AAPA Pavement Research & Technology: State of Play & Future Directions in liaison with Client Organisations

Introduction

The title of this segment of the Conference program actually depicts a long standing truism. AAPA's research and development efforts have been undertaken in close liaison with client organisations since the eighties. It was then that the AAPA National Technical Committee invited representatives of Australian State Road Authorities to join it. That initial unity has evolved over the years into the two current national Working Groups relating to asphalt and bituminous surfacing technologies, peopled by members of SRA's, ARRB and AAPA and serving related needs of the Austroads Pavements Task Force described in the previous presentation by Chris and John.

The ongoing close liaison between the AAPA team and its client road agencies has been very consciously continued in the management of AAPA's most recent major pavement initiative, the *Asphalt Pavement Solutions – for Life* project which has been over the past couple of years the *"state of play"* and representative of the *"future directions"* of our R&T contributions *"in liaison with client organisations".* An overview of the background, status and foreseen outcomes of that project and of the manner and extent to which it has been influenced by the input from our client agencies is thus the object of this presentation. Deeper technical detail from within the project will be provided in the illuminating papers later today by Bevan Sullivan and Saeed Yousefdoost and examined in even further detail during the Master Class on Thursday.

Background

The genesis for this project is probably the work reported by Mike Nunn in reviewing the condition of the British Motorways in the eighties when he identified that pavements achieving service life well beyond that of their design assumption were not failing by fatigue as predicated in the design models. In fact deflections at the base of the pavement were levelling off or decreasing – those pavements were stiffening with age. Recognition and acceptance of the existence of asphalt healing and a fatigue endurance limit for such pavements duly followed.

Australian industry members and road agencies have also put considerable effort and resources into LLAP studies since the mid-eighties. As identified in the paper by Peter Armstrong and me to the 2010 ARRB conference, none of these sites have failed in fatigue, the critical pavement thickness design parameter. Thus we know our designs are conservative but are unable to say by how much and will seemingly never have the resources to develop sufficient local data to give confidence to asset owners to change the existing design criteria.

Hence Peter and I recommended in our paper that we need to establish a link between the characteristics of our asphalt materials and overseas materials so as to effectively gain access to use of their much greater banks of field performance data for our own local design purposes. This recommendation virtually coincided with the report of the AAPA 2010 Study Tour to USA which revealed considerable savings were being made in locations in the US where pavement design systems had been modified to encompass results derived from LTPP and accelerated loading studies.

The AAPA Board supported the recommendation and the project started in 2011 with the objective to improve and accelerate the effective deployment of LLAP structures into Australian construction practice and so deliver the associated sustainable benefits to the Australian community.

Project Definition

Early engagement with senior management of SRA's and ARRB in refining the scope and content of the project was pursued. This was considered essential by the AAPA Board and management in order to optimise the direction of the work and, in an environment of restrained availability of total research and development funding across industry, to avoid potential duplication of effort and waste of resources.

Hence details of the envisaged project and its objectives were presented in early 2011 to senior executives of ARRB and to PTRP, resulting in PTRP nominating Geoff Jameson of ARRB to participate as a member of the Project Steering Group from its initial meeting in July 2011. Other representatives from SRA's and Brisbane City Council have come to be members as the project has progressed.

Basically, the project elements for consideration became a literature review, national asphalt materials characterisation study, LLAP thickness design development, validation of design against LTPP studies, environmental and sustainability factors, education and promotion. I was engaged as the principal consultant to the project and, together with the Steering Group members, put the meat to the bones of the plan elements covering from the literature review through to the validation of design against LTPP studies.

At the October 2011 AAPA Conference, I presented a paper *Asphalt Pavement Solutions – for Life: Implementation Project Update* detailing the project intent and status. The planned detail of the project was then reviewed in detail and strongly endorsed in effective peer review by a large group of visiting and local experts at a Master Class held following the Conference and facilitated by Australian pavement expert, Geoff Youdale.

The developed project plan, including the outcomes of the Master Class, was then presented to the PTF meeting jointly by Geoff Youdale and me in November 2011 and formal feedback from that senior group, detailing items suggested as warranting consideration in the project for enhanced alignment with Austroads' goals, was received in February 2012. Addressing those items during the conduct of the project has added to its merit considerably.

Materials Characterisation

The purpose of the materials characterisation component of the project was to provide real data on the performance characteristics of actual Australian standard mixes used on major road projects i.e., where the LLAP concept is most likely to be employed. The experimental design was consistent with the directions being taken internationally, with the ultimate goal being the development of dynamic modulus master curves to enable the derivation of mix modulus and visco-elastic properties across the spectrum of temperature and load frequency pertinent to Australian field conditions.

The mix selection process undertaken resulted in the study embracing 28 project mixes (14 of AC14 and 14 of AC20) from the Australian capital cities of Brisbane, Sydney, Canberra, Melbourne, Adelaide and Perth, selected to cover the range of aggregate types, design methods and binders used on major projects in Australia, while avoiding duplications of identical aggregate type and binder combination from each location. Binders included were Classes 320, 450, 600, Multigrade and A15E. Mixes were selected by the Steering Group and supplied anonymously from plants of the three national asphalt manufacturers (Boral Asphalts, Downer Australia and Fulton Hogan) and from Brisbane City Council.

To meet another objective of the study mentioned earlier, viz., comparison of the properties of our materials to those of materials manufactured overseas and so to enable transferability of the results of overseas research and long term field validation studies to Australian conditions, both compacted and raw samples were sent to NCAT in the United States for parallel testing.

Although the design parameter used in Austroads pavement design is the resilient modulus, the project team chose to use the dynamic modulus E*, determined using the IPC Global Asphalt Materials Performance Tester (AMPT), for characterisation purposes, the equipment owned by Fulton Hogan in their central laboratory in Sydney being engaged for the work. The decision rested upon the comparative benefits this test affords. It is considered to provide better characterisation of asphalt than the resilient modulus due to its characterisation of the mix over the full range of envisaged service temperature and loading regimes, the E* test and its resulting master curves are internationally accepted as being able to discriminate key performance properties, it has a standard AASHTO Test Method and established Precision, and holds the potential for provision of linkage between mix design and pavement design. However, given the use of resilient modulus in Austroads, the project was widened to include determination of correlation between the two.

Observations from the Characterisation Testing

An interesting observation from testing the Australian project mixes was that despite the various mix design methods (Marshall, gyratory, Superpave) and associated compaction effort employed around Australia, virtually all the mix gradations closely follow the maximum density line and the mixes fit into a very tight volumetric window. This foreshadows the capacity for appropriate grouping of our Australian project mixes for design purposes.

For the parallel testing at NCAT, we sent them 4 sets of cores which we had prepared using Shear Box Compaction and, as suggested by an Austroads member of our Steering Group, we also sent two samples of loose mix for NCAT to prepare using their Superpave Gyratory Compaction, so as to assess any variation in result caused by the method of compaction of the samples.

It is of great importance to observe the virtually identical results obtained in the NCAT testing and the Australian testing. Importantly, this is so whether compaction was done using SGC or Shear Box. The compaction method, compared as an addition to the project at the request of the Austroads input, was not an influence on the modulus results. Hence the project can utilise NCAT modulus results and performance data with confidence.

Master Curves

As already noted, dynamic modulus measurement provides the data to develop Master Curves, where time/temperature superposition is done, fundamentally allowing the prediction of long term behaviour of the asphalt from relatively short term tests, as in the dynamic modulus test. The

Steering Group decided to use a reference temperature of 25°C for Australia to be consistent with previous modulus methods. The stiffness of the Australian mixes can then be viewed without temperature as a variable.

This method of analysis thus allows for relative comparisons to be made between multiple mixes.

Master Curves from the Australian testing were produced for each combination of aggregate size and binder type. The results align well with anticipated logic, depicting the higher modulus (stiffer mix) attained for each aggregate size mix with the harder binders.

Comparison was then made with the NCAT test data for their compacted samples from the loose samples of the same production mix, noting that NCAT as a procedure have more frequencies and slightly different temps. The NCAT temperatures differ slightly due to their use of Imperial units rather than metric.

Both sets of data were seen to fit over each other i.e. the results of NCAT are the same as determined in the Australian mix characterisation and, additionally, the method of compaction of the sample is not an issue. Hence the link to their data is established.

It is worthy to note that this is the first time such work has been done in Australia.

Master Curves Validation

The next element of the project consisted of the empirical calibration of data using the demonstrated linkage, developing a relationship between dynamic modulus and field modulus and validating strain prediction.

NCAT is among the global leaders in long life pavement research. Their resource level and focus on field performance combined with the measurement of critical performance measures is unique.

Their field research involves the physical measurement of the pavement temperature and stress distribution regime under full scale traffic loading. In all, the NCAT test track comprises some 44 test sections of which 26 sections on the straights are primarily for structural performance measures. Each is instrumented to measured temperature and strain parameters to permit evaluation and correlation with observed performance.

The true modulus required for pavement design is relaxation modulus but its laboratory measurement is not easily achievable (involving Fourier transformations etc.) Neither dynamic nor resilient modulus fully addresses the complexities of distributions in load durations and temperature profiles which leads us to the concept of some field validation shifting.

Hence it was considered best to address the complexities of the issue by directly validating dynamic modulus against field results/performance, thereby bypassing debates about the time of loading formula through calibration to field performance.

By doing this, we gained the ability to measure the dynamic modulus in the lab and compare it to field modulus and then to strains under a moving vehicle.

Amendments and Additions in response to Austroads

The initial and ongoing input from the ARRB and SRA representatives on the Project Steering Group, together with the erudite discussions within the whole team, has led the study to undertake work clarifying a number of issues not originally envisaged within the scope.

To encompass this, the project framework has been intended to remain flexible so as to be able to embrace and incorporate changes and developments from whatever source or segment of the task.

I have already mentioned the example of the submission of uncompacted mix to NCAT to enable the comparison of results between Shear Box compacted and SGC compacted samples; the comparative testing revealing the compaction methods are immaterial on the dynamic modulus results, with identical results obtained.

The variation from existing Australian design procedures by preferring the use of dynamic modulus for materials characterisation in the study similarly expanded the project work to incorporate understandings of the relationship between dynamic modulus and both the resilient and beam moduli currently used in design. It is not the place of this overview to present the detail of the work done in this regard. Bevan Sullivan who has done so much brilliant work in the project will do so later in the Conference and Master Class. Suffice it here to say that the results have shown that dynamic modulus is different from both resilient modulus and beam modulus, if and only if, an inconsistent load period of the cycle are used and that conversion factors have been determined.

In another area, the input expressed concern at a possible over-reliance on NCAT as the source of field performance data in development of the LLAP design procedure. Accordingly, the team has accessed data from MnRoads test track and FHWA ALF testing in the US and AAPA has purchased a substantial amount of historical data from TRL relating to the VALMON studies of LTPP in UK to be used in design development. ARRB provided assistance in specifying the data requirement and in contact with TRL. The data purchased by AAPA has also been made fully available to ARRB for employment in relevant Austroads project works.

Linkages to Field Strain

(Bevan - Section 3.3)

Development of Modelling Parameters

(Bevan – Section 3.4)

Setting Performance Criteria

(Bevan – Section 3.5)

Summary of Conclusions to Date

1. The dynamic modulus test (E*), conducted using an Asphalt Materials Property Tester (AMPT) on 30 production mixes sampled from Australian suppliers, provides a better characterization of dense grade asphalt than the resilient modulus and beam tests currently used because of its full characterisation of the mix over the full range of temperatures and load frequencies that occur in Australian conditions.

2. The dynamic modulus E* test and the resulting master curves, are internationally accepted as being able to discriminate key asphalt performance properties.

3. For the 30 Australian production asphalt mixes tested, (covering two different aggregate sizes and five different binder types) the mix design method, aggregate source and the relatively small variance in volumetric properties have little effect on the shape of the master curve. This means, in the absence of dynamic modulus test results for a specific mix, the database of master curves can provide a solid basis for design.

4. Test results shown that dynamic modulus is only different to both resilient modulus and beam modulus, if and only if, an inconsistent load period of the cycle is used. Conversion factors have been determined so that existing resilient modulus and beam modulus data can be used to calculate dynamic modulus.

5. Comparative testing of Australian and NCAT has shown that the difference in compaction methods and test methods are immaterial on the dynamic modulus results, with identical results obtained. Therefore, the APS-fL project can utilize NCAT modulus results and performance data with confidence.

6. Comparison of laboratory dynamic modulus with field estimations of modulus from measurements using a Falling Weight Deflectometer (FWD) have shown that dynamic modulus in the laboratory can be directly related to modulus determined under a pulse loading in the field, by making allowances for the differences in time and frequency.

7. A means of modelling a multi-layer asphalt pavement by use of a single effective modulus to represent all asphalt layers has been developed.

8. Using the effective modulus carrying out a linear elastic analysis using CIRCLY for existing NCAT pavements has shown good correlation between measured strain and predicted strain. This provides a strong basis for using NCAT performance data to develop performance models for Australian pavements