Validation of Advanced Flexible Pavement Modeling with Accelerated Pavement Testing Data

1 Introduction

This document is meant to provide highlights which accompany the presentations given at the TRB Committee Workshop 110 "Validation of Advanced Flexible Pavement Modeling with Accelerated Pavement Testing Data" on January 13, 2008 at the Annual TRB Meeting.

2 Workshop goals and associated findings

<u>I.D. important aspects of modeling that are relevant to APT community</u>

- The ability to capture construction effects in pavement models such as quality of tack coats is desired if not necessary because construction has an amplified influence on APT experiments.

- APT strategically utilizes instrumentation to quantify the degradation of the pavements structure my measuring the changes in primary responses (deflection, stress and strain). These tend to be more useful than measuring secondary distress (cracking rutting) because primary responses provide the closes most direct link to pavement models. For example, utilization of multi-depth deflectometers is critical to the real-time or post-experimental analyses of the accelerated pavement test.

- Model may be, at times, used to determine if hypothetical changes in the pavement structure are occurring when instrumentation cannot provide; de-bonding is an example.

<u>Present the realistic characteristics of pavement materials that must be captured by material models in the laboratory</u>

- Utilizing viscoelasticity instead of elasticity to describe the asphalt layer has been found consistently useful and necessary when the shape of the strain history is important in addition to only the peak-to-peak magnitudes. Accurately capturing the strain history is important to understanding multiple axles and damage phenomena which may be rate-dependent and/or sensitive to coupled tensile-compressive phenomena.

- The degree to which viscoelasticity is necessary/useful for other full scale and APT analyses applications has not been demonstrated.

- Small scale laboratory wheel tracking tests can provide important model validation before proceeding to or in addition to full-scale and APT validation of models. Such tests have the ability to produced dilated shoulders at the edges of rut paths which can validate a material model's multiaxial capabilities because of the nature of the induced stresses at the location.

- Fatigue is generally a distress of importance in pavements of greater age in their life cycles. However, the density of asphalt layers does change contemporary with the accumulation of fatigue damage from the initial conditions. There is a need to make better connections to these coupled phenomena with respect to laboratory fatigue characterization methodologies.

- Mechanical damage from thermal expansion and contractions, not limited to classical extreme low temperature events, will more than likely come under greater scrutiny with advanced models which can track that damage. Small amounts of damage are generally expected and models should be checked for reasonableness such that they do not predict damage which is significantly large than expected.

- The above more than likely indicates the importance of the healing phenomenon associated with asphalt concrete pavements. Further, transfer functions between laboratory distresses and field distress can be quite large. The role which healing may have in improving transfer functions is not known but may be a strong candidate to investigate.

<u>Appropriate experiments for advanced models</u>

- Pavement instrumentation tends to favor measuring vertical stresses and less so for horizontal. Lateral stresses are coming under more and more scrutiny especially as base and other unbound material properties are investigated.

- Far field stresses, including lateral stresses, are also coming under scrutiny as dynamic effects become more important such as seismic field characterization tools and so forth.

- The degree to which mixed extension and compression in the laboratory explain cracking in asphalt pavement could benefit from more attention because this phenomenon occurs in full scaled and APT. Most laboratory characterization is single sided – flexure, compression only, tension only. Further, advanced models which account for damage eventually need to be extended to include growing damage which is couples extension, compression and multiple axes, so forth. This is a major undertaking.

- APT experiment can generally be designed to produce a single distress. Such APT experiments can be valuable when determining whether pavement performance prediction with advanced models or based on advanced models should couple the different distress or is a "Binary Model" sufficient. One interpretation of a "Binary Model" that when appropriate conditions are reached the active distress of interests (and associated internal state variables, etc) are switched on/off.

- Related to the above, an APT experiment which can be specifically designed and executed for either classical bottom-up cracking or top-down cracking.

- Can an experiment and associated modeling be conducted to determine if engineers can design against delaminating at all? Is it something within our control? Is it only associated with large loads or poor tack coats?

- Capturing multiaxial responses fairly well when certain stress states are not practically achievable in the laboratory.

<u>Current experience in model validation with APT experiments</u>

- Instrumentation is absolutely key. Many times it provides the only measure of truth or approximations of truth

- Best practices should be followed to ensure that instrumentation is not compromised during construction. For example, ensuring that materials that are not rate dependent indeed do not exhibit rate dependence.

- In a non-technical departure, more education and awareness is needed to communication to practitioners that FEM and advanced models are not a direct replacement for the practice and transfer functions and the like. There is a somewhat incorrect perception that FEM and advanced models are intended to provide more insight to problems where conventional practice and empirical methodologies are insufficient.

<u>I.D. areas where models can be improved based on APT data</u>

- De-laminations and slippage cause concern and may significantly influence primary response and performance during APT. The value and utility of a model can be increased by applying it scenarios where de-lamination may be likely or suspected such as composite pavements. The model can provide insight as to whether unexpected or highly damaging stresses or redistribution of stresses is occurring.

- The value and utility of models can also be increased by allowing a practitioner to take a core from an existing pavement showing distresses, perform characterization of the material in that state and them – like a remaining life prediction. This scenario is contrasted with the conventional scenario with all new construction in APT experiments (and the field).

- More computationally efficient numerical methods in engineering mechanics is always welcomed along with increase in processor speed

- Models can provide links between laboratory tests where the method of loading and prescribed stress states cannot reproduce field stress states.

- Research has shown that some models have included an additional manner of validation using small scale wheel tracking tests. Like in the full scale case, a moving load induces continually changing multiaxial stress state. These validations can provide complement to the larger full scale validation tests.

- There is a desire to see integration of different models such as coupling mechanical constitutive models with transient fluid flow models.

- When does confining stress, or to be more complete, when does multi-axial stress states and their rotations become important. Material models can

3 Panel Presentations

The reader is referred to the electronic versions of the presentations posed on the World Wide Web.

4 Panel Discussion

- There is a dilemma with fatigue characterization in the laboratory and how it relates to fatigue characterization with APT and field fatigue performance. The dilemma arises because of the transient nature of the air void content as traffic readjusts the pavement. Fatigue is not a concern during early pavement life, but density of the mixtures does change from the initial condition to the point where fatigue cracking occurs. It is unclear how this phenomenon can be best handled in laboratory fatigue characterization. Could it be as simple as testing at two air void contents or should air void content change through the test? Some dialogue and discussion on this topic would be beneficial. This was observed on WesTrac, but the amount of densification is certainly material dependent.

- The above issue is related to a topic where pavement modeling and APT could make a large impact - transfer functions. These functions which vary widely may be improved dramatically if the impact of changing air voids and even healing was understood better. Models would clearly need to have this capability. Regardless, the approaches for determining transfer functions should not be a 'fudge factor'.

- There is a general embarrassment when it comes to transfer functions in terms of power and significance. It was noted that statistical methods should not be discounted for elaborate Three-dimensional-visco-elasto-plastic finite elements.

- There is a general opinion that 3D-VEP-FEM computation takes too long and does not appear to be practical for everyday use. It is not. The response from the panel was fairly consistent. First it was pointed out that trends in computing speeds have been increasing. Most importantly, finite element models are intended for insight to a problem and not a complete solution. In other words, it was pointed out that FEM provides a way to come away form a problem with parameters that ought to be dealt with, and then routine tools can be developed base on insight.

- The impact of thermal contraction and expansion needs to be looked at closer. Advanced models which can account for mechanical damage should also evaluated under normal or daily expansion and contraction. This may be often overlooked and contain important information. As pointed out by a panel member, this may be investigated at with very low frequency tests in the laboratory and some APT facilities are looking into temperature fluctuation.

- How will all of the tools become integrated? For example, pore pressures are often overlooked during APT experiments and even field. Most models for unbound pavement materials ignore changes in pore pressure. What is being missed?

- From a practitioner's perspective, pavement layer bonding is important during construction because specifications are required for tack coats. Specifications do need improvement and there is ongoing research. For example, Illinois has a Pooled Fund Study. However, it was observed in the presentations that that most facilities encountered de-bonding at layer interfaces in APT experiments. There is a desire to design against delaminating such as to determine how thick a top lift/layer must be to avoid shearing from tiers and axles. Modes will play an important role here. LCPC stresses that tack coats become more and more important with larger and larger loads. Should the community be ready to accept that de-bonding may be something that cannot be designed?

- Can a practitioner test a field sample from a pavement partway through it's lifecycle and use advanced models to determine remaining life? This is an area where APT may be crucial. It was pointed out that Superpave Shear Tester or Simple Shear Tester is still viable candidate for this. Also, loading fixtures that incorporate both bending and axial loads (TU Delft) induces shear stresses on samples with relatively small dimensions

- At what temperature does confining stress become important for laboratory testing and how can advanced asphalt material models help answer this question? Are asphalt concrete properties under confining stress extremely dependent on the rate at which the confines stress is applied? More than likely yes. Also, static confining stresses may be are falling out of favor for advanced unbound pavement material modeling; why is this so?