UNR Releases *3D-Move Analysis* Software

The University of Nevada, Reno (UNR) has released new software for analysis of asphalt pavements. The new analytical model, called *3D-Move*, uses a continuum-based finite-layer approach to compute pavement responses. The *3D-Move* model can account for important pavement response factors such as moving loads, three dimensional contact stress distributions (normal and shear) of any shape, and viscoelastic material characterization for the pavement layers.

The finite-layer approach adopted in the *3D-Move* treats each pavement layer as a continuum and uses the Fourier transform technique; therefore, it can handle complex surface loadings such as multiple loads and non-uniform tire pavement contact stress distribution. Since the tire imprint can be of any shape, this approach is suitable to analyze tire imprints, including those generated by wide-base tires (Siddharthan et al. 1998; 2000; 2002).

The finite-layer method is much more computationally efficient than the moving load models based on the finite element method (Huhtala and Pihlajamaki 1992; Al-Qadi and Wang 2009). This is because often the pavements are horizontally layered, and pavement responses are required only at a few selected locations. For such problems the finite layer approach of *3D-Move* is ideally suited. Since rate-dependant material properties (viscoelastic) can be accommodated by the approach, it is an ideal tool to model the behavior of asphalt concrete (AC) layer and also to study pavement response as a function of vehicle speed. Frequency-domain solutions are adopted in *3D-Move*, which enables the direct use of the frequency sweep test data of AC mixtures in the analysis.

Many field calibration efforts (e.g. Penn State University test track, MnRoad and UNR Off-road Vehicle study) that compared a variety of independently-measured pavement responses (stresses, strains, and displacements) with those computed have been reported in the literature (Siddharthan et al. 2002, 2005). These verification studies have validated the applicability and versatility of the *3D-Move.*

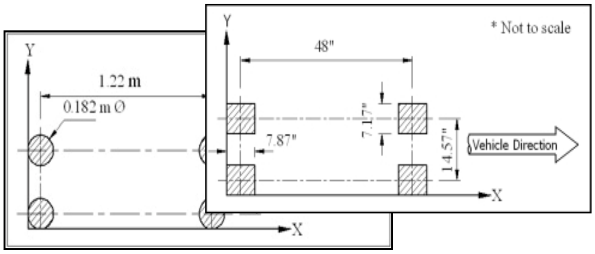
The software is available as a free download at http://www.arc.unr.edu/Software.html. This is a Windows®-based program that enables the user to analyze pavement response under a variety of vehicle loading conditions. To illustrate the capability of the current version 1.1 of the program, important features of the program have been highlighted below.

Selected Features of 3D-Move Analysis

Axle Configuration and Contact Pressure Distribution

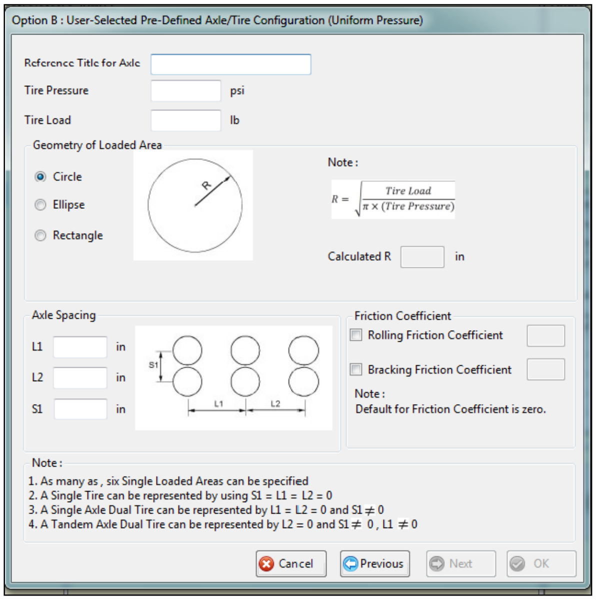
One of the important inputs to *3D-Move Analysis* is the pavement contact stress distribution. It is customary to assume simpler contact stress distributions, for example, circular or elliptical loaded areas with uniform vertical stress. However, the pavement contact stress distributions are non-uniform and more complex. There are six types of loading considered in the *3D-Move Analysis*.

Type 1: Pre-Defined Load Cases (Uniform/Non-Uniform Contact Pressure Distribution)



The nine load cases included under this option represent many widely-used field cases. User cannot modify the axle configuration and contact pressure distribution of any of the load cases.

Type 2: User-Selected Pre-Defined Axle/Tire Configuration (Uniform Contact Pressure Distribution)



Option B : User-Selected Pre-Defined Axle/Tire Configuration (Uniform Pressure)

Reference Title for Axle
Tire Pressure psi
Tire Load lb

Geometry of Loaded Area
● Circle
○ Ellipse
○ Rectangle

Note :

$$R = \sqrt{\frac{Tire\ Load}{\pi \times (Tire\ Pressure)}}$$

Calculated R in

Axle Spacing
L1 in
L2 in
S1 in

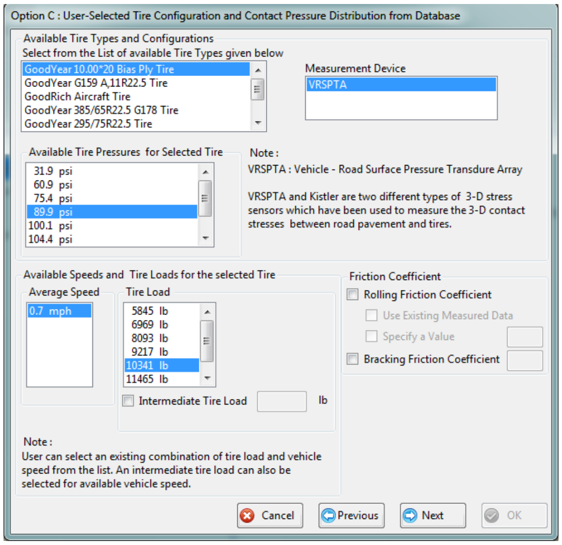
Friction Coefficient
☐ Rolling Friction Coefficient
☐ Bracking Friction Coefficient

Note :
Default for Friction Coefficient is zero.

Note :
1. As many as , six Single Loaded Areas can be specified
2. A Single Tire can be represented by using S1 = L1 = L2 = 0
3. A Single Axle Dual Tire can be represented by L1 = L2 = 0 and S1 ≠ 0
4. A Tandem Axle Dual Tire can be represented by L2 = 0 and S1 ≠ 0 , L1 ≠ 0

Here, the user can specify axle configuration and three types of contact pressure distribution (Circle, Ellipse and Rectangle).

Type 3: User-Selected Tire Configuration and Contact Pressure Distribution from Database (Non-Uniform Contact Pressure Distribution)



Option C : User-Selected Tire Configuration and Contact Pressure Distribution from Database

Available Tire Types and Configurations
Select from the List of available Tire Types given below
GoodYear 10.00*20 Bias Ply Tire
GoodYear G159 A,11R22.5 Tire
GoodRich Aircraft Tire
GoodYear 385/65R22.5 G178 Tire
GoodYear 295/75R22.5 Tire

Measurement Device
VRSPTA

Available Tire Pressures for Selected Tire
31.9 psi
60.9 psi
75.4 psi
89.9 psi
100.1 psi
104.4 psi

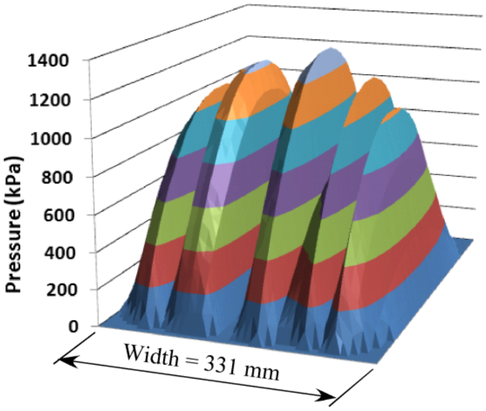
Note :
VRSPTA : Vehicle - Road Surface Pressure Transdure Array

VRSPTA and Kistler are two different types of 3-D stress sensors which have been used to measure the 3-D contact stresses between road pavement and tires.

Available Speeds and Tire Loads for the selected Tire
Average Speed
0.7 mph
Tire Load
5845 lb
6969 lb
8093 lb
9217 lb
10341 lb
11465 lb
☐ Intermediate Tire Load lb

Friction Coefficient
☐ Rolling Friction Coefficient
☐ Use Existing Measured Data
☐ Specify a Value
☐ Bracking Friction Coefficient

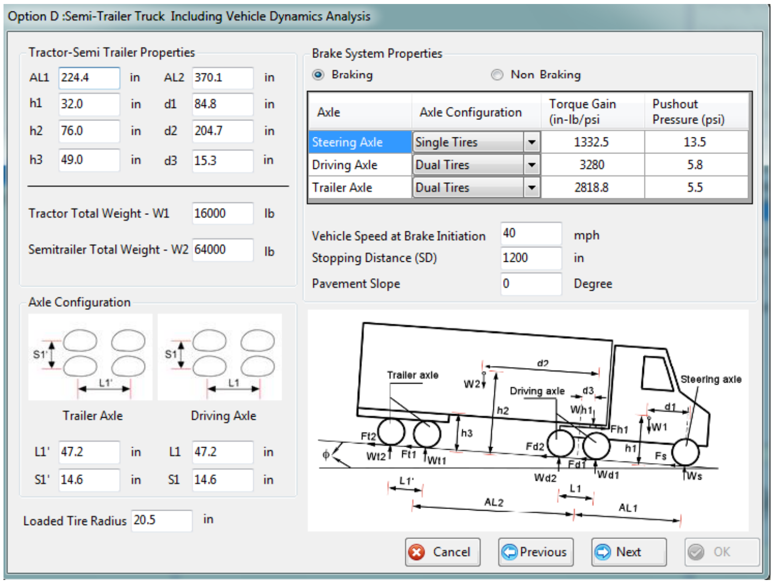
Note :
User can select an existing combination of tire load and vehicle speed from the list. An intermediate tire load can also be selected for available vehicle speed.



Contact Stress Distribution in Wide-Base Tires

In this case, VRSPTA (de Beer and Fisher (1997)) and Kistler MODULUS (Sime and Ashmore (1999)) databases which have reported measured contact pressure distributions for many single tires are used. A variety of tire types that include single and wide base tires under a tire pressure range of 220 – 1000 kPa and a tire load range of 26 – 106 kN are considered in both databases. The user can specify the axle configuration, which can vary from a single axle, single tire to a tridem axle, dual tire configuration. For a specified axle configuration and tire load, a contact pressure distribution can be generated from the available databases.

Type 4: Semi-Trailer Truck Including Vehicle Dynamics (Uniform / Non-Uniform Contact Pressure Distribution)



Option D :Semi-Trailer Truck Including Vehicle Dynamics Analysis

Tractor-Semi Trailer Properties

AL1	224.4	in	AL2	370.1	in
h1	32.0	in	d1	84.8	in
h2	76.0	in	d2	204.7	in
h3	49.0	in	d3	15.3	in

Tractor Total Weight - W1 16000 lb

Semitrailer Total Weight - W2 64000 lb

Axle Configuration

	Trailer Axle			Driving Axle	
L1'	47.2	in	L1	47.2	in
S1'	14.6	in	S1	14.6	in

Loaded Tire Radius 20.5 in

Brake System Properties

● Braking ○ Non Braking

Axle	Axle Configuration	Torque Gain (in-lb/psi	Pushout Pressure (psi)
Steering Axle	Single Tires	1332.5	13.5
Driving Axle	Dual Tires	3280	5.8
Trailer Axle	Dual Tires	2818.8	5.5

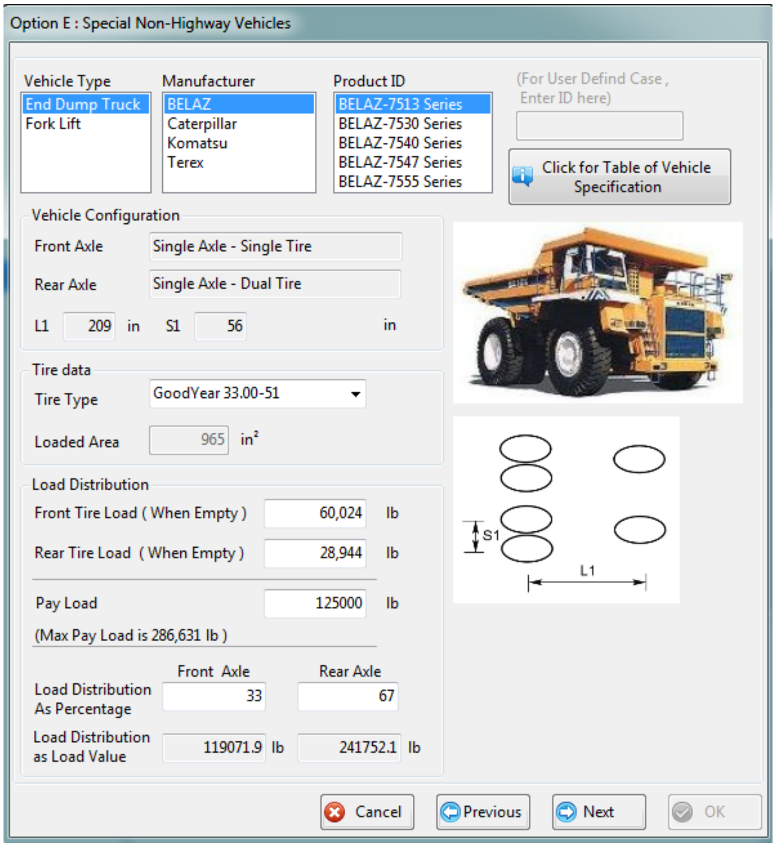
Vehicle Speed at Brake Initiation 40 mph

Stopping Distance (SD) 1200 in

Pavement Slope 0 Degree

Under this option, the load distribution on the various tires of the 18-wheel tractor-semitrailer during normal highway traffic and during braking is initially computed. Braking causes the vehicle to decelerate and the loads to transfer to the front of the vehicle. The resulting axle load can be higher or lower than the initial static load, depending on the location of the axle. Once the load distribution among the axles of the semitrailer is evaluated, the contact pressure distribution can be assigned (Uniform or Non-Uniform).

Type 5: Special Non-Highway Vehicles (Uniform Contact Pressure Distribution)



Option E : Special Non-Highway Vehicles

Vehicle Type	Manufacturer	Product ID
End Dump Truck	BELAZ	BELAZ-7513 Series
Fork Lift	Caterpillar	BELAZ-7530 Series
	Komatsu	BELAZ-7540 Series
	Terex	BELAZ-7547 Series
		BELAZ-7555 Series

(For User Defind Case , Enter ID here)

Vehicle Configuration

Front Axle Single Axle - Single Tire

Rear Axle Single Axle - Dual Tire

L1 209 in S1 56 in

Tire data

Tire Type GoodYear 33.00-51

Loaded Area 965 in^2

Load Distribution

Front Tire Load (When Empty) 60,024 lb

Rear Tire Load (When Empty) 28,944 lb

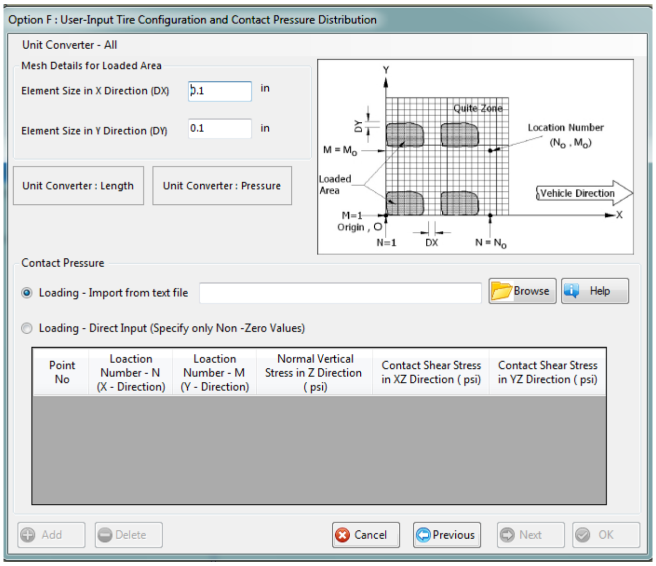
Pay Load 125000 lb

(Max Pay Load is 286,631 lb)

	Front Axle		Rear Axle	
Load Distribution As Percentage	33		67	
Load Distribution as Load Value	119071.9	lb	241752.1	lb

Under this option, two non-highway vehicles (an end dump truck and forklift) are included. Different manufacturers are presented for each vehicle. User can select an appropriate axle configuration and tire load from a database of manufacturer's specifications. Uniform contact pressure distribution is the only option available.

Type 6: User-Input Tire Configuration and Contact Pressure Distribution (Uniform / Non-Uniform Contact Pressure Distribution)



Option F : User-Input Tire Configuration and Contact Pressure Distribution

Unit Converter - All

Mesh Details for Loaded Area

Element Size in X Direction (DX): 0.1 in

Element Size in Y Direction (DY): 0.1 in

Contact Pressure

● Loading - Import from text file

○ Loading - Direct Input (Specify only Non -Zero Values)

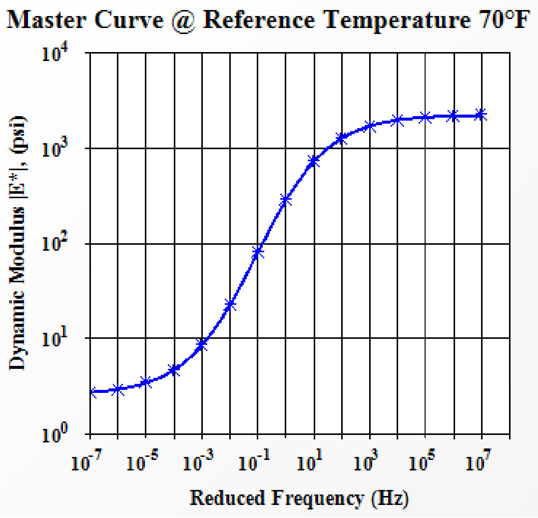
Point No	Loaction Number - N (X - Direction)	Loaction Number - M (Y - Direction)	Normal Vertical Stress in Z Direction (psi)	Contact Shear Stress in XZ Direction (psi)	Contact Shear Stress in YZ Direction (psi)

This option is entirely open to the user to define the contact pressure distributions. Contact may be uniform or non-uniform.

Characterization of Asphalt Materials

The asphalt layer material can be characterized as a linear elastic material or as a viscoelastic material. The dynamic modulus, |E*|, is required for the viscoelastic analysis. |E*| can be input in three ways:

Dynamic Modulus Lab Data
Asphalt material properties can be specified using the dynamic modulus lab data. The *3D-Move Analysis* incorporates the master curve, which enables the input of dynamic modulus at any selected pavement temperature in the analysis. It uses an optimization tool which is independent of Microsoft Excel to construct the master curve from the lab data.

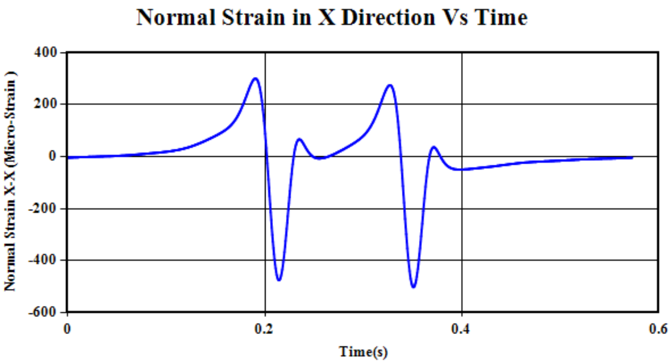


Witczak Model
In this version of *3D-Move Analysis*, the Witczak model is included to calculate the frequency-dependent dynamic modulus based on the gradation and binder properties of the mixture.

User Defined Materials Properties
A set of data of |E*| as function of frequency can be specified by the user. Other input variables (Poisson's and Damping ratios) can be either specified as constants or as a function of frequency.

Output

An important component of the analysis package is the user-friendly documentation and portability of the results to other platforms. The *3D-Move Analysis* output can be viewed using Text Mode, Tabular Mode, or Graphical Mode.



Graphical Mode.
(Available only for dynamic analysis.)

References:

Al-Qadi, I.L., and Wang, H., “Evaluation of Pavement Damage due to New Tire Designs,” Research Report ICT-09-048, Illinois Center for Transportation, IL., May 2009.

Huhtala, M. and Pihlajamaki, K. “New Concepts on Load Equivalency Measurements,” Proc. 7th Int. Conf. Asphalt Pavements, Nottingham, U.K., 1992, pp. 194-208.

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Siddharthan, R.V., Krishnamenon, N., El-Mously, M., and Sebaaly, P.E., “Investigation of Tire Contact Stress Distributions on Pavement Response,” *Journal of Transportation Engineering,* ASCE, Vol. 128(2), March/April, 2002, pp. 136-144.

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Siddharthan, R., Sebaaly, P.E., El-Desouky, M., Strand, D., and Huft, D. “Heavy Off-road Vehicle Tire-Pavement Interactions and Response,” *Journal of Transportation Engineering,* ASCE, Vol. 131(3), March/April 2005, pp. 239-247.