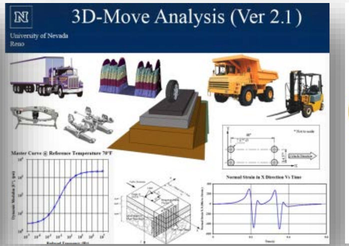


ARC Deliverables/Products Presentation and Workshop

http://www.arc.unr.edu/

Western Regional Superpave Center (WRSC)
University of Nevada, Reno

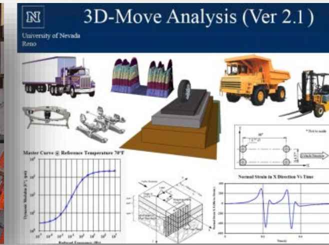
Washington, DC – January 15, 2015

ARC
Asphalt Research Consortium

Western Regional Superpave Center

11:05 – 11:30:	Pavement Engineering Software: Pavement Response Model to Dynamic Loads (3D-Move).
11:35 – 12:00:	Rutting Performance of Asphalt Mixtures Under Critical Conditions.
1:00 – 1:25:	Mix Design for Cold in-Place Recycling (CIR).
1:30 – 1:55:	Pavement Engineering Software: Thermal Cracking Analysis Package (TCAP).

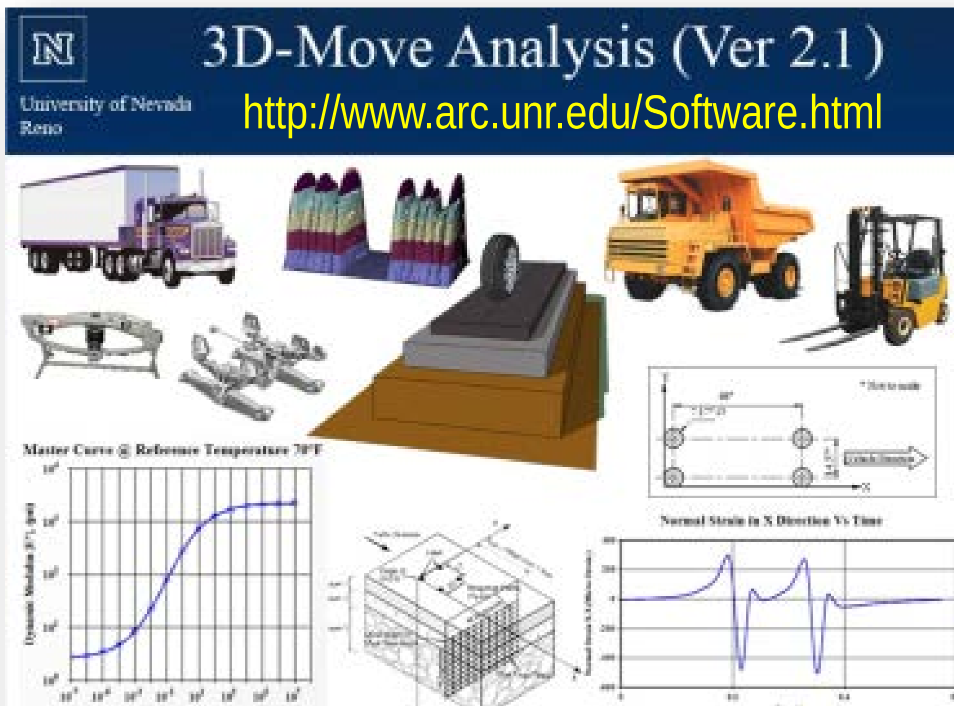


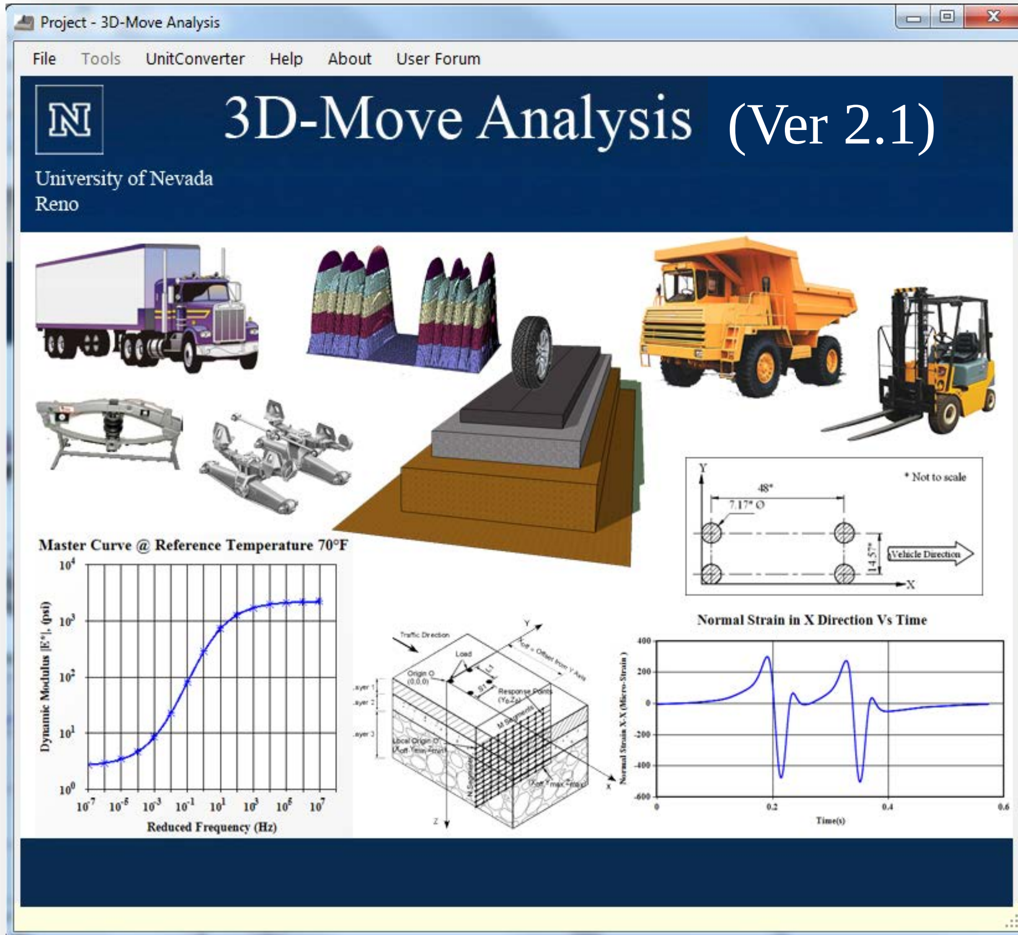
ARC Deliverables/Products Presentation and Workshop

Pavement Response Model to Dynamic Loads:

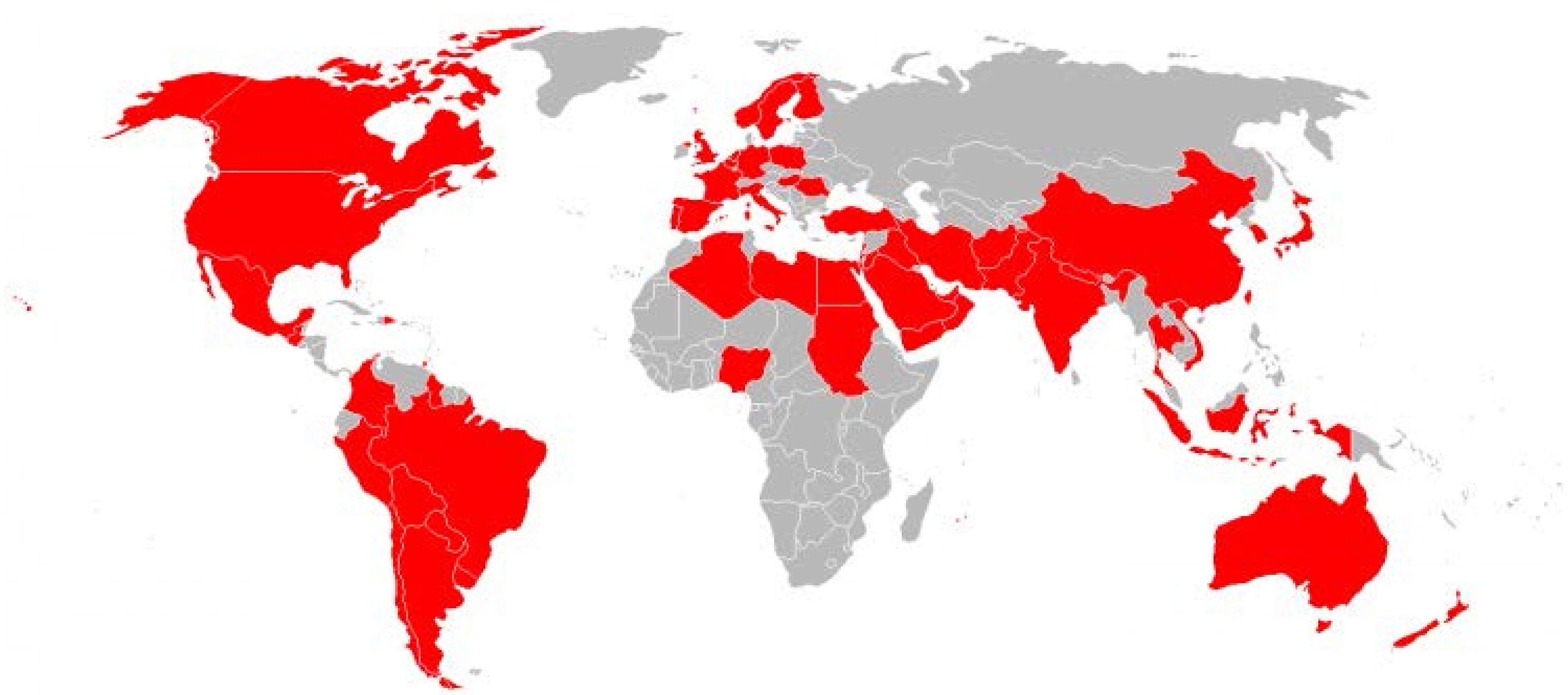
3D-Move Analysis Software



How to Download 3D-Move!
Visit ARC website @ http://www.arc.unr.edu/Software.html



3D-Move Analysis Software
Over 750 Users from around the world!



Summary: Elements of the 3D-Move Analysis Software

(1) Uses Finite-Layer Continuum Approach – Takes Advantage of Horizontally-Layered Pavement Layers; No Discretization; No Lateral Boundary Effects. – Computer Efficient.

(2) Models Moving 3D-Surface Stresses (Dynamic; Normal & Shear Contact Stresses) – Handles Vehicle Speed and Vehicle Braking.

(3) Direct Use of Frequency-Sweep Data (Viscoelastic Modeling).

(4) Ideally-Suited when Responses are Needed at a Selected Few Locations - Computer Efficient.

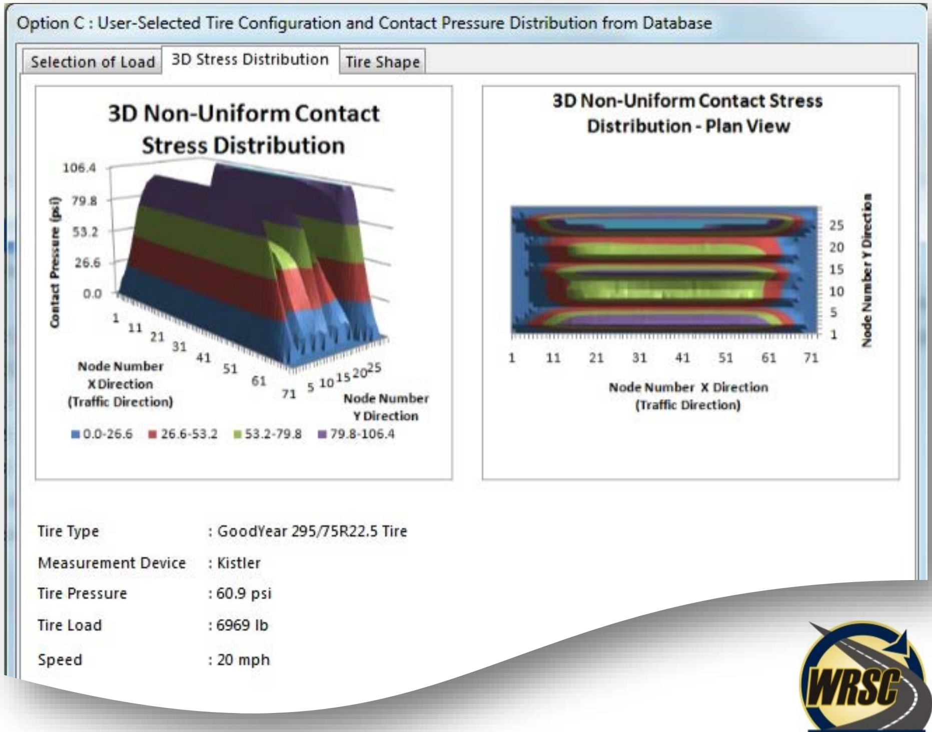
Important Attributes of Pavement Modeling

Factor	Layered Elastic Analysis (LEA)	Finite Element Method (FEM)	3D-Move Model
Important Attributes of Pavement Modeling: Load-Related			
Non-Circular Loaded Shape	NO	YES	YES
Non-Uniform Vertical Contact Stress	NO	YES	YES
Contact Shear Stresses (Braking & Sloping Pavements)	NO	YES	YES
Moving Load (Non-Stationary) and Inertia Included (i.e. Dynamic)	NO	NO/YES	YES
Important Attributes of Pavement Modeling: Material Properties			
Viscoelastic Properties (Modulus and Phase Angle)	NO	YES	YES
Vehicle Speed	NO	YES	YES
Direct Use of Freq. Sweep Data	NO	NO	YES

Attributes of 3D-Move[1]

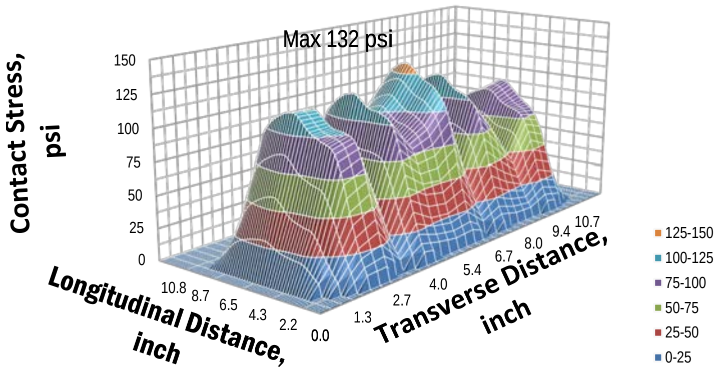
Non-Uniform Contact Stress Distribution[1]

- Non-Uniform 3D Contact Stress Distributions (Normal and Shear Contact Stresses)
  - Vertical, Longitudinal, and Transverse Directions
- Shear interface stresses are needed for braking and sloping pavements.



Attributes of 3D-Move, 2
Non-Uniform Contact Stress Distribution, 2

- Hajj et al. (2012)[a]:
  - Impact of non-uniform contact stress distribution on pavement responses & performance found to be *significant*.
  - Effect of vehicle braking on pavement responses *should be considered* when designing pavements that are to be placed at intersections and sopping areas.



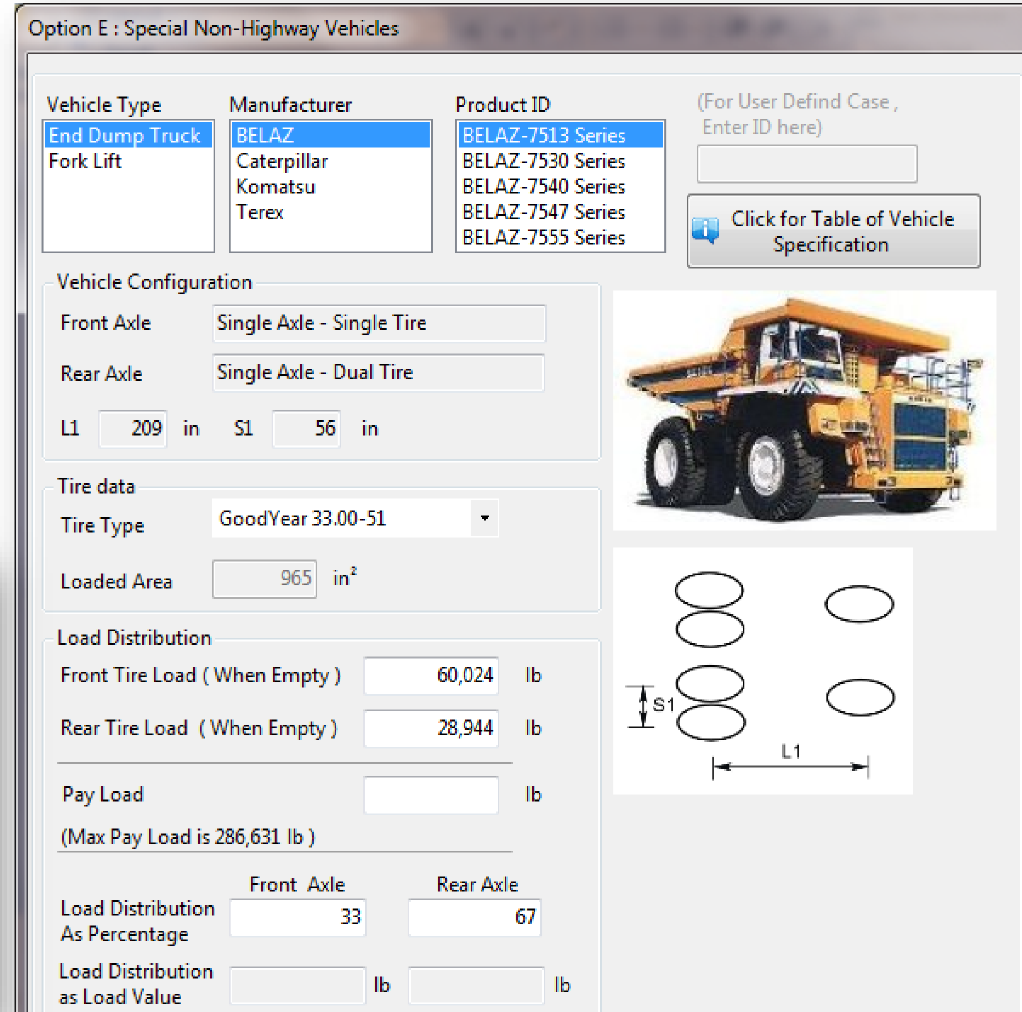
[a] Hajj et al. (2012). Influence of tire-pavement stress distribution, shape, and braking on performance predictions for asphalt pavement. Transportation Research Record: Journal of the Transportation Research Board, Vol 2306, pp.73-85.

Non-Uniform Contact Stress Distribution[3]

- Ready-to-use database:
  - Council for Scientific and Industrial Research (CSIR)
  - University of California at Berkeley (UCB)
  - Nevada Automotive Test Center (NATC)
    - VRSPTA: 123 (Single)+ 38 (Supersingle)+15 (Dual) =176
    - Kistler: 64 (Dual) + 64 (Singled out Dual) + 64 (widebase) + 48 (Dual with differential Pressure) = 240
    - Others

Attributes of 3D-Move$_4$
Non-Standard Vehicles

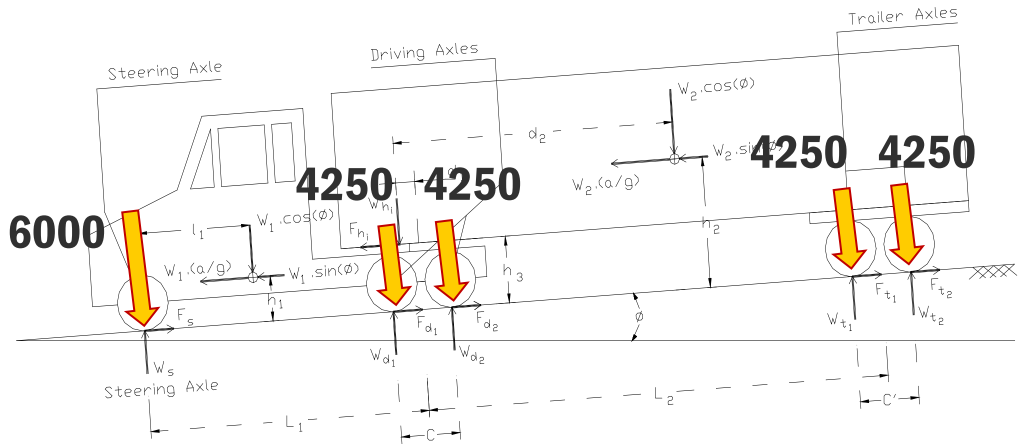
- End Dump Trucks
  - Belaz (5)
  - Caterpillar (6)
  - Komatsu (11)
  - Terex (6)
- Fork Lift
  - Hyster (9)

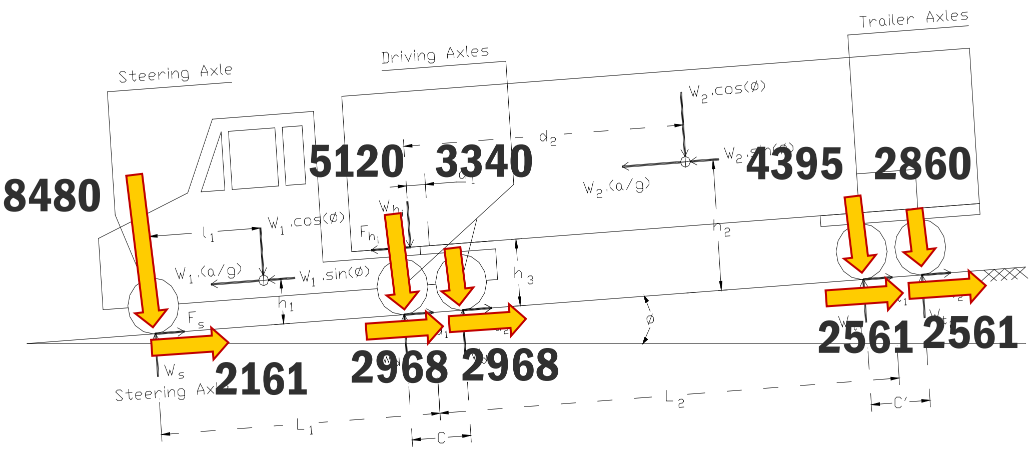


Attributes of 3D-Move$_5$

Built-in Model for Braking of a Semi-Trailer Truck

- Load Distribution During Braking:
  - 11 equilibrium equations
  - 3 characteristic equations:
    - Application (treadle output) v/s actuation (brake chamber) pressure/axle – linear brake system.
    - Brake force v/s actuation pressure on each axle.
    - Dynamic load transfer coefficient.

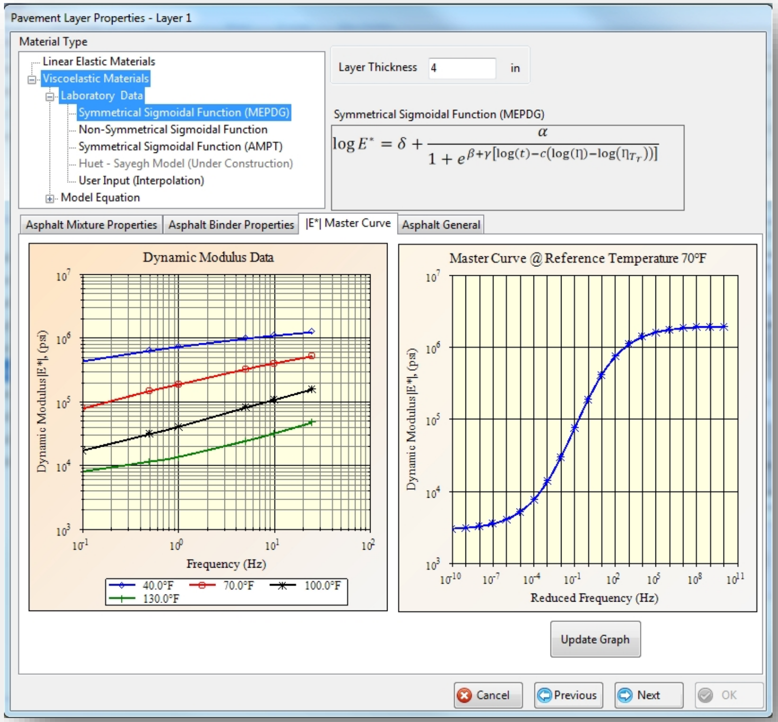




Attributes of 3D-Move$_6$

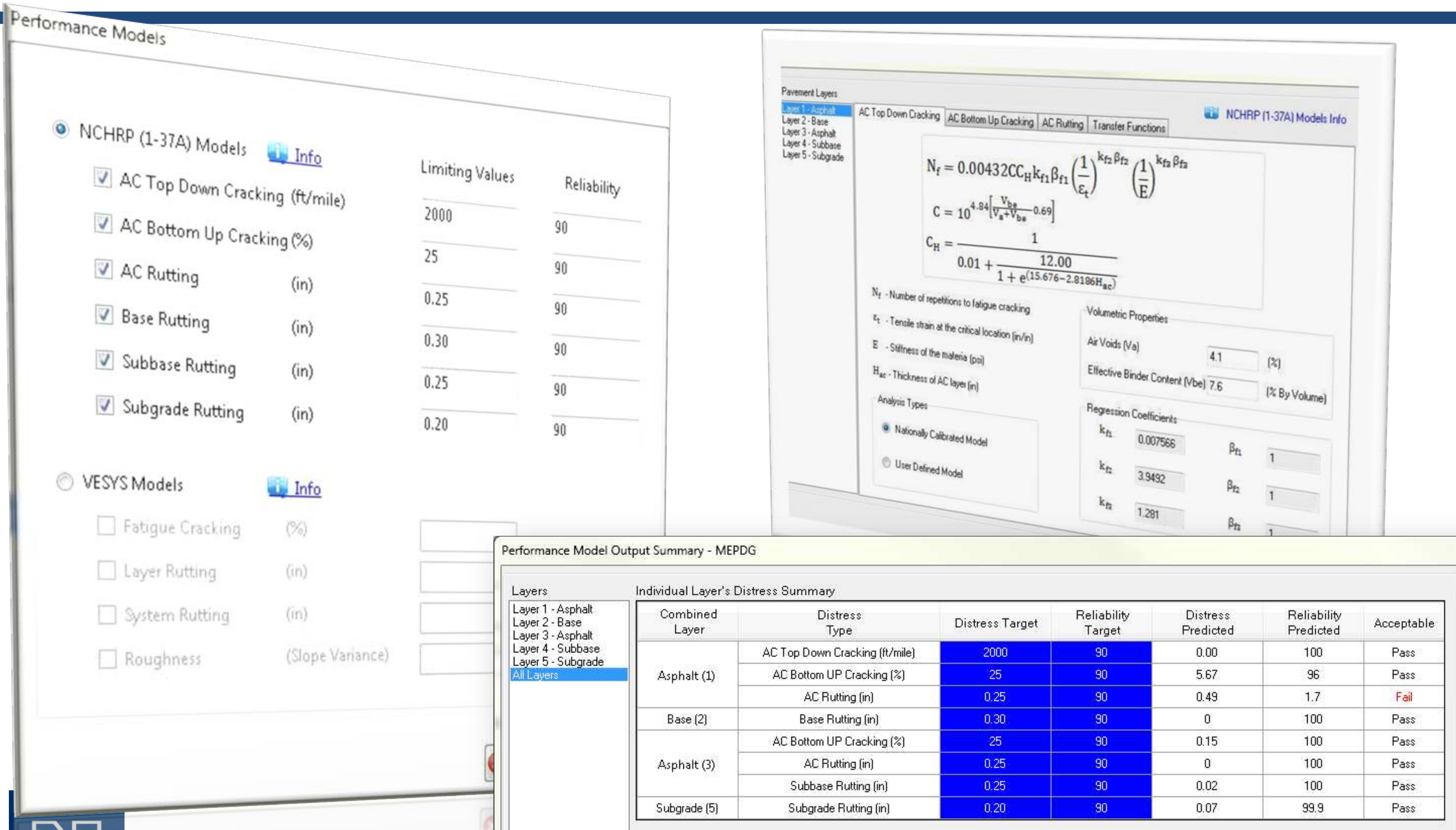
Materials Input: Viscoelastic Property of AC

- Dynamic Modulus and Phase Angle data:
  - Symmetrical Sigmoidal Function (MEPDG)
  - Non-Symmetrical Sigmoidal Function
  - Symmetrical Sigmoidal Function (AMPT)
  - User Input (Interpolation)
- Model Equation
  - Witczak Model (1-37A)



Attributes of 3D-Move$_8$

Pavement Performance Predictions



$$N_f = 0.00432 C C_H k_{f1} \beta_{f1} \left(\frac{1}{\varepsilon_t}\right)^{k_{f2}\beta_{f2}} \left(\frac{1}{E}\right)^{k_{f3}\beta_{f3}}$$

$$C = 10^{4.84\left[\frac{V_{be}}{V_a+V_{be}} - 0.69\right]}$$

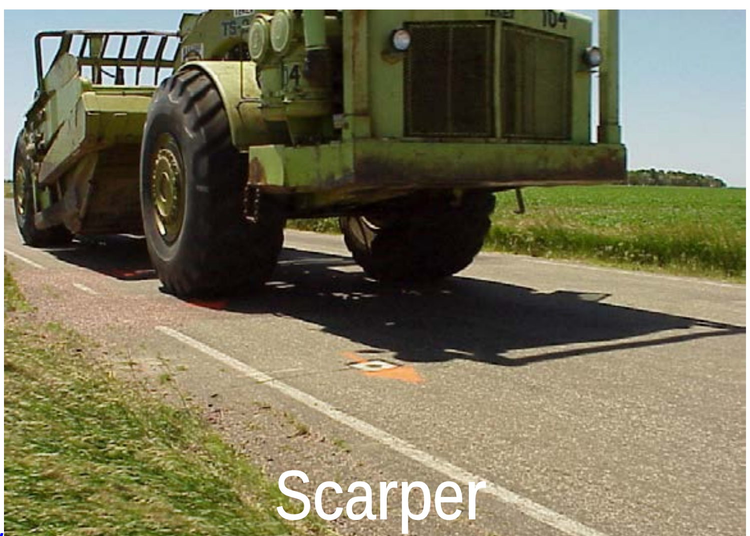
$$C_H = \frac{1}{0.01 + \frac{12.00}{1+e^{(15.676-2.8186H_{ac})}}}$$

Examples of 3D-Move Applications
(1) Estimate of Damage Under Off-Road Farm Vehicles[1]

- South Dakota DOT (Project SD99-15) – Objectives:
  - What additional damage off-road vehicles impose?
  - Should they be allowed on public roads?
- Experimental Approach:
  - Construct instrumented field sections
  - Measure pavement responses
  - Use measured response to validate 3D-Move
  - Use 3D-Move to evaluate damage

Examples of 3D-Move Applications

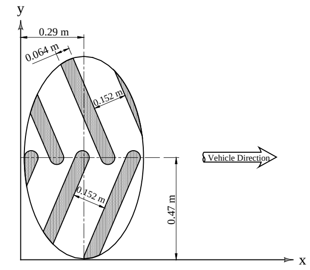
(1) Estimate of Damage Under Off-Road Farm Vehicles[2]

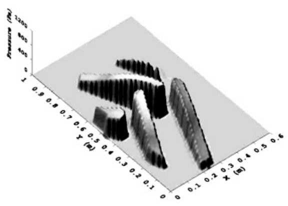


Examples of 3D-Move Applications

(1) Estimate of Damage Under Off-Road Farm Vehicles[3]

- Characteristics of Off-Road Equipment
  - Massive Tires: 0.95 m vs. 0.20 m (Conventional)
  - Tire Lugs: off-road vs. conventional tires
  - Tire Loads: 100 kN vs. 22.5 kN (Conventional)
  - Tire Pressure: 250 kPa vs. 850 kPa (Conventional)
  - Vehicle Speed: 60 km/h vs. 100 km/h (Conventional)





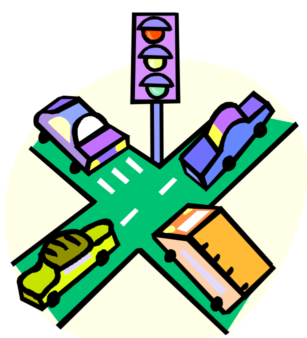
(1) Estimate of Damage Under Off-Road Farm Vehicles[4]

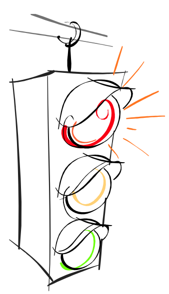
- Implementation:
  - Do not ban agriculture equipment on highways.
  - Allow empty Terragators and Grain Carts to move over highway pavements.
  - Use legally loaded standard trucks to move fertilizers and grains to the field locations.

(2) Analysis of Pavement Performance at Intersection$_1$

- Vehicle loads at intersections (on/off ramps) are significantly different from those at highways.

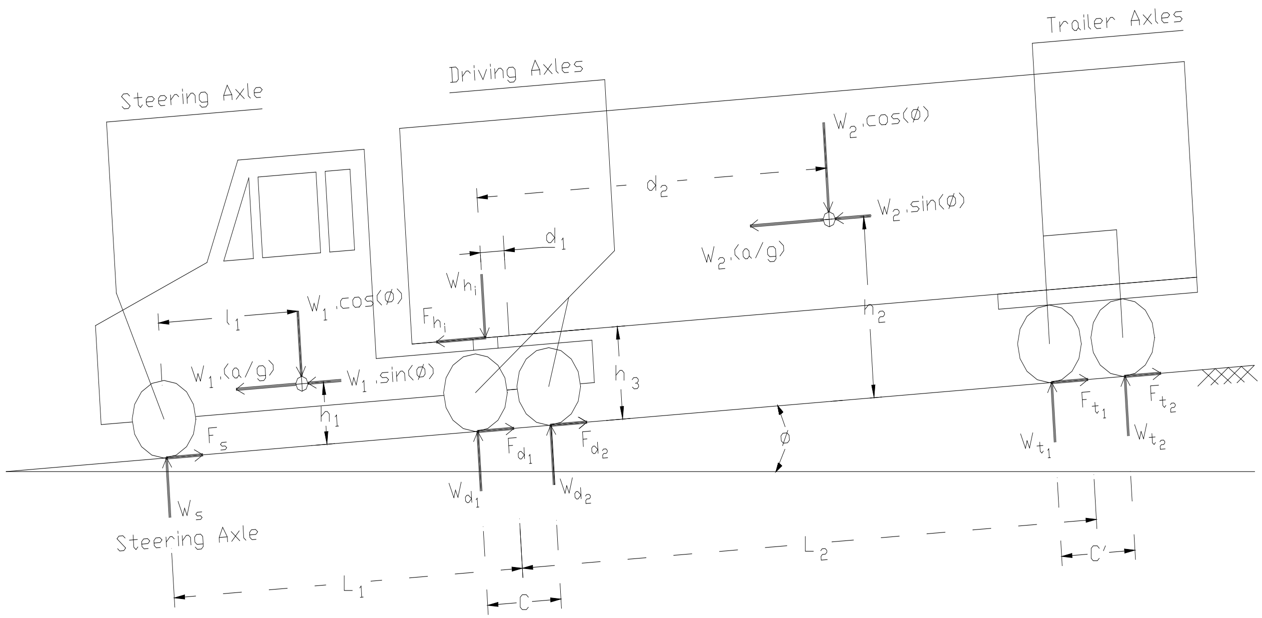
- Asphalt Mixtures at/near a braking stop:
  - Subjected to more complex stresses due to *braking*.
  - Behaves weaker as subjected to slow moving or stopped vehicles.



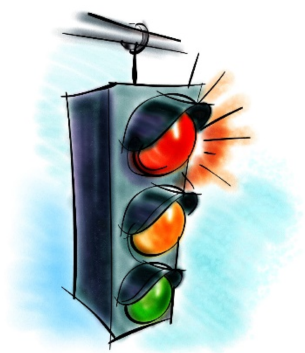


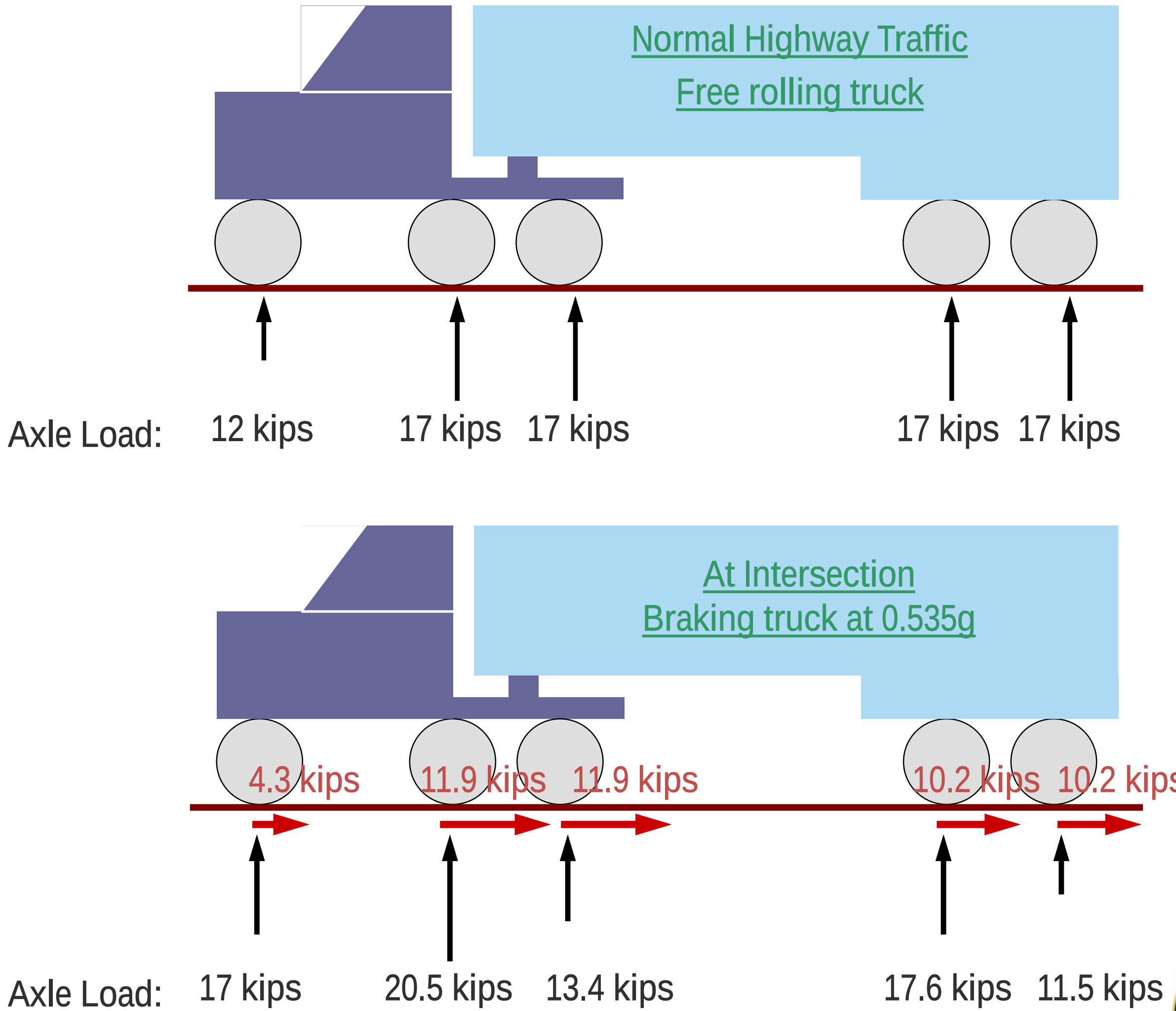
Examples of 3D-Move Applications
(2) Analysis of Pavement Performance at Intersection$_2$

- Vehicle *load redistribution* during braking.
- Additional *interface shear stresses* due to braking.
- *Single vs. wide base* tires.
- Non-uniform tire contact pressure distribution.
- etc…



Examples of 3D-Move Applications
(2) Analysis of Pavement Performance at Intersection[3]





Examples of 3D-Move Applications

(3) Assessing Damage from Bus Rapid Transits[1]

	Front	Drive	Rear
GAWR Load, lbs	15,653	20,944	14,330
Axle Configuration	Single Axle/ Single Tire	Single Axle/ Dual Tires	Single Axle/ Single Tire
Tire Pressure, psi	120	85	110
Tire Type	Michelin XZU/305/70R 22.5		

	Front	Drive	Rear
GAWR Load, lbs	16,094	28,660	25,574
Axle Configuration	Single Axle/ Single Tire	Single Axle/ **Widebase** Tire	Single Axle/ **Widebase** Tire
Tire Pressure, psi	130	130	130
Tire Type	275/70R 22.5	494/45 R22.5	494/45 R22.6

	Front	Drive	Rear
GAWR Load, lbs	14,780	24,250	27,760
Axle Configuration	Single Axle/ Single Tire	Single Axle/ Dual Tires	Single Axle/ DualTire
Tire Pressure, psi	120	120	120
Tire Type	Michelin XZU/305/70R 22.5		

(4) Pavement Damage Due to OS/OW or SHL Moves[1]

- "Non-Generic" axle and tire configurations.
- Slow moving loads.

http://www.folsomlakefordfleet.com/thingsyouneedtoknow/weightsizelimits.html

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Thank You!

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University of Nevada, Reno, www.wrsc.unr.edu

Thank You!