Construction Materials
Volume 170 Issue CM4
Editorial
Hunter

Proceedings of the Institution of Civil Engineers
Construction Materials 170 August 2017 Issue CM4
Pages 163–165 http://dx.doi.org/10.1680/jcoma.2017.170.4.163

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Editorial

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Despite the fact that the vast majority of asphalts are little more than mixtures of aggregate and bitumen, they are a source of endless fascination for those of us engaged in road and airfield pavements. In the UK, the terms 'bituminous mixtures' and 'bituminous materials' became 'asphalts' in December 2001. Despite this, the old terminology remains commonly used, not least in the titles of European Standards – publications that really ought to adopt the correct terminology.

As readers will know, the *Construction Materials* journal is one of many technical documents that are published regularly by the Institution of Civil Engineers. Each journal title is overseen by a panel of experts in their particular fields. Thus, at any time, the *Construction Materials* panel will consist of several concrete and other cementitious specialists and experts in areas such as asphalts, timber, plastics and other particular materials. The panel works hard to produce a journal that contains papers on the full range of materials. When the number of submissions addressing a particular subject area is adequate, an edition dealing with a particular materials group can be published. This edition, containing seven papers, is one such example, dealing as it does with asphalts.

The first paper is entitled 'Rutting analysis of modified asphalt concrete pavements' by Imaninasab and Bakhshi (2017). Bitumen can be modified by the addition of a small proportion of another material. The reason for doing so is to improve one or more properties of the bitumen; for example, in order to improve the workability of a particular mixture, or to improve the adhesive characteristics of the bitumen so that chippings stick more effectively in the road surface – important in a surface dressing. However, the most common reason for modifying the properties of asphalt is likely to be to improve the deformation resistance.

Among the authors' conclusions are the following

- static loading resulted in greater rut depth than cyclic loading
- cellulose fibres reduce the optimum binder content but increase the rut depth in stone mastic asphalt mixtures.

Deformation (rutting and deformation are interchangeable terms) is the single most common structural failure mode of pavements. Research in this area is therefore of substantial importance. This paper looks at the effects on asphalt deformation of adding cellulose fibres and, probably the most sophisticated polymer modifier, styrene-butadiene-styrene.

The second paper is 'Disproving bottom-up fatigue cracking in well-constructed asphalt pavements' (Hunter, 2017). Traditionally it has been the view that pavements fail structurally because of one of two failure mechanisms; (1) fatigue cracking originating at the underside of the asphalt layers and (2) vertical downwards movement of the subgrade (Powell *et al*., 1984).

Much of the work I do is connected with ascertaining the reason(s) why particular pavements have failed. I have never encountered a flexible pavement (i.e. a fully asphaltic pavement) that has failed as a result of fatigue cracking. Indeed, I have never seen an example of fatigue cracking. Over many years, I have read numerous papers analysing the reasons why fatigue cracking can occur and how it can be countered. Unfortunately, I think that the effort invested in these analyses is wasted. Put simply, in well-constructed flexible pavements consisting of 200 mm or more of asphalt (being the sum of the thicknesses of the surface course, binder course and base), fatigue cracking will not occur. I am not alone in this view; several other papers support this view, most significantly TRL 250 (Nunn *et al.* 1997). It is important that the occurrence or otherwise of fatigue cracking is properly established, hence the reason why this paper was written.

Bitumen modification features in the third paper, 'Effect of cross-linkers on the performance of polyethylene-modified asphalt pavements' by Moghadas Nejad *et al.* (2017). When the properties of bitumen have been altered by the addition of a modifier, it is important that the mixture of bitumen and modifier do not separate back into their key components. This process may be described as a 'lack of storage stability' or 'phase separation'. This paper aims to solve the problem of the susceptibility of binders modified with high-density polyethylene to phase separation by using cross-linking agents. The authors conclude that the addition of polyphosphoric acid to bitumen that has been modified with a high-density polyethylene not only improves the resistance to phase separation but also improves the fatigue characteristics at low strain levels.

In order to mix bitumen and aggregates to produce asphalts, the viscosity of the bitumen needs to be reduced. This is normally achieved by mixing heated bitumen with aggregates at a high temperature. The bitumen then acts like a binding agent to produce an asphalt. There are, however, other methods of reducing the viscosity of the bitumen. One means of so doing is by the use of foamed bitumen.

The fourth paper is entitled 'Impact of binder on properties of foamed bituminous mixtures' by Kar *et al.* (2017). According to *The Shell Bitumen Handbook* (Beer *et al.*, 2015), foaming of bitumen 'is a means of temporarily reducing the binder viscosity and increasing the binder volume of a bitumen' and was introduced in the late 1950s. Foamed bitumen is typically produced by adding some 2–3% of water to hot bitumen.

The authors state that foamed bitumen technology offers advantages in terms of reduced energy consumption, materials recycling and reduced bitumen requirement. This paper concentrates on the influence of the binder properties on the foaming characteristics of bitumen and the properties of foamed bitumen mixtures. Four binders of different grades were evaluated for physical properties and foaming characteristics. The optimum foam content was then used to produce foamed asphalts containing recycled asphalt pavement. These mixtures were evaluated for their mechanical properties, including indirect tensile strength, retained tensile strength and resilient modulus.

One of the authors' conclusions is that the mechanical properties of the foamed asphalts depend primarily on the physical properties of the bitumen, the properties of the recycled asphalt and the binder content. They also conclude that using a bitumen with lower viscosity requires less energy during the foaming process than is the case with a higher viscosity bitumen. They also note that using a higher viscosity binder results in the foamed asphalt having a significant higher indirect tensile strength.

The fifth paper is entitled 'Effect of binder in recycled asphalt on cold-mix pavements' by Ojum and Thom. This paper addresses various notions and perceptions associated with using recycled asphalt pavements (RAPs) for road construction. The research investigates how the residual binder in very old asphalt pavements used for recycling with penetrations of 3 to 7 influences cold asphalt emulsion mixtures in comparison to moderately aged RAPs with a penetration of around 20. The RAP was aged to simulate moderately and severely aged asphalt pavement conditions (20 and 5 dmm, respectively).

The authors manufactured samples of asphalts, which they use to simulate RAP. Bitumen was added and the sample aged such that the bitumen had a penetration value of 20. The procedure was repeated such that the bitumen had a penetration value of 5. Stiffness, fatigue and deformation parameters were measured on samples with penetration values of 20 and 5 and also samples where the bitumen had been removed. The results show that cold asphalt emulsion mixtures produced using RAPs with residual binder in them had considerably higher stiffness, fatigue and permanent deformation results in comparison to RAPs without the residual binder. The 20 pen RAPs produced the stiffest specimens and gave the greatest fatigue lives, although the 5 pen RAPs gave the best resistance to permanent deformation. Specimens with RAPs from which the binder had been removed performed poorly. The authors claim that this research study shows that the residual binder in RAPs adds valuable mechanical and performance properties to cold-mix asphalt.

The sixth paper is entitled 'Inclusion of design variability in flexible highway pavement life-cycle cost analysis' and was written by Dalla Valle and Thom (2017). This is a most unusual paper in that it examines the variability of the most important factors involved in pavement design

- layer thickness
- asphalt stiffness
- subgrade stiffness.

Variability is described by statistical terms such as mean and standard deviation and by its probability density distribution. A model is then proposed that represents an improvement on the method of equivalent thickness for the rapid and repeated calculation of performance life. A Monte Carlo analysis (a computerised mathematical technique that permits allowance for risk in quantitative analysis and enables better decision making to take place) is used to estimate pavement performance life to account for uncertainty of input variables and to calculate the probability of failure of a pavement structure. The output is a statistical assessment of the estimated pavement performance. Rather than the single deterministic result that would be derived by considering average values of input variables, a range of values and probabilities is found for any particular outcome. The probabilistic approach offers a way of incorporating risk assessment considerations that are vital for whole-life-cycle economic analysis and decisions. The paper investigates how variability affects the life-cycle cost of a pavement over a 60 year analysis period.

Although whole-life cost analysis can be performed deterministically with sensitivity analysis of key variables, the ultimate extension of sensitivity analysis is a probabilistic approach, which allows all significant inputs to vary simultaneously. A Monte Carlo simulation is generally used to characterise uncertainty. The probabilistic approach to pavement design offers a simple and practical tool for an expert to assess the impact of input design parameter variability on the expected performance life for a particular site. The design risk can be calculated and economically priced.

As I explained in relation to the first paper, deformation is the single most common structural failure mode of pavements. Every time a heavy load is applied to an asphalt pavement, there is a degree of deformation that is not recovered. It is a very small component but it accumulates over time to the point where it becomes significant and requires action to be taken to restore the pavement (many engineers regard a value of deformation between 10 and 20 mm as requiring action – values that originally appeared in a paper by Lister (1972) from the Transport and Road Research Laboratory, now TRL Limited).

The amount of deformation is affected by the ambient temperature (i.e. it increases in higher temperatures). Another key factor is the speed of traffic; the slower the traffic, the higher the amount of deformation. Unlike some other countries such as Australia, UK design methods take no account of the speed of traffic.

Asphalt pavements can be subjected to stationary and transient loadings. It is possible for a pavement to be able to support transient loads without detriment but then fail after a few hours of stationary loading. The final paper is entitled 'Deformation of asphalt surfacings under stationary and slow-moving traffic' and was written by Artamendi *et al.* (2017). In this paper, the authors investigated the effect of traffic speed and type of loading on the deformation of three 14 mm asphalt concretes. An asphalt indentation test was used to simulate the effect of stationary and slow moving traffic on asphalt deformation. Indentation tests were carried out under both static and cyclic loading conditions. It was found that the deformation of asphalt surfacings under static loading depended on the duration and magnitude of the contact pressure. In addition, deformation increased when the frequency of loading was reduced (i.e. when traffic speed decreased).

The authors conclude that the current standard methods to characterise the permanent deformation of an asphalt provide information about the deformation resistance of a mixture subjected to dynamic (transient) traffic loads. The suitability of these methods is, however, limited when the same mixture is subjected to static loads. The static indentation test presented in this study can be used to better evaluate the performance of a mixture subjected to this type of loading.

Under static loading conditions, the contact pressure had a large effect on the extent of surface deformation. Contact pressures can be selected depending on the asphalt application in order to assess the suitability of a mixture for a particular application. Results from the cyclic indentation tests showed the effect of loading frequency, and therefore traffic speed, on surface deformation. It was shown that as the loading frequency was reduced, the deformation of the asphalt surface increased. This implies that deformation increased as the traffic speed was reduced. This can have implications when selecting, for instance, asphalts for heavily congested roads where the traffic speed is slow.

In a final conclusion, the authors suggest that the UK specifications for deformation based on the wheel tracking tests do not fully recognise the effect of the type of loading (static or dynamic) or the effect of traffic speed. Thus, in order to provide a higher level of confidence in the performance of particular asphalts, alternative test methods such as those presented in this study should be taken into consideration.

This themed issue of *Construction Materials* provides a wide range of papers considering important aspects of asphalt performance. The panel and the Institution of Civil Engineers are grateful to the authors for giving *Construction Materials* the opportunity to publish their papers.

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