

# Vehicle-Pavement Interaction ARC Year 5 Plan Overview

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March 14, 2011

*Fundamental Properties and Advanced  
Models ETG*

Phoenix, Arizona



## 3D-Move:

Freeware Download at: <http://www.arc.unr.edu/Software.html>



### Asphalt Research Consortium

Home Outreach Project Team Software Publications Workshops Newsletters Contacts Links

#### Software

3D-Move

#### Free Softwares

3D-Move (NEW: Version 1.2) Now Available Online!

**Announcement to 3D-Move Users (Posted on August 29, 2010):**  
*Inconsistency Between Text and Excel Output Files of Ver. 1.1*

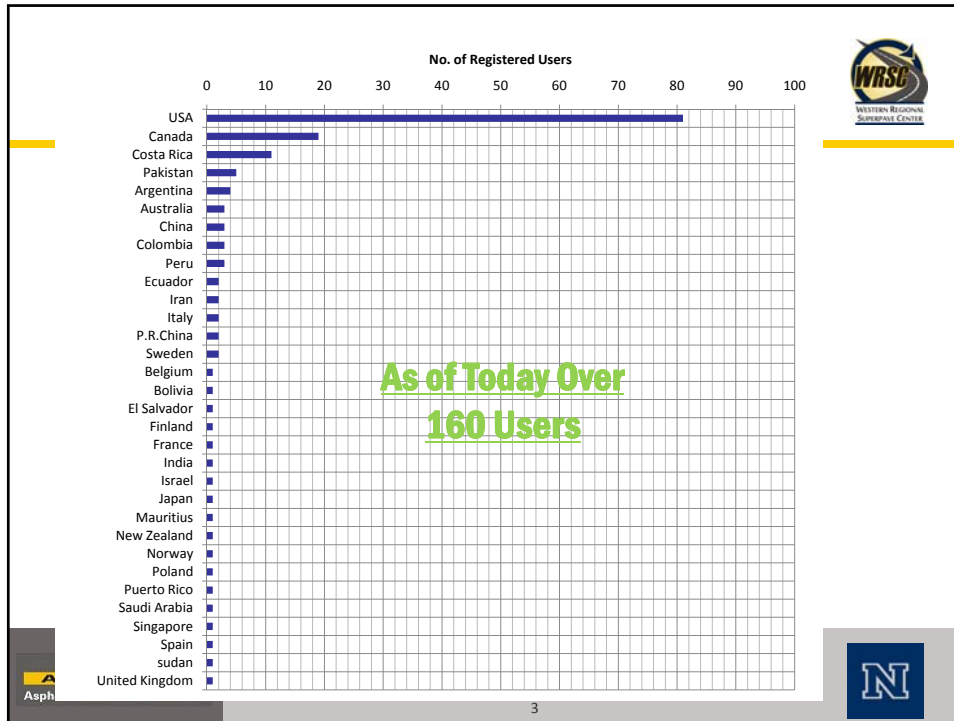


#### Announcements

**DISCUSSION GROUP\* at**  
[3d-move.finddiscussion.com](http://3d-move.finddiscussion.com) to  
provide your feedback or  
post your questions on the  
3D-Move Analysis Software.

The last beta-version of the 3D-Move Analysis (ver 1.1) was released on July, 2010. In 3D-Move, output is provided in formats: Text and Excel. An inconsistency has inadvertently occurred when these two formats were integrated. The **inconsistency was present only in the Excel file**, while the **Text file output is correct**. The origin of the slip-up was traced to the allocation of the columns when the data sharing between Text and Excel output files occurred. Further, there were concerns about the units of the 3D-Move responses being not prominently displayed. These issues have been corrected and a modified beta-version of 3D-Move (ver 1.2) is now available for [download](#).





## ARC Year 5 Plan Overview

- *3D-Move Analysis Software*
  - Visco-elastic material input
  - Performance evaluation
  - Graphical display for measured stress distributions
  - Assess the need for ANN to predict non-uniform contact stress distribution
- Operational, Verification & Validation Plan

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N

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# New Features in Version 2.0

## Viscoelastic Materials Input Options



- **Laboratory Data:**
  - Symmetrical Sigmoidal Function (MEPDG) – *Completed*
  - Non-Symmetrical Sigmoidal Function – *Completed*
  - Symmetrical Sigmoidal Function (AMPT) – *Completed*
  - Huet-Sayegh Model – *In Progress*
  - User Input (Interpolation) – *Completed*
- **Model Equation**
  - Witczak Model – *Completed*
  - Huet-Sayegh – *Completed*



**Using Lab Data**

The screenshot displays the software interface for defining viscoelastic material properties. It features several overlapping windows:

- Material Selection:** A list of material models including Laboratory Data, Symmetrical Sigmoidal Function (MEPDG), Non-Symmetrical Sigmoidal Function, Symmetrical Sigmoidal Function (AMPT), Huet-Sayegh Model, and User Input (Interpolation).
- Equation Inputs:**
  - Symmetrical Sigmoidal Function (MEPDG):  $\log E^* = \delta + \frac{\alpha}{1 + e^{\beta + (\log f) - (\log f_0 - \log f_1)}}$
  - Non-Symmetrical Sigmoidal Function:  $\log E^* = \delta + \frac{\alpha}{1 + \lambda e^{\beta + \gamma (\log f)}}$
  - Symmetrical Sigmoidal Function (AMPT):  $\log E^* = \delta + \frac{\text{Max} - \delta}{1 + e^{\beta + (\log f - \log f_1) \left( \frac{1}{f_2} - \frac{1}{f_1} \right)}}$
- Dynamic Modulus Graphs:** Plots of Dynamic Modulus  $E^*$  (Pa) versus Frequency (Hz) for temperatures 40°F, 100°F, and 120°F. The graphs show the frequency dependence of the modulus at different temperatures.
- Temperature Data Table:**

Temperature (°F)	No. of	No. of
40	83300	1142
70	86700	220
100	82600	184
130	5200	60
- User Defined Properties:** A table for defining material properties such as Frequency (Hz), Dynamic Modulus  $E^*$ , Poisson's Ratio, and Damping Ratio (%).

# New Features in Version 2.0

## Viscoelastic Materials Input Options – Model Equation



**Witzak's Model**

$$E^*(\omega) = 0.75862 + 0.02702E_{00} - 0.001707E_{00}^2 - 0.00284E_{00}^3 - 0.00097E_{00}^4 - 0.00229E_{00}^5 + \frac{E_{00}^6}{(1 + \delta(\omega\tau)^{-k} + (\omega\tau)^{-h})}$$

Layer Thickness: 4 in

**Asphalt Mix Properties** | Asphalt Binder Properties | Asphalt General

Dynamic Modulus  $E^*$  from Witzak Equation

Aggregate Gradation

Volumetric Properties

Effective Binder Content (By Volume) %

Air Voids %

Poisson's Ratio

Constant Poisson's Ratio  Poisson's Ratio from Model  Click to see the Poisson's Ratio Model

Parameter a:  Parameter b:

Note: a and b are constants. Typical Values: a = -0.53 and b = 3.88-6

Poisson's Ratio vs Frequency (Hz)

Frequency (Hz)  Poisson's Ratio

Damping Ratio %

**Huet - Sayegh Model**

$$E^*(\omega) = E_0 + \frac{E_{\infty} - E_0}{1 + \delta(\omega\tau)^{-k} + (\omega\tau)^{-h}}$$

Layer Thickness: 4 in

**Huet - Sayegh Model Parameter** | Asphalt General

Huet - Sayegh Model

$$E^*(\omega) = E_0 + \frac{E_{\infty} - E_0}{1 + \delta(\omega\tau)^{-k} + (\omega\tau)^{-h}}$$

Characteristics Time Equation

$$\tau = e^{c+bT+aT^2}$$

Where

$E_{\infty}$  - Stiffness at Low Temperature       $\tau$  - Characteristic Time

$E_0$  - Stiffness at High Temperature       $a, b, c$  - Regression Constants representing Materials Characteristics

$\delta, h, k$  - Characteristics of Pavement Elements

$E_{\infty}$    $\delta$    $k$    $b$

$E_0$    $h$    $a$    $c$



# New Features in Version 2.0

## Pavement Performance Models



Example 6 - 3D-Move Analysis

File Tools UnitConverter Help About User Forum

Analysis Status

Site / Project Identification

Site / Dynamic Response Analysis

Extended Analyses

Inputs

Axle Configuration and Contact Pressure Distribution

Vehicle Suspension and Road Roughness

Drifts

Pavement Structure

Pavement Layer Properties

Performance Models

Response Points

Output

**Extended Analyses**

**Performance Models**

**MEPDG Models** [Info](#)

Model	Limiting Values	Reliability
<input checked="" type="checkbox"/> AC Top Down Cracking (ft/mile)	2000	90
<input checked="" type="checkbox"/> AC Bottom Up Cracking (%)	25	90
<input checked="" type="checkbox"/> AC Rutting (in)	0.25	90
<input checked="" type="checkbox"/> Base Rutting (in)	0.30	90
<input type="checkbox"/> Subbase Rutting (in)		
<input checked="" type="checkbox"/> Subgrade Rutting (in)	0.20	90

**VESYS Models** [Info](#)

<input type="checkbox"/> Fatigue Cracking (ft/mile)		
<input type="checkbox"/> Layer Rutting (in)		
<input type="checkbox"/> System Rutting (in)		
<input type="checkbox"/> Roughness		

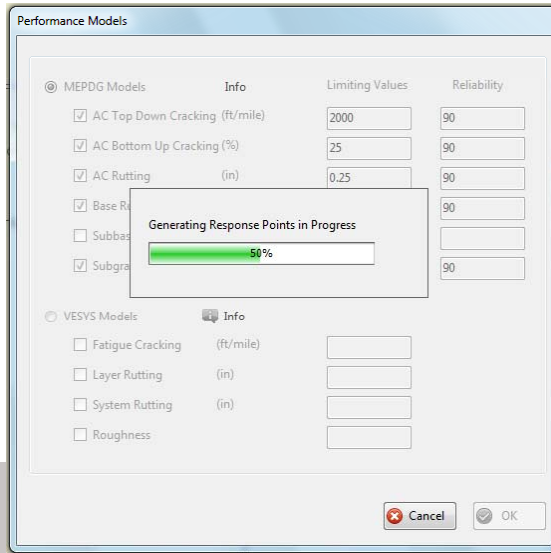
Cancel OK

## New Features in Version 2.0

### Pavement Performance Models

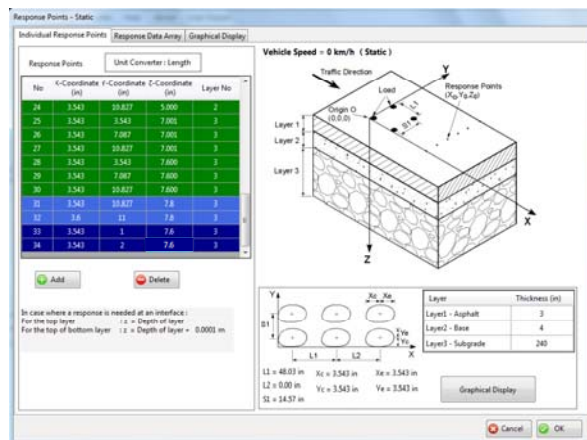


- Once the “OK” is hit, it does internally produce response points at the pre-defined critical locations.



## New Features in Version 2.0

### Pavement Performance Models



- Recommended Points
- Added Points by User Considered for Performance Analysis
- Added Points by User But Not Considered for Performance Analysis



# New Features in Version 2.0

## Pavement Performance Models



Graphical display of Response Points Locations

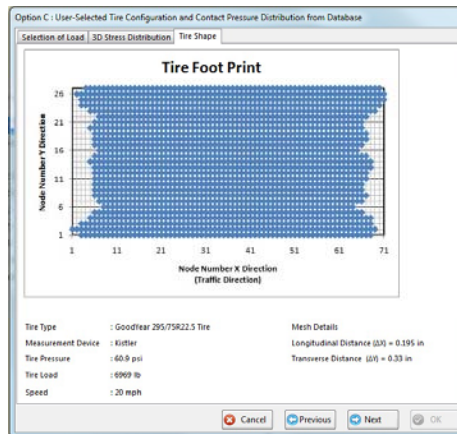
# New Features in Version 2.0

## Non-Uniform Contact Stress Distribution Graphical Display




## New Features in Version 2.0

### Non-Uniform Contact Stress Distribution Graphical Display



## ANN for Non-Uniform Contact Stress Distributions



- Contact stress distribution only available under limited levels of inflation pressure and tire load
- Evaluate the impact of *linear interpolation* and *extrapolation* of stress distributions from currently available measurements on the response & performance of HMA pavements



## ANN for Non-Uniform Contact Stress Distributions



- Pavement responses under:
  - Measured stress distributions under 5, 25, 30 & 36 kN
  - 25 kN *interpolated* from [5 kN; 30 kN]
  - 30 kN *interpolated* from [25 kN; 36 kN]
  - 25 kN *extrapolated* from [30 kN; 36 kN]
- Data under analysis



## 3D-Move Evaluation, Verification & Validation



- The UNR team will start an Evaluation, Verification and Validation of the *3D-Move Analysis* software in three phases





## 3D-Move Evaluation, Verification & Validation



- *Phase I: Operational Evaluation*
  - Plan will help identifying potential errors, bugs, and difficulties involved in using the software for pavement analysis purposes.



## 3D-Move Evaluation, Verification & Validation



- *Phase I: Operational Evaluation*
  - Address key questions:
    - Can users successfully generate the assigned examples in the 3D-Move software?
    - Is the software status clear to users at all times?
    - Are the input steps logically organized and grouped for the users?
    - Are the pictures and illustrations used in the various windows helpful to users and do they facilitate the software use/understanding?
    - Was the help menu useful and easy to navigate?
    - Is the output format clear and provide the necessary information for the analysis of the data?
    - What are the main benefits of using the software?
    - In what case studies does the user perceive a great use of the software?
    - Will the agency/user be willing to adopt the software for their pavement analysis?
    - What are the user recommendations for modification or enhancement to make the software more useful and practical?



## 3D-Move Evaluation, Verification & Validation



- *Phase I: Operational Evaluation*
  - In the process of preparing three different problem cases
  - In the process of putting together a report form



## 3D-Move Evaluation, Verification & Validation



- *Phase I: Operational Evaluation*
  - Potential Participants:

**Representatives of public agencies:**

N. Krishnamenon (Caltrans)  
Magdy Mikhail (TxDOT)  
Dr. Charlie Pan (NDOT)  
Ambi Thurai (Orange County Airport, CA)  
Dr. Armelle Chabot (IFFSTAR, France)  
Ken Walsh (OHDOT)

**Representatives of academic/researchers:**

Dr. Adrián Ricardo Archilla (Univ. of Hawaii at Manoa)  
Fujie Zhou (TTI)  
Dr. Nam Tram (NCAT)

**Representatives of private industries:**

Dr. Zia Zafir (Kleinfelder)  
Dr Raj Dongre (DLSI),  
Dr. Guangming (William) Wang (QES)  
Dr. Shakir Shatnawi (SHATEC)  
George Way

**Representative of FHWA:**

Eric Weaver (FHWA)  
Nelson Gibson (FHWA)



## 3D-Move Evaluation, Verification & Validation



- *Phase II: Verification*
  - Verify selected *3D-Move Analysis* pavement responses with measured field data.
  - Identify datasets that include vehicle dynamics and sufficient laboratory characterization and documentation.



## 3D-Move Evaluation, Verification & Validation



- *Phase II: Verification*
  - Potentially Suitable Datasets:
    - VTRC SmartRoad,
    - WesTrack,
    - IFFSTAR,
    - NCAT
    - OHDOT
    - Nottingham data
    - ...?



## 3D-Move Evaluation, Verification & Validation



- *Phase III: Validation*
  - Validate the findings from Phase II with an independent dataset



## ARC Database



- *Work element TT1d and TT1e: Development of materials and research database*
  - Store information related to *sources & properties of materials* used in various consortium research activities.
  - Includes results update in form of *reports, white papers* or *any other type of documents* for each research task...



# Overall Introduction



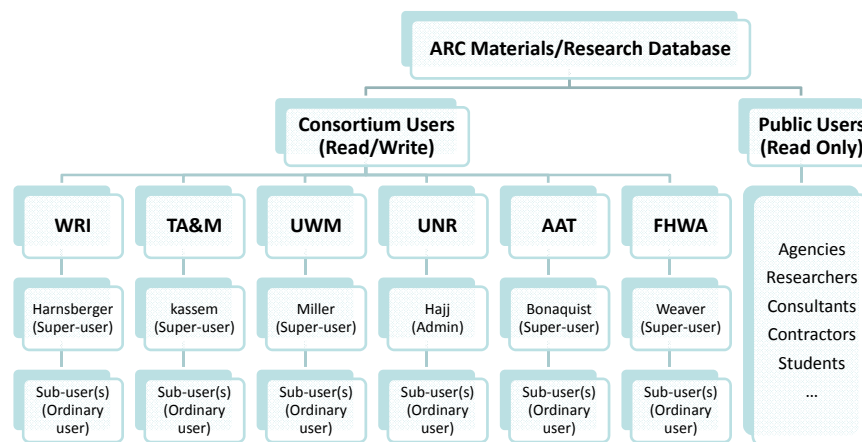
- **Challenges:**

- No software installation – web-base system
- Flexibility (No hard-coded data)
- central database
- Multiple users (role-based infrastructure)
  - Add/Delete/Edit materials information
  - Retrieve information (Public interface)
- Different users' roles
- Common materials use
- Multiple measures for the same material
- Ability to relate material(s) to validation sections
- ...



# Overall Introduction

## General Users' Diagram



## Getting to the Application



- Using Internet Explorer, visit <http://www.business.unr.edu/arc>
- Click the **Login** button and enter credentials



## Selection and Filtering



- Materials (and other elements) can be selected and filtered by
  - Material type
  - Material category
  - Organization
  - Supplier
  - Work tasks
  - Validation section
  - Component materials



## Support Files (Introduction)



- Support files can include
  - reports,
  - scanned document,
  - picture,
  - just about anything related to the ARC project
- Support files can be filtered by work items (program area, category, work element, subtask)



## Selection and Filtering



The screenshot shows the 'ARC - Materials Editor' web application. The main content area is titled 'Select Material To Edit From Tree:'. It features a 'Filters' section with four dropdown menus: 'Material Type' (set to [ALL]), 'Material Category' (set to [ALL]), 'Primary Organization' (set to [ALL]), and 'Supplier' (set to [ALL]). Below the filters are three checkboxes: 'Work Tasks' (checked), 'Validation Sections' (checked), and 'Component Material' (unchecked). Under 'Work Tasks', there are four dropdown menus: 'Program Area' (Validation (V)), 'Category' (V1: Field Validation), 'Work Element' (V1b: Construction and Monitoring of Additional Comparative Pavement Valids), and 'Subtask' (V1b-1: Construction and Monitoring of Additional Comparative Pavement Vali...).

Below the checkboxes is a 'Show Detail' section with three dropdown menus: 'Select Validation Site' (PTH9-RAP Project), 'Select Validation Section' (63R107), and 'Select Layer' (1). At the bottom left, there is a 'Filter By' section with radio buttons for 'Site', 'Section', and 'Layer', with 'Layer' selected.

## Final Reports



- Follow FHWA Research Report Format  
<http://www.fhwa.dot.gov/publications/research/general/03074/index.cfm>
- Compliant with section 508
- Owned by FHWA.
  - With the permission of FHWA final reports can be uploaded to the ARC site otherwise
  - have a link referring to the publication

