FHWA
Asphalt Fundamental Properties and Advanced Modeling
Expert Task Group
February 7-8, 2007
Phoenix, AZ

The meeting of the FHWA Asphalt Fundamental Properties and Advanced Modeling (Models) Expert Task Group (ETG) was held on February 7 and 8, 2007 in Phoenix, Arizona. Chairman A. (Tom) Scarpas with the Delft University of Technology, Co-Chairman Dallas N. Little of the Texas Transportation Institute., and Secretary Katherine Petros of the Federal Highway Administration (FHWA) conducted the meeting. Jimmy Brumfield of Burns Cooley Dennis, Inc. was present and assisted by serving as Secretariat for the meeting.

*The following members of the FHWA Asphalt Models ETG **were** in attendance:*

A. Tom Scarpas, Delft University of Technology (Chairman)
Dallas N. Little, Texas Transportation Institute (Co-Chairman)
Katherine Petros, Federal Highway Administration (Secretary)
Imad L. Al-Qadi, University of Illinois at Urbana-Champaign
Jo Sias Daniel, University of New Hampshire
Gayle King, GHK, Inc.
Bob Kluttz, Kraton Polymers
Richard W. May, SemMaterials, L.P.
Magdy Y. Mikhail, Texas DOT
Julie Kliewer, Arizona DOT
Charles Schwartz, University of Maryland - College Park
Bob Statz, Consultant
Linbing Wang, Virginia Polytechnic Institute and State University (Virginia Tech)

*The following members of the FHWA Asphalt Models ETG **were not** in attendance:*

William Buttlar, University of Illinois at Urbana-Champaign
Jon Epps, Granite Construction

*The following liaison member of the FHWA Asphalt Models ETG **was** in attendance:*

Michael Anderson, Asphalt Institute

*The following liaison members of the FHWA Asphalt Models ETG **were not** in attendance:*

David E. Newcomb, National Asphalt Pavement
Edward Harrigan, Transportation Research Board (TRB)

*The following **"friends"** of the FHWA Asphalt Models ETG **were** in attendance:*

Chris Abadie, Louisiana DOTD
Haleh Azari, AMRL
Gaylon Baumgardner, PTSi
Hussian Bahia, University of Wisconsin
Ramon Bonaquist, Advanced Asphalt Technology
John Casola, Malvern
Halil Ceylan, Iowa State University
Karim Chatti, Michigan State University
Matthew Corrigan, FHWA
John D'Angelo, FHWA
Armando De La Rocha, Western Technologies
Raj Dongré, Consultant
Mohamed El-Basyouny, Arizona State University
Sherif El-Badawy, Arizona State University
Frank Fee, Citgo Asphalt
Nelson Gibson, FHWA–TFHRC
Brent Hadfield, Utah DOT
Mike Harnsberger, WRI
Rick Holmgreen, Conoco Phillips
Robert Humer, Asphalt Institute
Richard Kim, North Carolina State University
Yong-Rak Kim, University of Nebraska–Lincoln
Kamil Kaloush, Arizona State University
Mike Mamlouk, Arizona State University
Eyad Masad, Texas A & M University
Louay Mohammad, Louisiana State University
Ala Mohseni, Consultant
Jim Moulthrop, Fugro, Inc.
Luiz G Z Mello, University of Brasilia
Troy Pauli, WRI
Joe Phillips, AMEC
Don Powell, San Joaquin Refining
Murari Pradhan, Arizona DOT
Ray Robertson, WRI
Cheryl Richter, FHWA
Geoff Rowe, Abatech
Judie Ryan, Wisconsin DOT
Peter Sebaaly, University of Nevada
Ed Starbuck, San Joaquin Refining
Ken Thomas, WRI
Kevin VanFrank, Utah DOT
Eric Weaver, FHWA
Matt Witczak, Arizona State University
Jack Youtcheff, FHWA

OBJECTIVE

The primary objective of the FHWA Asphalt Fundamental Properties and Advanced Modeling Expert Task Group is to provide a forum for the discussion of ongoing asphalt research and also to provide technical input for future research related to fundamental properties and advanced modeling.

DAY 1 - Wednesday, February 7, 2007

Welcome and Introductions - Tom Scarpas (Delft University of Technology)

Tom Scarpas called the meeting to order and on behalf of himself and Secretary Katherine Petros welcomed all in attendance. Dr. Scarpas stated that this was a special meeting in the sense that it was decided to veer off from the standard style of past meetings addressing issues relating to the Consortium and it was decided to set up topics and issues that have risen the last few months perhaps a little longer concerning how one can utilize experimental data into mechanical-empirical design guide. Dr. Scarpas stated that they had set up a "problem" (*an agenda*) with a list of speakers who they hoped would be able to present the theoretical aspects of the problem and who had been dealing with it the past so many months. Dr. Scarpas stated that he would not spend time himself going into technicalities as he had invited Nelson Gibson with FHWA to go over the problem and set up a framework for the discussion.

Dr. Scarpas then called for self introduction. Dr. Scarpas stated that the minutes of the previous meeting in Urbana were sent by email to everybody and that there were a lot of post-meeting responses received which Katherine Petros had managed to include. Dr. Scarpas asked if there were any comments regarding the minutes of the previous meeting and asked those who had sent comments if they were happy that the spirit of their comments had been captured. Hearing no comments Dr. Scarpas stated that if there were no strong objections he would like to suggest that we approve the minutes. Dr. Scarpas thanked the group.

Dr. Scarpas next stated that there would be a slight change in the agenda for today. Before the presentation of Imad Al-Qadi, Richard Kim had been invited to also make a short presentation on some relevant work that he has been doing.

Dr. Scarpas then called on Katherine Petros to take over and continue with the rest of the agenda.

(1) Models ETG Role - Katherine Petros (FHWA)

Ms. Petros presented the role of the Models ETG. Ms. Petros stated that the ETG was to ensure that everyone was on the same page and the role of the ETG was to facilitate the discussion by the overall asphalt community on ongoing and planned research; to provide the forum for the exchange of ideas on what research and technology are needed to

provide basic knowledge on asphalt factors that affect pavement performance; to provide ideas on the applicability of research and possible future direction for planned and current research; to provide ideas on how research should be moved forward into application in standard practice; and, to provide a forum for discussion of emerging issues. Ms. Petros next stressed again that whether you were a member or friend everybody's input was welcomed and equal and there was no difference between members and friends, other than how their travel to the meeting was funded.

(2) Asphalt Roadmap Update - Katherine Petros (FHWA)

Ms. Petros next wanted to spend some time taking care of some old business concerning the Asphalt Roadmap that was discussed at the last meeting and what was happening with that. She stated everyone will recall we discussed the Roadmap and we spent a couple hours going through it. As a result of our going through it, Gayle King recommended a revised vision statement which has now been incorporated into the Roadmap. The vision now reads, "*To develop improved asphalt pavement technologies that ensure the continued delivery of safe and economical pavements to satisfy our Nation's needs.*" Ms. Petros gave a big thank you to Gayle King for his recommendation. Gayle King stated it was not as good as apple pie. Ms. Petros stated it was better than the one we had before.

Ms. Petros stated that the draft Roadmap had been posted on NAPA's website last August. She reminded all of the discussions at the ETGs and that all were broken up into task groups over the seven various program areas and feedback in each of those program areas had been submitted. Ms. Petros stated that NAPA's Committee for Asphalt Research and Technology (CART) met for a day and half and went through the Roadmap and provided input, and that individuals also provided input. As a result of all that input, the Roadmap has been revised. The revised Roadmap is currently posted at NAPA's website. It is going to be posted as a draft at the NAPA website until the 15th of April. Comments are still welcomed from everybody and all can go there as an individual and make comments. The final document is expected by the beginning of July 2007. Ms. Petros presented a slide showing NAPA's website and how it looks for those who haven't gone to the site. She stated that you could download the whole thing in either pdf or Word file or you can go in there and make comments on the program areas or individual projects or you can suggest additional projects that may be needed. The website address was presented as www.hotmix.org and Ms. Petros again stated the site would be open for input until the 15th of April. Ms. Petros stated that the target audience for the Roadmap is the overall asphalt community which included everybody in the DOTs, industry and academia. The goal once it is ready in July, is to take it to the various AASHTO meetings this summer in the hopes that individual project statements could be endorsed for funding through NCHRP. She stated that the next step was the make the Roadmap a living document to see Gayle's vision become a reality.

LOAD PULSE TIME/FREQUENCY DISCUSSION

(3) Introduction of the Issues - Nelson Gibson (FHWA)

Dr. Gibson presented his PowerPoint presentation titled *"Introduction to Discussion Session: Flexible Pavement Frequency and Load Pulse."* The presentation focused on the outline for the Models ETG agenda at this meeting with the idea of setting up a framework for discussion.

(4) Fundamentals of Pavement Dynamics - Karim Chatti (Michigan State University)

The next presentation was provided by Dr. Karim Chatti of Michigan State University. His presentation was titled *"Pavement Dynamics"* and dealt with moving loads and the modeling of a moving load. Moving traffic on the roadway results in dynamic loads generated by the interaction between vehicles and pavement roughness. Dr. Chatti listed three types of external dynamic loadings which include: stationary vibrating (which includes harmonic and transient), moving non-vibrating and moving vibrating. He then posed the question of whether dynamic loadings impact fatigue, rutting and/or smoothness. In order to answer this question, he evaluated the internal forces within a pavement. The different types of analysis he conducted included static analysis, which involves elastic theory, viscoelastic analysis, which includes elastic and viscous theory, and dynamic analysis, which includes elastic, viscous and inertial theory. Dr. Chatti then discussed the use of wave propagation in the evaluation of pavement systems. Finally, he provided a number of derivations to model a moving wheel and to use information to calculate pavement responses.

(5) Issues of HMA Material Modeling - Eyad Masad (Texas A & M University)

Eyad Masad next gave a presentation on viscoelastic properties and work he was involved with. He discussed stress relaxation and creep compliance equations and mentioned that viscoelastic models are capable of yielding permanent deformation. He discussed asphalt mix behavior versus linear isotropic viscoelasticity sighting typical errors in linear viscoelasticity. He stated that Poisson's ratio was time dependent and that for transverse strain it was history dependent. He stated that typical Poisson Ratio for polymeric materials showed that shear relaxation/retardation occurs much faster than dilatational relaxation/retardation. He next went through what he considered errors in calculations using the simplified Poisson's Ratio equation versus stress history. He next discussed the coupling of normal and shear loading of the plastic strain rate ratio versus axial strain for different aggregates. He then discussed nonlinear viscoelastic effects of strain versus time presenting results from unaged and aged binders. He next presented the constitutive relationship of viscoelastic and viscoplastic strain for permanent deformation, damage and healing. Due to time constraints he was unable to go into any modeling framework.

(6) How this was addressed in the MEPDG - Matt Witczak (Arizona State University)

Dr. Witczak with Arizona State University gave the next presentation on the topic *"Issues dealing with the Interaction of Fatigue Damage, Environment & AC Thickness in the ME-PDG Procedure."* Dr. Witczak began by talking about the influence of E^*_{eff} upon the predicted fatigue cracking of thick versus thin asphalt pavements. Dr. Witczak

stated that the majority of damage of thick pavements is at high temperatures and low mixture stiffness and therefore the mix should be as stiff as possible to lower strains. He stated that for thin asphalt pavement sections the binder should be of the lowest stiffness possible since majority of damage occurs at high mixture stiffness. Dr. Witczak next discussed the numerical optimization of the E* master curve in the ME-PDG and issues dealing with time-frequency conversion for use in E* in the ME-PDG. In the conversion of time to frequency of the harmonic/sinusoidal motion, Dr. Witczak stated that definition of time was a "period" and was actually the time required for the response to begin repeating itself in the sinusoidal response. He stated that this period was t_{load} or the time of loading which was equal to one divided by the frequency (1/f) with this being the fundamentally accepted definition exclusive of rheologists. In the equation for loading time and frequency, Dr. Witczak uses f_c because it is a compressive value. Dr. Witczak next moved into Odemark's layer transformation and discussed the zone of stress (area under the wheel load). Dr. Witczak showed a slide representing a moving wheel over the pavement surface and talked about a point near the surface (where Z = 0) and asked the group to calculate the time of load for a vehicle moving at 60 mph.. He stated that the time of load would have to be less than one hundredth (0.01) of a second which transforms into cycles of 105 to 106 hertz. Dr. Witczak stated that the speed is proportional to the length of time the pulse is going to be there, and in reality you get into very low frequency values as the speed decreases at or near the surface of the asphalt. Therefore, axle loads in the transverse direction doesn't make that much of a significant difference. After Dr. Witczak's presentation there was much discussion which followed concerning time domain and frequency.

(7) Issues raised via 2006 AAPT - Raj Dongré (Consultant)

The next presentation was provided by Raj Dongré and was titled *"Testing Frequency to Pavement Loading Time Conversion."* Dr. Dongré stated that his presentation was presented in 2005 as an AAPT paper titled "Field Evaluation of Witczak and Hirsch Models for Predicting Dynamic Modulus of Hot-Mix Asphalt" and that it addresses some important issues that we have been talking about today. He stated that he would give some background information, his approach, some findings and some recommendations. Dr. Dongré asked, "What are really after?" He stated that what we were looking for were transient properties that have to be time dependent. We are trying to simulate what is happening on the roadway. We do frequency sweep because that is the easiest way of determining load time properties. Dr. Dongré asked, "Why not do creep test or stress relaxation test? He stated that we couldn't get the short time data accurate just because of the way you load it. In frequency sweep you can do it; however, the problem is you have this structure that is variable and you we want to do stress analysis for it, and then you have to convert the frequency sweep data to transient data (time dependent data).

After much discussion and exchange of comments over the issue of using $1/f$ versus $1/\omega$ for the loading time conversion issue, Dr. Dongré moved onto the approach they had decided to take in order to be absolute certain about what they went to Dr. Witczak with. The first goal to the approach was to determine what was the common technique employed for converting from frequency domain to time domain by reviewing rheology

literature in the fields of polymer, food, and concrete rheology including numerous available textbooks in rheology, review asphalt and hot-mix asphalt rheology literature, and consult with some experts in the field of rheology. Goal two was to just get some data. Dr. Dongré stated that you always have to show some data with everything and goal two was to see what went into the design guide with the two different definitions of time - what would happen to his predictions. He said that they studied E* values from five asphalt binders from the mobile lab ranging from PG 58-28 (a very soft asphalt) to PG76-16 (a very hard asphalt) from binder terminology. Dr. Dongré next went into their findings and stated that for goal one all text books in the field of rheology used the conversion method of $t = 1/\omega$ and it's used mostly for stress analysis. Some researchers use a slightly different version $t = 0.1/f$. He stated that they did not find a single instance where the method of conversion of $t = 1/f$ (used in ME-PDG) was used. In physics books T (not t) is simply the period of a cycle in seconds and may be expressed as $T = 1/f = 2\pi/\omega$. From the literature review Dr. Dongré stated that in asphalt binder and hot-mix asphalt rheology fields the earliest use $t = 1/\omega$ for hot-mix asphalt was found in a paper by Papazian in the first international pavement design conference. He said that the Shell pavement design also uses $t = 1/\omega$ for hot-mix asphalt rheology. Recently, Richard Kim and Jo Daniel used a slightly different version of $t = 0.08/f$. He further stated that in the field of asphalt binder and hot-mix asphalt rheology he found a paper that Imad Al-Qadi had done where he said in this study, the loading time used in performing the resilient modulus test was 0.03 second, the equivalent angular frequency would be 33.3rad/s ($\omega = 1/t$, where ω is the angular frequency and t is the loading time). The angular frequency is then converted to frequency, by dividing by 2π. This results in a frequency of 5.2Hz. Hence, the comparison was conducted between the dynamic modulus at 5 Hz and resilient modulus tests. He concluded that even in this paper $1/f$ will not get you there. Dr. Dongré next asked, "Why is $t = 1/\omega$ used in rheology?" He said that what you have to do is you have to use the Inverse Fourier Transform (IFT) to convert from frequency domain to time domain. Dr. Dongré next gave a summary of the findings for goal 1 and the varying differences used. For goal 2, Dr. Dongré presented a table that showed the potential percent change from using $t = 1/\omega$ versus $t = 1/f$ for both AC rutting and fatigue cracking at various temperatures (PG grades). He pointed out the impact that the two conversion methods had on rutting and fatigue predictions with the percent change ranging from a maximum of 117 % to a minimum of 17 % for rutting and a maximum of 118 % and a minimum of 37 % for fatigue.

Dr. Dongré closed by stating, "This is where I give you my two cents and a chance for me to get into trouble." He then gave his recommendations stating that the dynamic (complex) modulus E* has no physical meaning in the time domain. It is strictly valid only in the frequency domain where it is measured. The relaxation modulus, E(t), on the other hand must be used if modulus value is needed in the time domain. E(t) can be predicted from the storage modulus E' if phase angle data from the E* measurements is reliable. Approximate conversion methods are widely available in the literature. If the calculation of E(t), the relaxation modulus, is considered too complicated (which it might be), then as a first step E* may be used as an approximation (direct replacement) of E(t). However, frequency in rad/s ($\omega=2\pi f$) must be used in conversion of frequency to time ($t = 1/\omega$). The advantage of instituting this change in the MEPDG is that by doing so the

enhancements affected by polymer modification in the time dependence of asphalt binders may be fully realized. In other words, a shift in $1/2\pi$ on the time axis will allow the use of E* values in the loading time region where rutting resistance is better characterized for unmodified and modified hot-mix asphalt. The correct testing frequency to pavement loading time conversion procedure should be further investigated for hot-mix asphalt using data from time domain tests such as creep or relaxation step tests and comparing them to frequency domain tests such as the Simple Performance Test to determine E* as a function of frequency. Both these tests must be conducted within the linear viscoelastic limits of hot-mix asphalt.

(8) Presentation - Richard Kim (North Carolina State University)

The NCHRP 1-37A Mechanistic-Empirical Pavement Design Guide (MEPDG) utilizes the dynamic modulus of asphalt concrete in a multilayered elastic analysis to determine the primary responses in asphalt pavements. The dynamic modulus depends on temperature and loading frequency. In the MEPDG, the pulse time is used to determine the loading frequency. This methodology has been under scrutiny due to the large modulus it estimates. Dr. Kim's presentation discussed an evaluation of several approximation methods, including the MEPDG analysis, for the calculation of stresses and strains in linear viscoelastic materials by comparing the analysis results with the solutions from the exact linear viscoelastic analysis. Sources of the errors that result from different approximation methods were discussed, and an alternative method for determining the appropriate representative elastic modulus of asphalt concrete in the MEPDG was proposed.

(9) Pulse loading responses: Measured and Finite Element - Imad Al-Qadi (University of Illinois at Urbana-Champaign)

Dr. Al-Qadi started by stating that the new MEPDG makes use of the complex modulus to simulate the time and temperature dependency of HMA. In order to account for the time dependency of the HMA, a simplified procedure was adopted to calculate the frequency of the applied load as a function of the vehicle speed and the pavement structure. In this approach, it is assumed that stress distribution occurs at a constant slope of 45° in pavement layers. Concerns were raised that this methodology may be over-estimating the frequency and thus the calculated complex modulus may be inaccurate. To validate this approach, results of the MEPDG methodology were compared to an advanced 3D FE model, which considers the viscoelastic behavior of HMA and the effect of the moving load in three dimensions. A comparison was then established between the MEPDG and the 3D FE analysis. In his presentation he went through the drawback of the elastic method, the need for using viscoelastic characteristics for HMA, as well as the application of a moving load. Then he concluded by presenting a method to calculate the frequency of load application.

Dr. Al-Qadi began by emphasizing that the stress distribution at 45 degrees would affect the E* prediction. He also commented that the hot-mix asphalt has a time-dependent response particularly during the unloading phase that may not be modeled as elastic. In

addition, he mentioned that the approaching-leaving rolling wheel may not be simulated in the Odemark approach. In addition, the tire stress is not uniform and may not be simulated as circular. The aforementioned drawbacks of the current MEPG can lead to erroneous results. He suggested that the only approach to predict the behavior of the hot-mix asphalt response to loading is through using 3-D finite element analysis and model the hot-mix asphalt as viscoelastic.

Dr. Al-Qadi initially talked about the loading pulse measurements and explained the different approaches that have been presented over the years by researchers including Barksdale, Brown, McLean, and finally Al-Qadi and coworkers in 2002. The latest research showed that a haversine and a normalized-bell-shape can be used to simulate the pulse from a moving load.

He showed schematics of the sections at the Smart Road and the instrumentations for measuring pavement responses in hot-mix asphalt including stresses and strains. He showed field data of measured pulses at various speeds and at different depths inside the pavement. It was evident that the loading pulse increased with an increase in depth and decreased by increasing the speed when the amplitude values were normalized.

Changing the pavement design sections did not have any significant effect on the pulse shape and width or amplitude when it was taken at the same speed and depth. Both the normalized-bell-shape and the haversine adequately describe the pulse shape; with the bell-shaped provided better results. It was evident from the extensive data that was collected at the Smart Road that speed had no effect on the measured vertical stress while the values were increasing as the temperature increased; on the other hand the width of the pulse remained constant as the temperature changed. However, the measured strains were found to increase as the speed increased at intermediate to high temperatures.

The elastic approaches using KENPAVE and ABAQUS showed that the measured values for stresses and strains were different from the analytically predicted values. Al-Qadi presented an overview of the difference between using layer-theory and finite element and then proceeded to present the finite element model that was used in his study. He showed the dimensions of the model as well as the importance in using the infinite elements at the edges. The importance of the boundary conditions that will prevent any of the stress reflections were also presented with values. The validation of the model using elastic loading was conducted in order to demonstrate the functionality of the model.

For the viscoelastic modeling, Al-Qadi showed the use of the complex modulus values and the fitting process to obtain 11-13 Prony-series terms that allow the calculation of the creep response, which was used in ABAQUS for the hot-mix asphalt.

For the loading amplitude, he showed the difference between the triangular, trapezoidal, and rectangular amplitudes using impulse loading (hammering) and the newly developed continuous loading approach. He showed in this approach the difference between the loading and unloading process and how that would affect the pavement response. Then he presented the response of the pavements as the wheel is moving on the pavement and the

difference underneath the tire and between the tires at different depths. Then he validated the calculated values from his model with field measured values from the Smart Road. The agreement was considered very well. This shows that the developed model was working appropriately.

A new thing that Al-Qadi has been recently adding to his model is the inclusion of surface tangential stresses. He first presented the compressive, transversal, and longitudinal stresses that result from the tire (as a whole and for each tire-rib). He mentioned that transversal stresses can be as high as 52% of the compressive stresses. He then focused on the effect of each tire rib showing that the middle rib in the dual tire is causing the highest longitudinal strains. However, when he included the tangential stresses, the effect on the vertical shear strain was very significant, especially near the surface and it diminishes as the depth increases. Also, within the same rib, he showed at the surface that the shear stresses change direction (from positive to negative or vice versa). He also clearly showed the cause of the double humps that sometimes occur in the strains near the surface and the role that tangential stresses play in that. The surface tensile stresses was also shown that they are highly affected by the tangential stresses as well as the vertical shear strains, which Al-Qadi relates top-down cracking to both of these factors. He also emphasized that vertical shear strain inside hot-mix asphalt could be very critical and could also play a strong role in the cracking that is seen on the surface. These values of the vertical shear strain are shown to be greater than the maximum tensile strain at the bottom of the HMA.

Utilizing his 3D finite element model, Dr. Al-Qadi showed the difference in pavement response when using the material as viscoelastic, elastic, and elastic at 10 Hz at different levels in the pavements for both stiff and soft mixes as well as thin and thick hot-mix asphalt layers. He also showed the combination effect of temperature and speed on the developed loading pulse (width, and amplitude).

For the loading time calculation, he suggested the use of compressive stress because there is no change in direction and he showed a method to calculate the pulse width from pavement response and then he showed extensive analysis for eight different cases of pavements where the loading frequency is calculated using the MEPG approach (1/t) as well as (1/2∏t). Results using both approaches were presented. He shared the need for a correction of both methods based on the 3-D finite element response at different depths. Dr. Al-Qadi indicated in his presentation that the use of frequency = 1/t is fundamentally wrong and should not be used; while (1/2∏t) is an approximation that could be accepted three decades ago; but we can do better utilizing the current available tools. Instead, he proposed that the only method that can accurately predict the frequency is by changing the loading pulse from time domain to a frequency domain. The only approach to doing that is using fast Fourier transform. He proved his approach by using real field data from the Smart Road at different thicknesses and obtained from that the frequency and the results simply made sense.

Analysis based on the MEPDG for frequency calculation indicates that the calculated frequencies were greater than the ones determined from the 3D FE method. This would

correspond to greater complex modulus, and hence underdesign the pavement system. Analysis based on the rheological approach for frequency calculation indicates that the calculated frequencies based on the MEPDG were also greater than the ones determined from the 3D FE method when angular frequency is considered. This indicates that the loading time determined from the MEPDG would not be conservative since the associated complex modulus will be greater than what it actually is under normal operating conditions. Based on the presented limited results, it was found that for the same pavement depth, the calculated loading frequency was independent of the considered pavement design. However, analysis based on Fast Fourier Transform (FFT) was used to do further investigation.

Professor Al-Qadi concluded by stating that moving vehicles can produce pressure and displacement waves that propagate through the pavement system. The wave response spectrum or magnitude at a particular frequency can be inspected using a FFT and are a popular method to do such analysis. The time domain of a pulse can transform to the frequency domain with the FFT and faster vehicles will induce a response with more components in the faster frequency range and slower vehicles vice versa. This spectrum is also a function of the pavement system characteristics (depth and stiffness) as well as the vehicle speed. One approach in obtaining the frequency, to be used in determining the HMA complex modulus, is to use the weight center of the frequency spectrum at various depths and under various vehicle speeds. Based on a study by Al-Qadi and his co-workers (Loulizi et al. 2002), it appears that the bell shaped curve better represents the measured normalized compressive stress pulse than the haversine does in the time domain. Preliminary investigation showed that the bell-shaped has potential to be used in generating FFT. It is recommended that loading pulse be calculated from the bell-shaped suggested by Al-Qadi and co-workers in 2002 based on the extensive data from the Smart Road. In addition, further research into the feasibility of using FFT to identify the loading frequency for various depths, materials, and loading conditions should be conducted. The results may be summarized to create a correction factor relationship that may be used to improve the loading frequency used in the MEPDG.

(10) WRI/Consortium Perspective on this Issue - Peter Sebaaly (University of Nevada)

Dr. Peter Sebaaly closed the first day with his presentation titled, *"Flexible Pavement Consortium Approach to the Pavement-Vehicle Interaction Problem."* He stated that the flexible pavement Consortium had as one of their tasks to develop a fundamental model to predict the response of flexible pavements to traffic loads moving at a certain speed. Dr. Sebaaly said that they were going to use dynamic analysis that includes inertia effect, but they were not proposing at this point to use any of this in the MEPDG as that was not their objective. He stated that their work will be used as an advanced analysis model for intersections, heavy loads and off-road equipment or extremely heavy loads on flexible pavements. He said that everything that he would show in his presentation is based on previous work by FHWA, the University of Illinois, Texas A & M, University of Nevada - Reno, Delft University and others that have done pre-Consortium work. He stated they have not started the Consortium work yet and that everything that he showed would be

pre-Consortium. He stated that the Consortium was going to take all this information and put it into a model that combines the best available technology. He further stated that this technology needed to be practical, needed to be public domain and needed to be implementable. Dr. Sebaaly next discussed pavement responses to loads showing a three dimensional diagram of strain at the bottom of the HMA layer under a moving 18-wheeler. He stated that they wanted to simulate that with their models as closely as possible and that in order to do that they must look at certain components. He gave as component one the dynamic load that is affected by truck suspension, road roughness, braking/acceleration, and speed. He next stated that once they understood what the dynamic loads were doing they would move from the dynamic loads to the tire-pavement interface which is affected by inflation pressure, tire type, tire load, and speed. After that he stated they would go to the pavement response and include inertia and material characteristics as much as they could. Dr. Sebaaly next presented the factors that influenced the dynamic loads including bounce, pitch and roll and discussed load distribution during braking. He then gave tire-pavement interface data and moved to pavement response where he discussed modeling surface pressure and material characterization.

Dr. Sebaaly closed by saying that the Consortium work was to develop a flexible pavement analysis model that combines the best available technology in dynamic loads, tire-pavement interface pressures, materials characterization, and structural modeling. He stated that all options were open, but that the developed model has to be public domain, time efficient, and user friendly and applicable to a wide range of problems.

DAY 2 - Thursday, February 8, 2007

(11) Development of an HMA PRS based on the MEPDG - Matt Witczak (Arizona State University)

Dr. Matt Witczak opened the second day with his presentation titled *"Development of a Rational Methodology to Assess Performance Related Pay Factors for Asphalt Pavements."* His presentation began with the project objective of NCHRP 9-22 that was to integration of the MEPDG methodology from NCHRP 1-37A & NCHRP 1-40 with the SPT methodology from NCHRP 9-19 to develop a probabilistic PRS for the quality assurance of HMA construction. He gave the members of the NCHRP 9-22 research team and moved to the requirements for the development of a probabilistic based PRS model. He pointed out that in order to visualize HMA PRS developed from the MEPDG user needs to start thinking of key AC / pavement parameters for two separate functions with these being lab or Job Mix Design (demand function) and actual product produced by Contractor in-situ (capacity function) with the obvious desire that the capacity function being greater than the demand function. Dr. Witczak stated that the Monte Carlo simulation of actual MEPDG code was not a viable probabilistic approach at this point in time to develop PRS for HMAC. He stated that there were 72 variables that go into the analysis and what we need is a solution that can be given in seconds or minutes (rapid) and must be simple to implement. He stated that initially they were looking at

excel spreadsheet solutions. Dr. Witczak gave a summary overview of the NCHRP 9-22 approach and discussed the major differences in the NCHRP 9-22 approach and the approach from the MEPDG solution. He stated that the binder plays a most important role and that we do not have an axle load spectrum approach. He said that the effective temperature concept was critical and discussed the effective temperature (with T_{eff} definition and background on effective temperature for rutting) on the model for AC rutting distresses and gave comparisons of rutting effective temperature models of measured versus predicted data comparisons. He stated that he listened to John D'Angelo and he had a new effective temperature model for AC rutting distresses. Dr. Witczak pointed out that the effective temperature for fatigue was not the same as effective temperature for rutting, that the mean annual air temperature (MAAT) was 44º F less for fatigue than rutting. He next gave a comparison between effective temperature for bottom-up fatigue cracking and AC rutting. He next discussed the calculation of predicted life differences (PLD) and stated that the program allows the user to select the PLD to be calculated using either one of two methods. In the first method, the predicted life difference "PLD_T" is calculated as the average difference between the cumulative frequency distribution curve of the in-situ mix life and the constant target design life; whereas in the second method, the predicted life difference "PLD_J" is calculated as the average difference between the cumulative frequency distribution curves for the in-situ mix life and the job mix life. Dr. Witczak asked, "How do we do this?" He then presented a slide on the calculation of the variance associated with the service life and stated that up to 1000 Monte Carlo simulations are performed on the Witczak dynamic modulus predictive equation with each of the variables in the equation being treated as a random number following a normal probability distribution with a mean and standard deviation calculated from the statistical analysis of the field measured values for the as-constructed mix. For the JMF (JMD), historical (National or State) standard deviations of these variables are used and for the "as produced" product, actual lot-project standard deviations of same key variables are used with the AC rutting mean and variance being predicted based on these E* values from the Monte Carlo simulation runs. Dr. Witczak next presented what he called a most meaningful slide on the cumulative frequency distribution of the service life of a mix with a comparison of a good mix and a bad mix to the design mix using the design life year of the design mix. He next gave examples of actual data from an Arizona project showing a comparison between the cumulative distribution of the in-situ mix and target life and a comparison between the cumulative distribution of the in-situ mix and lab mix. Dr. Witczak then moved into pay factors and discussed penalty/bonus factor (P/B) versus predicted life difference (PLD). He handed out a questionnaire on remaining service life versus penalty/bonus factor for AC rutting and asked that everyone complete and return. He next discussed the closed form solutions (equations) used in NCHRP 9-22 giving a comparison between the percent fatigue damage predicted from the MEPDG and that predicted from the spreadsheet for different asphalt thicknesses. He then discussed the program and spreadsheet solution in the MEPDG going through the input windows in the program and calling special attention to the MODE I Output slide that he called the most important slide and wanted all to see. Dr. Witczak closed his presentation showing sensitivity (graphical) analysis for the NCHRP 9-22 solution for asphalt cement rutting utilizing actual QA/QC project data from an Arizona DOT project.

ETG INTERACTION WITH WRI/CONSORTIUM EFFORTS

(12) Summary of Input Received - Katherine Petros (FHWA)

Katherine Petros next spoke on the feedback received to date on the WRI/Consortium previous presentations. Ms. Petros stated that when the agenda was put together for this particular ETG, that they were at the beginning stages of both efforts, as the Consortium cooperative agreement and the fundamental properties contract had just been signed. They are in the process now of gathering information and putting together a work plan. She stated that we are in a transition area right now and rather than hearing what was heard at the previous ETG meetings in terms of the plans of what can be done, it was thought that time should be spend talking about how this ETG can function in terms of providing input on those major efforts. After talking with Dallas Little about this, they wanted to get the Consortium's feedback in terms of how they thought the comments functioned in terms of feedback. Ms. Petros stated that Dallas asked that she start the discussion off with a summary of the feedback that had been received so far. The feedback came as a response (primarily as post ETG meeting emails) to presentations at the previous two sets of ETG meetings as well as to the work program which Ms. Petros had sent out as email to all the members and friends. She stated that it represented what came to the Models ETG, but having sat in on the other two ETG meetings she had heard similar comments made at the other ETGs as well. Ms. Petros next presented a listing of the kind of feedback that had been received.

Ms. Petros stated that the feedback ranged from scope, coordination, implementation, specific comments on individual technical areas, the role of the ETG, and the role of the FHWA in these efforts.

Ms. Petros stated that some comments were received on the scope of the two projects. She iterated that the feedback was both for the Consortium cooperative agreement and the WRI fundamental properties contract and that all should recognize that there are two separate efforts. She stated that the feedback goes to both of them in terms of being too wide, too small a group, and too short a time for everything that was proposed.

Ms. Petros stated that a comment was made to consider narrowing the scope to have a better, more detailed, thought out and developed proposals that include well defined objectives and products. She stated that a comment was made that there was no major, overarching SuperPave-like advance coming out of the work. Additionally, she emphasized that if you look at the size of these two earmarks at a $6+ million/year combined effort, then it really could have a major overarching SuperPave-like advance like the previous SHRP effort had.

Ms. Petros stated that the question was asked if there was really agreement among the research community, that fatigue cracking and moisture damage are the two major

unsolved pavement problems. The feeling was that maybe these were identified as work areas due to prior interest or prior work of members of the Consortium.

Next Ms. Petros gave some comments on coordination. She stated that people questioned whether there was overlap or duplication, how the two efforts are being coordinated between each other, and how are the efforts within each project being coordinated. She stated that some had the feeling that coordination was not really addressed and what was there to prevent each member from doing their own thing under these projects. Also, the work plans presented at the previous ETGs did not convey a sense of top down strategic planning. People making the comments said look at how SHRP and SHRP II efforts had planned how they were going to spend $50 million.

Ms. Petros gave one specific comment received on coordination with the Poly Phosphoric Acid (PPA) work and whether what was proposed in the fundamental contact was being coordinated to that which was being done out at Turner Fairbank.

How does work planned in these projects address the needs that are identified in the asphalt Roadmap? Will these projects formally link distress prediction models to the chemical composition of binders and aggregates?

Ms. Petros stated that comments were received on implementation and that more consideration on implementation should be given, specifically that the consideration of implementation should be during the research and that cost, time and ease of use should be considered. She also said that a comment was received stating clear cut implementation plans were needed and a question was asked on how the work would end up in practical applications.

Ms. Petros next transitioned into the comments received in the specific technical areas. In the fatigue area she said there was a comment made that there was a need for a simple fatigue test to include in mix design verification and that this should be tied to fundamentals. Measure healing rate (Lytton) to get at endurance limit and base it on the rate at which traffic supplies energy to a pavement. Use molecular mobilities and internal energetics/dynamics to assess fatigue and relate it to relaxation times and energy dissipation. Ms. Petros stated that one could see that the comments were ranging from a broad big picture to very specific technical comments and she further stated all comments were welcomed.

In the engineered materials area, Ms. Petros stated a comment was received to develop criteria to evaluate the uniformity of RAP stockpiles. Also, develop models to predict changes in air void structure of open graded friction courses and relate that to environment and traffic.

She said that a comment was received in the vehicle-pavement interaction, which we spent all yesterday talking about, that the proposed approach employs old methods as opposed to cutting edge work being done in other parts of the project. Another comment

that was also heard yesterday was to quantify the change in loading with pavement life as pavement loading changes as a function of roughness.

A comment was made that moisture damage should be a high priority within the projects. Question was asked, "How are the efforts of the two projects different?" There seems to be a lot of overlap. There needs to be an implementation plan. Show when to use lime or liquid or either correlate fundamental procedures to Hamburg wheel tracking.

Ms. Petros stated that in the area of other topics, the following comments were received: have more effort to address rutting, in conjunction with the moisture damage and fatigue work as this should be a higher priority than engineered materials and vehicle-pavement interaction. Explore the impact of particle size distribution of minus 200 materials for various aggregates. With respect to microorganisms, if we find that bacteria are eating our highways, what will we do about it? Is there merit in working on ways to slow down or prevent aging? What about making asphalts better? Not by adding additives, but changing the asphalt chemically. Comment was made that more asphalt is being coked to gasoline and that maybe we should be looking at alternate binders.

She further stated that the question was asked, "Use of taxpayer funds, is it appropriate for the government to fund the development of a modified binder?" What about patent issues? The chemistry and technology of lime and limestone are well known by the industry, so what value is being added by these taxpayer funded projects?

Questions were asked about the ETG's role relative to WRI. Hopefully the ETG is intended to be more than just window dressing for the two projects. What is the point of providing input? Will it be addressed? Why should I provide my unique ideas or stuff that I have been working on the past five years and have somebody else use them and get all the credit? Are they able to subcontract or will they just take them for their own use?

The ETGs wanted to know what opportunity there was for ETG input. Looks like the work plans have been set and they plan to proceed with minimal outside interference. Ms. Petros stated the work plans are a scope which is being prepared now and that they are going to be sent to the ETGs for input prior to FHWA approval.

Ms. Petros stated that people ask her whether FHWA was actually going to have a role in terms of overseeing these efforts. She stated that FHWA has a responsibility to make sure that taxpayer funds are spent wisely and they do intend to have input. The work plan items previously presented are not a done deal. She stated that FHWA strongly encourages your (ETG members and friends) input. FHWA would like to hear from the ETGs on new research areas and/or on specific proposed studies in terms of what to add, subtract, or alter in what they (WRI/Consortium) propose. As a part of that, WRI will be preparing white papers in the major technical areas and those will also come to the ETGs for review. She stated that she hopes everyone will take the time to review and provide written comments on the work plans and white papers as these comment will be what FHWA will have to go back to.

(13) State Agency Perspective/Expectations - Julie Kliewer (Arizona DOT)

Ms. Kliewer gave an overview of what she felt was expected to come out of the Consortium. Her comments follow:

Ms. Kliewer stated that her points were not in any particular order. She stated that from a state agency perspective, we think there needs to be more work to close the gap between design and construction. We have put in an awful lot of effort in how to design a better road, but if we can't take those designs and place them on the roadway then we're losing value to those improvements. Our experience for pavement failures we look at are almost always construction related not design related. Throughout the process, implementation at the agency level needs to be considered. How can it be implemented and used? We have real fears that people are going to try and wait until the technology is perfect before it is used. If we wait until the technology is perfect, we'll never have anything to use. We need to be willing to put out less than perfect products along the way that we can use and get value out of. And when you put them out you have to remember who is going to be using those tools. If it takes a PHD to use it, then the state agencies are not going to use it. I'm not saying you have to dumb it down, but you're going to have to find ways that it's simplified, that the kind of person that is going to use it will be able to with limited amount of training. If it's going to cost me a lot of money to use this product, but I can't see any value that I'm going to get out of it, then we aren't going to use it. We aren't saying not to do the theoretical research, make sure there is some application to use on the ground. It may be a perfect model, but if there is no way to put it on the ground, then it has no value. Don't forget to consider the impact of construction variability on performance predictions. Once again, if we can't build the design, we are not going to use it. Don't forget to listen to us. She stated that this was echoed by all the states she talked to. Don't always tell us what to do. We do have some good value and we see a different perspective than a lot of you do because we have to go out to use the tools and engage roads for the traveling public. Don't forget to listen to us; we have some good things to tell you. Don't forget about the training element.

Ms. Kliewer points can be summed up as follows:

- Pavement failures are almost always construction related;
- Has the fear that most will wait until technology is perfect. If it takes a PHD to use, then states aren't going to use it;
- If there is a cost without benefit, the states will not use;
- If we can't build the design, then it has no benefit;
- Don't forget to listen to us (states). Don't tell us what we are going to do;
- Don't forget about the training issue.

(14) Researcher Perspective on ETG Input - Chuck Schwartz (University of Maryland - College Park)

Dr. Schwartz stated his comments would be quite general and brief.

Dr. Schwartz commented that this was a large effort both in magnitude and direction and a large undertaking. He also stated that funding was rare and precious for this type of engineering research. He stated that he would not get into the specifics of the work plan as the Consortium has not had a chance yet to articulate its plan fully.

He stated that he really had only three points to make.

(1) The first was, "What's the BHAG ("Big Hairy Audacious Goal")? The WRI/FPC efforts are big projects and need big goals. The SHRP program (similar in size and scope) had some of these big hairy audacious goals and kept to them. SHRP had a top-down organization that proceeded from goals to specific research contracts and tasks. The WRI/FPC research appears to be more of a bottom-up program.

(2) The second point was, "Where do we want to end up?" Research must support goals; we must have some idea of where we want to end up. What is the expected product? From FHWA's standpoint, research must ultimately support their mission.

(3) The third point was, "How will we know we're keeping on track?" Civil engineers do not have a particularly good track record in managing and controlling research projects of this magnitude. The SHRP program was a notable exception. Dr. Schwartz stated that the Consortium has not yet detailed their coordination and management plans.

Dr. Schwartz next stated that he actually had a fourth point.

(4) Dr. Schwartz turned to the issue of the ETG and asked, "What is it going to take for us to make an impact here?" We hope and expect to have some impact on the course of the work. We all have things we could be doing other than going to these ETG meetings but we come here because we feel we do have something to offer and an impact to make. I think we need to have some way of having the ETG reach some sort of consensus on a lot of these issues. I do not feel that an unfiltered laundry list of comments is particularly helpful to the Federal Highway Administration or to the contractors. I don't know what the mechanism is, but I think that for the ETG to be effective there has to be some way of having discussion for us to come to a consensus. We must be more creative.

Discussion:

Scarpas: How would you structure it?

Schwartz: It would depend on the topic, I guess. And this is not a particularly good example, but let's look at the discussion we had yesterday. What do we take away from that? It was pretty wide ranging and rambling. I have my own ideas of what the "take aways" were from the discussion. I think it would be helpful if we had discussion session afterwards to boil everything down.

Scarpas: I think what you are pointing out, and using yesterday as a good example, merits discussion. I like the concept of using the ETG as a platform. But at the same

time in one day you will not resolve, no matter how many discussions you have, issues which have not been resolved for so many years. What the ETG can do, and we discussed briefly over the break, is not to drop a topic, but to sort of keep going back to it until it resolves itself. So we become, really what Katherine and others have implied from the beginning, a group of people who can pick up an issue and discuss it. The problem I see with the ETG that we started without really knowing what we have to do. We have already had three ETG meetings and we are suppose to be looking at the contract or at the work related to the contract which does not exist yet, or it's not in its final form. So for at least the last three meetings you know and I know that we have been attempting to find literally find something to discuss. We discussed what happened in the past. We discussed what happened now. We discussed what the Consortium may do once they get the contract in the future. I don't think this is a role agency. I agree with you that the ETG should pick up a topic, probably a topic that comes out of the Consortium, and try to provide input. Are we going to resolve the issue? Sometimes yes, sometimes no! If the issues are simple perhaps bring more expects who can come to a concession. If they are more complicated then whether you define the complication level it's what the frequency complicates. It's a complicated issue and part of it is. And then we need more meetings. What we want to go back home with is the concept and the message that you suggest that we discuss that in deed perhaps the ETG once we pick up an issue, whatever the issue is, we should continue it rather than just provide a platform and then close it and go home.

And with regards particularly to yesterday, that's why I said let's wait until we have some interest from some members and try to see how this can become a discussion group, but beyond that I don't know whether we are legally authorized once we have a decision to do anything with it. So it will remain a discussion group.

What do I benefit? As a researcher, I think it is a ticket to the future. The fact that we have a chance to participate in a group that will spend a lot of money, which I cannot spend and I don't have a chance of getting to spend myself, I think that provides a window to the future. And I think personally that is my motivation for being in this group. I get to see things which will take two to five years to publication - today. And, that is a pretty good motivation. It's the same motivation that I ask of my reviewers. We give them a window to the future. The fact they get see the research, they get to read and comment on the research which will not be published next yet - I don't know we have a good publishing record so I'm not going to put a time tree. That's what we benefit, I think. And, yes, the good company.

Schwartz: All that you say is true. The motivation for my comment can be seen a bit in Katherine's slides. This admittedly is somewhat premature because the contracts that are the focus of this ETG really haven't gotten started yet. But, our mode of operation so far has been to come the the ETG meetings, listen to the presentations, have some discussion, then everybody goes back and then sends in their comments. You then get this undifferentiated list of comments that goes into Katherine after the

fact and she must try to make some sense out of it all. I don't think that is particularly useful.

Scarpas: I don't want to reply on behalf of Katherine, but if I were a researcher in the Consortium, I would like to be aware as a researcher of what are the feelings for what I do for the community. I'll tell you today, what you don't want to do is to be isolated or have the feeling that you are researching on their own direction. I don't believe as a professional that you want to isolate yourselves from the comments of your peers. And that is the role I see of this ETG. That there are several dozen people here who are good in what they do and whose comments we hope to hear by those within the Consortium who we hope would like at least to know if not to accept and agree with. I don't know what some of the Consortium people feel. Dallas do you pay close attention to what I recommend or do you just ignore me?

Little: I ignore you!

Scarpas: Thank you!

Little: No! First of all I would like to commend Chuck. I thought that was an excellent job of articulating a lot of things from the research community standpoint. I suggest perhaps in response that we let Ray lead here and give us a little perspective on where we stand and then maybe a few of us can chime in for a few minutes

(15) WRI/Consortium Perspective on ETG Input - Ray Robertson (WRI) and Dallas Little (Texas A & M University)

Robertson – I very much appreciate what each of you has had to say and we understand that research has to go some place which is implementable. I appreciate the comments that Chuck has made and that each of you have made. This is still in the planning process. Actually it is in the process of being contracted. We spent some number of years, we the Consortium members, collecting from a lot of you that are here and a lot of other people, what do you perceive to be the most critical problem in the highway industry today and we've tried to reflect those back and forth with the federal highway people. And what was solicited from us then reflected, I believe, the input from an awful lot of people as to what the most critical problems were. Moisture damage - is an unsolved problem in my opinion. Fatigue damage - long ways to go in that!

So, the type of program that we were asked to put together is more or less give us your ideas of the direction. It's really an idea package proposal and going back all the way to the SAFETEA-LU legislation where this comes from. It's set to get stakeholders input. That's not just us. That's research contracts across the board. This is a part of the stakeholders group. We do welcome the input. I'm glad that Katherine has pulled together some of the comments and other people from the federal highway have pulled together various comments. We will respond to all these comments and will consider those as we now the next step by design is to put together a detail research plan. We see

that as well. What Tom said I think brings real good help. The exact mechanic of it probably still needs to be worked out. Again that is by design.

Clearly the first things we are going to go after in the detailed research plan are things which are essentially not arguable like some of the basic mechanics of moisture damage – just using that as an example. The input, at least I my opinion, that is really valuable, is: I got some expertise in moisture damage, Ken Thomas has some expertise in moisture damage, you got some, you got some, you got some. Let's as we develop plans or as we are ready to develop plans, let's hear technical input from people who think, awe I have some thoughts on moisture damage or I have some thoughts on fatigue damage or on vehicle pavement interaction. Let us hear those thoughts that will help shape the direction of this program so that it does meet the stakeholder input and the stakeholder expectations and does make effective use of the federal funds.

Maybe there are comments or questions on that! Obviously, I can't do what you want, you want, or you want. That has to be focused through the federal highway people. Nothing that we do will be done without approval of a group from the Federal Highway Administration. They are the contracting agency. They will direct the research. But, please feel free, we urge you, not just this group - other technical groups as well, to get input to these people to make known what you consider most important and least important if you like, and also, your technical expertise. And, feel free to do so. So that I think kind of summarizes the Consortium where it stands today. It is not an up and going operation. It is a planned operation and the plan is to address the needs of the highway community.

As Dr. Schwartz said there is some basic research that needs to be done and as Julie made very clear there are plenty implementable products that need to be done. And, they don't have to be letter perfect. Have you ever seen one Julie?

Julie Kliewer: Not yet.

Robertson: So, I think that some of the others of the Consortium would like to have some things to say also. This kind of sets the general pattern of where we want to go.

Little: Let me add just one or two things. There was a question as to whether or not there was kind of a mission statement or goal statement. I copied something from the request for application to show it to you that kind of summarizes what our mission and goal statement is. The other thing that I would like to say is that this is not something that just evolved. We've been working on this for several years actually trying to plan the team and trying to probably at least for a year and a half in providing and developing a work plan. And, this work plan we realize is something that could change vastly. It may be totally turned around some of the efforts might be redirected as we submit the work plan at the end of the next four months and work with FHWA to refine it and then it will be presented to the ETGs and finalized.

But the things that I want to emphasize just real briefly, that we have been working for some time on developing at least the straw-man work plan. And, as I said before, that might change quite significantly. There are also several venues for input from the ETGs that are included in the management plan of that work plan.

This is the mission statement or goal: *"….. The Consortium will systematically develop and evaluate appropriate tests, procedures, and guidelines for extending the life cycle and improving the overall performance of asphalt and asphalt pavements; develop new models or advance existing models that capture pavement performance; work cooperatively with other Federal research activities to minimize duplication and to optimize the overall research effort; and disseminate knowledge learned."* So it is general. A lot of this is fundamental research. Some is research in the developmental stage and can be applied in the next few years. So there is a wide range of research topic we'll be looking at in these areas.

Work on moisture damage, and fatigue damage, and the tire pavement interaction and then the work on engineered materials are all consistent with the Asphalt Pavement Roadmap.

Dr. Little next went through the management plan on how the Consortium is incorporated. Dallas stated that in the Consortium plan there is an Advisory Board which is essentially comprised of members of the Consortium that get together each year and refine and update the annual work plan. There is the strategic plan which is the overall five year plan that defines how everything is coordinated during those five year period. And, there is the annual plan that is revised each year. There is a self evaluation plan and there are plans for specific document review, detailed documents and reports that are prepared by the Consortium members, there are review plans for those.

The Advisory Committee sets the direction for research with concurrence with the technical representative – the co-AOTRs from FHWA, and one specific charge for this advisory committee is to attend all the ETG meetings. That information from the ETGs will be transmitted to the AOTRs and communicated to the Consortium. So all of this is in the work plan and I just want to point that out.

The Strategic and Annual Work Plan also points out that the Annual Plan will be developed and incorporate the comments of the ETG. So I'm trying to so you in detail what the management plan looks like or the coordination plan looks like, but I want you to see that the word ETG is in here at several points and it's been on the mind of this Consortium that the ETGs are the primary point of contact and communication that we have to incorporate into the plan.

Self Evaluation - There is a self evaluation plan that will be developed by the Consortium and once again the input of the ETG at our various meetings will go into that plan and that plan will be revised throughout the contract.

In Specific Detailed Review - our specific publications and products: And, once again you see the word ETG in there and the ETG input is to be incorporated into our evaluation plan.

Is there anyone else within the Consortium that would like to speak? Are there any questions on this or comments?

(16) ETG Discussion on Providing Input - All

Gayle King: Looking back to the SHRP implementation plan. Part of it was for training and part for individual projects. More importantly this committee needs to say what needs to be in Phase II of the design guide. Should viscoelastic be going into it? We need to agree on what needs to be run to take the next step. Can some of these funds be directed? To help move all things forward - do not commit all funds up front. Drive the goal or at least the modeling. Do not preprogram everything in the beginning, but rather adapt as we learn.

Bukowski: We walk a fine line between clearly technical inputs. We need to figure that out.

Robertson: John could I follow up on that. In the fundamentals contract there is call for white papers to kind of draw together disperse topics - bits and pieces that have been collected over time and our job has been to put together all these on what the state of the art is today and what the missing elements are today. Are these important elements to address? This is another element of this. How do you set direction? Well, you have to understand the problem first. In some cases there are problems that no one really has a handle on.

As Dallas has pointed out here, many times throughout his presentations you see the term AOTR. If you are not familiar with what that means, that is the Agreement Officer's Technical Representative. Let me introduce those individuals. At this point Dr. Robertson introduced co-AOTRs Jack Youtcheff and Eric Weaver.

Little: My only point in this brief presentation is the coordination document that also may change in the next four months as the detailed work plan is prepared. This is just a working document. It is on our minds. These comments that Katherine went over, we saw them just yesterday so we haven't had time to respond to any of them. Of course, we have initial responses, but we think a review, a careful review, is necessary before we give you any responses. And, I'm sure at the next ETG that you will have responses from this Consortium on those initial comments.

Robertson: And if I can add to that. We know that there are other comments and people either plan to made or have made to other people and we want to collect the whole set of comments and response to them.

I mentioned this the other day at the Binder Expert Task Group meeting. I'll do it again here. FHWA has its point of contact. We likewise have point of contacts and it goes with this subject of coordination. The program coordinator is Mike Harnsberger with Western Research Institute. Likewise, for the terminal properties contract - Ken Thomas is the person. And, Gayle I though your comments were made well. There are subjects that need a little attention now. There is a mechanism for doing that.

Gayle King: And, can we keep enough funds available to be somewhat flexible so as needs come along it's not all committed from day one to projects?

Robertson: Yep! Yep! I don't know how else to answer your question, but yes that is part of the plan.

Scarpas: So will we have the possibility to review the contract or look at the contract at the next ETG perhaps so we'll know what you are talking about?

Robertson: The detailed work plan?

Scarpas: The work plan, so that we will know what is planned. There is no point in asking to comment if we don't know what is really going to happen. Otherwise, we'll have to bring the people that we feel they fit. But unless the committee has a chance to look at what's in the plan at least for the first year how can we be expected to provide input?

Robertson: Oh, I think that is what we expect to do.

Scarpas: So the plan is to see them at the next ETG meeting.

Are there any comments on any of the presentations? Certainly we would like to encourage those who would like to submit written comments to send them to Katherine, please.

Ala Mohseni: Commented on Julie Kliewer's presentation.

Scarpas: Thank you. This brings us to the official end of what we had planned. After Matt Witczak's presentation Halil Ceylan approached and said, "May I please show for five minutes something that I've been working on." So, I would like to give him the chance since he came all the way here to do that. And please keep it to five minutes.

(17) Presentation - Halil Ceylan (Iowa State University)

A presentation titled "*Emergent Modeling Paradigms in Pavement Materials Characterization and Performance Prediction*" was presented by Halil Ceylan. **(Attachment 16)** Dr. Ceylan discussed work that had been done with the Artificial Neural Networks (ANN) as an improvement to numerical/statistical methods for the HMA E* prediction (the current approach). Dr. Ceylan presented comparisons of the

ANN Model to both the Witczak 1999 Model and the Witczak 2006 Model for predicted E* versus measured E* values with R^2 values for the ANN Model being higher in both instances. Dr. Ceylan discussed the potential applications of the ANN in Mechanistic-Empirical (M-E) analysis and design and stated that the ANN model could be easily incorporated into the MEPDG and other pavement performance prediction tools. He stated that with it we could have up to 100,000 predictions in one second.

Closing Comments – Chairman Scarpas (Delft University of Technology)

Action Items: It was suggested that the presenters send a short summary outlining their presentation to Chairman Scarpas and/or Secretary Petros. Also, the ETG members are to forward any comments to Secretary Petros particularly in regards to the WRI/Consortium. The WRI/Consortium is to complete a draft of the Work Plan for the ETG members that can be discussed at the next ETG meeting.

Chairman Scarpas stated that the next meeting would probably be in Denver, CO during the week of July 23rd as that was the week set by the Binder ETG group on Tuesday.

Post Meeting Note: The next meeting of the Advanced Models and Fundamental Properties ETG will be from 8:00am on Monday July 23 until noon on July 24, 2007 in Denver, CO.

Input Received After the ETG Meeting – Sent to Secretary. Petros

Overall, I thought the meeting went well and was productive. One small logistical comment: Although the hotel was quite nice, it was a bit sequestered. I'd prefer a downtown location with easy access to after-hours "discussion" venues. But, I appreciate that downtown Tempe/Phoenix in February is pretty pricey.

Load Pulse Time/Frequency Discussion

Regarding the issue of whether the "correct" loading time is $1/f$ or $1/\omega$, I repeat the thrust of my comments from the first ETG meeting: This issue is a tempest in a teapot that does not merit the exhaustive treatment it has received at these meetings. For a real viscoelastic or viscoplastic pavement system subjected to a moving (or even a "bouncing") wheel load, there is no unique "loading time"—rather, the rate of loading varies continuously both vertically and horizontally within the pavement layers and is in fact different in different directions at each point (vertical vs. longitudinal vs. latitudinal). An analogy is the modeling of pavement layers having stress-dependent stiffness using multilayer elastic theory: the stiffness varies continuously throughout each layer, but one must choose a "representative" point at which to estimate an effective constant modulus for the entire layer. The notion of an effective loading time at some representative point is a gross approximation that is mandated by our inadequate analysis model.

Of course, if one retreats to simple laboratory test configurations (recognizing that the traveling public does not actually drive over laboratory test specimens), the issue of $1/f$ or $1/\omega$ has slightly more relevance, but even here I think the main issue is one of

consistency—i.e., loading time should be defined in terms of the same units as the material characterization. I grant that the issue is actually a bit more complicated, but I think that Richard Kim's excellent presentation of the rigorous viscoelastic analytical framework for how "loading time" should be interpreted in the context of laboratory dynamic modulus tests should finally put this issue to bed. (I hope that Kim's presentation and subsequent write-up will be posted soon on the ETG web site.)

The presentations by Chatti, Al-Qadi, and Sebaaly were far more relevant to the real problem of interest. In my view, though, the thrust of these moving wheel viscoelastic analyses at this point should be on clarifying the conditions under which vehicle speed and/or dynamic effects have a significant impact on the pavement response versus the conditions under which these effects can be safely ignored. I think we would prefer not to have to do moving wheel and/or dynamic analyses in a design mode if the impacts are only minor. Some of the observations made by the presenters relevant to my point include (if my notes are correct): "Speed effects are not significant for vehicle speeds greater than 10-20%" (Chatti) and "Neglecting inertia effects can produce errors as high as 29% [details not provided]" (Al-Qadi). We need more of these kinds of insights.

Finally, I think that Masad gave a suggestion of the real "elephant in the room:" 2D/3D viscoelastic analyses of moving/dynamic wheel loads may be an unproductive line of inquiry because the underlying material model is wrong, and material model effects are far more significant than the loading rate/dynamic effects [my paraphrase of Masad's observations]. We must be careful not to pursue 2D/3D viscoelastic analyses simply because we can; we should only pursue them if they can produce relevant and important insights into real pavement response and performance.