)	Coefficient of Variation (%)
Heavy-Duty Pavement				
Asphalt Concrete	3.0	25	No Data	No Data
Base Course	0.15	33	---	---
Subgrade	0.25	35	---	---
Light-Duty Pavement				
Asphalt Concrete	3.1	19	126 (18.3)	30
Base Course	0.39	32	124 (18.0)	31
Subgrade	0.30	30	124 (18.0)	31

Of particular note in Table 7 are the differences between back-calculated asphalt moduli, as obtained with different types of pavements (heavy-duty versus light-duty) and as obtained with different pavement responses (stresses versus deflections). When measured stresses were used for back-calculation, asphalt moduli for the light-duty pavement were found to be five times higher than those for the heavy-duty pavement. The difference between asphalt moduli, when comparing the use of stresses or deflections for back-calculation, was a factor of 50. Back-calculated moduli for subgrade and base materials tended to be similar. The moduli for these materials were lower when backcalculations were conducted with deflection estimates and measurements.

Table 7.
Back-Calculated Material Properties Using the Layered Linear Elastic Approach

Pavement Layer	Elastic Moduli Back-Calculated from Stresses		Elastic Moduli Back-Calculated from Deflections	
	Mean, kPa (ksi)	Coefficient of Variation (%)	Mean, MPa (ksi)	Coefficient of Variation (%)
Heavy-Duty Pavement				
Asphalt Concrete	1720 (250)	0	No Data	No Data
Base Course	266 (38.7)	22	---	---
Subgrade	266 (38.7)	22	---	---
Light-Duty Pavement				
Asphalt Concrete	8560 (1240)	37	162 (23.5)	38
Base Course	320 (46.5)	22	162 (23.5)	38
Subgrade	264 (38.3)	32	156 (22.7)	31

The back-calculated moduli that were collected in this study were used to predict pavement responses to load at all locations of pressure and deflection gages. For each pavement test section and each load type, predictions were accomplished for three different depths and one to three lateral offsets (offsets between tire load and gage). Maximum deviations between response predictions measured responses are shown in Tables 8 and 9 for stresses and deflections, respectively. Each table includes predictions accomplished with both the particulate media approach and the layered linear elastic approach. The maximum deviations shown for the layered linear elastic approach were established using only the most appropriate modulus values: stress predictions considered only the moduli that were back-calculated using measured stresses and deflection predictions considered only the moduli that were back-calculated using measured deflections. Given this precaution for the layered linear elastic approach, the two methods of analysis proved to be comparable in terms of their ability to predict pavement response to load.

Table 8.
Maximum Differences Between Measured and Predicted Stresses

Test Item (Date)	Tire Type[a] (Load, kN)	Maximum Deviation for Stress, kPa (psi)	
		Particulate Media Approach	Layered Linear Elastic Approach
North (12 Mar. '99)	C-17	-17 (-2.5)	41 (5.9)
South (12 Mar. '99)	C-17	10 (1.5)	22 (3.2)
North (25 Apr. '00)	C-17	-14 (-2.0)	17 (2.5)
Lane 4 (06 Nov. '01)	SS (40 kN)	-2.1 (-0.3)	-31 (-4.5)
	SS (67 kN)	-3.4 (-0.5)	4.1 (0.6)
Lane 4 (18 Dec. '02)	F-15	10 (1.5)	32 (4.6)
Lane 6 (07 Jan. '03)	SS (40 kN)	-15 (-2.2)	32 (4.6)
	SS (67 kN)	-21 (-3.0)	46 (6.7)
	F-15	-15 (-2.2)	39 (5.7)

[a] SS = super-single

Table 9.
Maximum Differences Between Measured and Predicted Deflections

Test Item (Date)	Tire Type[a] (Load, kN)	Maximum Deviation for Deflection, um (mils)			
		Particulate Media Approach		Layered Linear Elastic Approach	
North (12 Mar. '99)	C-17	No data		No data	
South (12 Mar. '99)	C-17	No data		No data	
North (25 Apr. '00)	C-17	No data		No data	
Lane 4 (06 Nov. '01)	SS (40 kN)	51	(2.0)	100	(3.9)
	SS (67 kN)	-150	(-5.9)	140	(5.5)
Lane 4 (18 Dec. '02)	F-15	330	(13)	330	(13)
Lane 6 (07 Jan. '03)	SS (40 kN)	230	(9.1)	160	(6.3)
	SS (67 kN)	330	(13)	200	(7.9)
	F-15	230	(9.1)	140	(5.5)

[a] SS = super-single

SUMMARY

This paper demonstrates the usefulness of an alternative method for predicting vertical stress and vertical deflection responses within flexible pavements. The alternative method is called the "particulate media approach" and its derivation stems from applying random walk concepts to the transmission of unknown forces between particles. Predictions of stress state require a single material property for each pavement layer. This property, which has been named coefficient of lateral stress (ν), reflects the tendency for stress to be transmitted horizontally versus vertically. This material property is similar to the coefficient of lateral earth pressure (K), a well-known material property in geotechnical engineering. For each pavement layer, a second material property controls the amount of compression that is experienced by the layer, given the state of stress. Similar to conventional linear elastic theory, elastic modulus (E) is used for representing this susceptibility to material compression. However, unlike conventional linear elastic theory, E does not affect stress state.

The independent effects of ν and E on pavement response predictions provide for simple computations and effective prediction of both stress and deflection in pavements. Measured stresses and deflections within pavement test items were used in this paper to demonstrate the effectiveness of the particulate media approach and to demonstrate the inaccuracies that can be encountered when attempting to predict both stress and deflection by the conventional layered linear elastic approach. The ν-values for the unbound pavement materials, which provided for the most accurate stress predictions, were commensurate with the traditional K-values that one would expect for the same materials. The ν-values for asphalt concrete, which also provided for the most accurate stress predictions, were on the order of ten times the ν-values for the unbound materials. The relatively large magnitude of ν for asphalt concrete reflects its superior ability to distribute loads laterally.

As its name implies, the particulate media approach was originally developed for predicting stress state within unbound particulate materials. Future research will include the development of methods for combining the layered elastic approach (for bound materials) with the particulate media approach (for unbound materials). Future research will also include the development of a laboratory test for the purpose of characterizing ν-values for pavement materials.

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